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Assessing and controlling the spread and the effects of common ragweed in Europe

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Executive summary

Background: Ragweed in Europe

Common ragweed *Ambrosia artemisiifolia* is a non-native species which is highly invasive across Europe and has harmful impacts on a range of sectors, especially human health and agriculture. This project had the aim to synthesise and systematically review information, highlight knowledge gaps and utilise modern modelling methods to achieve: an understanding of the current extent of ragweed infestation in Europe; economic, social and environmental quantification of direct and indirect harmful effects in all sectors; assessment of measures to control ragweed spread and introduction (now and in future climates); and the dissemination of accurate and up-to-date scientifically-based evidence to stakeholders. We achieved these aims by implementing a coordinated project involving a large number of experts from across Europe working on a number of inter-linked tasks.

Task 1: The spreading mechanisms of *Ambrosia artemisiifolia*

Several vectors are likely to assist the spread of ragweed *A. artemisiifolia*. The literature review showed that the most important dispersal vectors for the spread of ragweed were (in no particular order): - natural seed dispersal; transport of seeds in imported seed for crops and food; contaminated animal fodder including bird food; the spread of seed along transport routes; seed in transported soil and other organic matter, including on agricultural machinery; and by floods affecting rivers and roads.

Natural processes appear relatively unimportant for the spread of ragweed. Ragweed spread can occur naturally *via* wind dispersal, but the species is not well adapted for wind dispersal; seeds fall <2 m from the plant. There is evidence of animal dispersal, but this primarily through the spread of seeds *via* cattle slurry and manure. However, these mechanisms are believed to be less important than anthropogenic processes for ragweed spread.

Rivers and waterways play an important role in the spread of ragweed to new areas. One important natural spread mechanism may be seed dispersal by water. Lighter ragweed seeds are able to float and may travel great distances along water bodies. Riparian habitats are often reported to contain ragweed populations and are a likely route through which it can invade new areas.

Seed import is a key factor in ragweed introduction. The import of contaminated seed and grain is widely believed to be responsible for the initial introduction of ragweed to a number of countries; e.g, casual occurrences are observed in harbour areas where grain and seed is imported. Genetic studies of ragweed colonies suggest multiple source populations, probably as a result of separate introductions. Introduction *via* imported bird feed has been well documented, but is only important locally in private gardens, parks with bird feeders and locations with aviaries; whilst there is also evidence for introduction of seeds in cattle fodder.

Transportation of seeds in contaminated litter and soil from infested areas facilitates the introduction of ragweed. Seeds transported in litter and soil by agricultural machinery from infested areas is widely reported. Spread by mowing machinery is less studied, but is probably also important. Construction sites are commonly invaded by ragweed, which suggests translocation of soils and gravels from construction sites in infected areas.

A ranking of those industries or systems as a whole that facilitate ragweed spread within Europe suggests the agro-industry and the road systems are of greatest and equal importance, with the construction industry slightly less important. Railways and waterways are considered to be important in some countries but less so in others, and so are ranked as of moderate importance. Natural seed dispersal by wind or animals is considered to be least important

Individual seed dispersal vectors can be ranked in terms of their relative importance: litter > soil > harvested crops > production process for human food > aggregates > waterways > production process for animal food > wind > wild animals.

<u>Task 2: The conditions and drivers favouring spread of *Ambrosia artemisiifolia*</u>

Anthropogenic factors have played an important role in the spread of ragweed. Ragweed is generally found in frequently disturbed areas such as arable crops, ploughed field margins, road verges, railway embankments, riversides and watercourses, construction sites, landfills and wastelands. Regular anthropogenic disturbance of ground has created large areas of ruderal habitats which have favoured the spread of ragweed. There is strong evidence that the international trade of seeds and grain was an important factor in the initial introduction of the species and has a continuing influence today by repeated introductions from native areas and trade between EU territories. There is also evidence that political change and wars may have furthered the spread through a number of factors. Changes in agricultural practices after the Common Agricultural Policy reforms of the mid 1990s may have increased the amount of setaside land which ragweed could colonise. The subsidisation of sunflower crops (of which ragweed is a common contaminant) is also likely to have aided ragweed spread.

Temperature is the key factor limiting the spread of ragweed. In cooler climates, casual ragweed populations do not become naturalised as plants fail either to flower or to produce ripe seeds. However, the temperature regime in much of Europe is similar to that of its native range in North America making much of the region habitable for the species.

Ragweed has a wide ecological tolerance allowing it to spread vigorously. There is little evidence to suggest that there are ecological barriers aside from climate that are preventing the spread of ragweed. Higher CO_2 levels increase the photosynthetic rate of ragweed whilst also increasing pollen production. Soil moisture conditions are also shown to have little effect on seedling survival rates. There is some evidence that the ragweed is tolerant of acidic conditions, but there is little research of responses to levels of soil nutrients or organic content. A tolerance of saline conditions has been reported which allows ragweed to colonise roadside areas treated with de-icing salts.

There has been no loss of genetic diversity during the invasion of Europe. Genetic studies of European populations show that there has been no loss of diversity compared with native North America populations. In fact, comparisons with historical populations in France have shown that genetic diversity is increasing (probably as a result of multiple introductions), which may have a positive effect on its ability to react to new pressures.

Ragweed plants produce large quantities of seeds with a high longevity. Ragweed has a very high reproductive output with each plant producing several thousand seeds, which are able to remain viable in the seed bank for up to 35 years. This combination of factors combined with the regular disturbance of crop fields and setaside land by ploughing is believed to be of particular importance to the spread of the species.

Task 3: Mapping the distribution of *Ambrosia artemisiifolia* across the EU27

Previous European ragweed distribution maps do not use all available data. The Delivering Alien Species Inventories for Europe (DAISE) and Global Biodiversity Information Database (GBIF) provided maps showing the known distribution of ragweed *A. artemisiifolia* in much of Europe. However, they revealed data gaps in the Carpathian Basin, northern Italy, Poland, Czech Republic, Austria and Switzerland, as well as parts of the former Soviet Union where significant infestations are known to occur. Records from other sources suggested that data were available for these areas.

We were able to retrieve and map ragweed distribution data for a large number of European territories. A list of countries in the EU and its immediate neighbourhood where ragweed was known to occur was drawn up and national experts from each country assisted in data retrieval. This process produced a number of data sets which were then subjected to a quality control process to ensure they met the agreed standards. Data sets were standardised into the World Geodetic System 1984.

Distribution data varied in quality. A European county-based presence/absence map for ragweed was used to test the mapping of the data sets. The exercise identified several issues concerning merging data sets and the required changes were made to the final methodology. The resulting distribution maps were based on (i) a 50 x 50 km grid (for EU wide mapping); and (ii) a 10 x 10 km grid (for mapping individual countries). Maps showing relative abundance and spatial/temporal distribution were also produced. It should be noted that such presence data cannot distinguish whether ragweed is casual or well established in the recorded location.

At 50 x 50 km resolution, ragweed appears to have a wide distribution across a significant part of Europe. It occurs from the UK in the west across to the Black Sea in the east, and from Scandinavia in the north to the Mediterranean basin in the south. We found distribution records for ragweed in Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, and UK. No data were found for Belarus, Estonia or Lithuania.

At 10 x 10 km resolution, however, the distribution of ragweed is more patchy. The densest population areas occur in the Rhône valley (France), Hungary and Serbia.

The distribution maps of ragweed developed in this study improved significantly upon those from previous studies. In particular, northern Italy, Croatia and Serbia, which were previously unmapped, were shown to support significant populations. Furthermore, the maps show that the French Rhône valley, northern Italy, Croatia, Hungary and Serbia are the most heavily infested areas because of the prevalence of ports, transport corridors, and land use changes.

The mapping methodology used was successful. The use of 10 x 10 km and 50 x 50 km resolution grid maps allowed both broad European and more specific country conclusions to be drawn regarding the range and distribution of ragweed. However, some data collected during the retrieval process proved difficult to analyse as not all data sets provided the same information (e.g. date of record). Information concerning the population abundance, density and size was difficult to standardise as there are no rigid criteria for how this data should be supplied and the quality of data across the region also varied making comparisons difficult.

<u>Task 4: A general systematic methodology to assess the social, environmental and economic impacts of invasive species and ragweed</u>

Human health is the most important impact of ragweed in Europe. In the regions infested with ragweed, the incidence of ragweed allergy ranges widely from 2-50% of the allergic population (roughly ¼ of the European population shows general allergic rhinitis). Allergic responses comprise rhinitis, hayfever and, less commonly, dermatitis and asthma. Ragweed pollen is highly allergenic, with evidence that it is worse than grass or tree pollen. There is some, poorly quantified, evidence that the incidence of allergy to ragweed is increasing in Europe – in line with higher ragweed abundances, poorer air quality, and the general rise in allergies. Ragweed pollen causes allergic reactions at relatively low concentrations; about 5-20 pollen grains m^{-3} of air. Furthermore, ragweed pollen can be transported 100s of km by air masses and can cause allergic reactions large distances from infestations. Children and urban populations are most affected by pollen allergies in general, the latter being caused by interactions with air pollution. Climate change may exacerbate ragweed allergies by increasing pollen production and extending the pollen season. However, allergic reactions to ragweed are treatable by the same medications as used for other pollen allergies in Europe.

Animal health impacts of ragweed are most evident for pets. There is evidence for allergic reactions in horses, dogs and cats, but it is unclear whether there are effects on livestock. Livestock may suffer more by grazing ragweed, which is known in North America as a potential animal health hazard due to its capacity to accumulate nitrate. Dermatitis caused by ragweed is reported for dogs and cats in Europe and the USA, and there is some limited evidence in the USA for dermatitis in horses. However, the number of cases is not documented.

Ragweed is a severe agricultural weed in parts of Europe. In most countries in which it is widespread and in large numbers, ragweed ranks amongst the most serious agricultural weeds. It infests arable crops at high densities, with row crops appearing to be the most susceptible. Sunflower is the most affected, especially as its close relationship to ragweed limits the herbicides that can be used. Other susceptible crops include maize, potatoes and soya bean, as well as peas, sugar beet, small grain crops, tobacco, pumpkins, various legume crops, sorghum, oilseed rape, vineyards, orchards and field vegetables. Yield losses can be very high; figures depend on infestation levels and success of control, but losses of >50% are reported. Ragweed is much less important as a pasture weed, where it generally indicates overgrazing.

The general evidence is that ragweed currently causes limited problems for biodiversity in Europe. The evidence suggests that ragweed may be a 'passenger', riding on habitat degradation or disturbance, rather than being a true driver of community change. Ragweed is generally found in ruderal and highly disturbed ecosystems, especially those created by humans, such as urban areas and the transport infrastructure, cleared forest, arable land, and degraded pasture. Semi-natural habitats invaded by ragweed in Europe also tend to be disturbed, either naturally – e.g. dry river beds or flood plains – or through human activity – with examples of tall herb communities, sand and steppe grasslands reported. A few protected areas have been invaded, but this is again linked to human activities. Regarding species of conservation concern, it is suggested that ragweed may threaten certain plants associated with ruderal communities, such as rare crop weed associations, or annually flooded communities. Furthermore, it is feared that control measures against ragweed may threaten these species more than ragweed itself.

There are no reported impacts of ragweed on the wider environment or other ecosystem services. Other than impacts on human well-being and agricultural production, there is no evidence of impacts on other ecosystem services. This is partly due to a lack of studies on such other possible impacts, but may also relate to our hypothesis that ragweed follows the 'passenger' model of invasion; it responds to environmental change (i.e. disturbance) rather than a causing changes.

There is little evidence for ragweed impacts on transport, construction and tourism industries in Europe. No evidence was found for ragweed impacts on the construction or the transport sector. This is generally reported as a lack of information, but the general perception is that there are no effects. Human allergic reactions to ragweed could in future have a detrimental impact on tourism by dissuading tourists from visiting infested regions, and certain authorities have voiced concerns about this potential problem.

<u>Task 5: Quantitative and costs analysis of the impacts of ragweed</u>

Modelling of the economic impacts of ragweed in Europe is possible but is subject to significant assumptions and uncertainties. Measures of the impacts across the study area (the EU27 and adjacent countries: Albania, Belarus, Bosnia and Herzegovina, Croatia, Kosovo, Macedonia, Moldova, Montenegro, Norway, Russia, Switzerland, Turkey, Ukraine) were estimated based on data from the other Tasks. Costs were estimated using economic models in relation to ragweed impacts on:

Farming**.** Impacts were assessed for the probability-adjusted area of cropland subject to invasion by ragweed. Costs were calculated for residual loss of crop yields (assuming a 25% loss of crop yield for crops invaded by ragweed).

Human health**.** Impacts were assessed for the probability-adjusted human population exposed to ragweed pollen. Costs were calculated in relation to increased costs of medication (assumed to be €303 yr^{-1}) and of staff time to give treatment (with costs based on countries wage rates for nurses and doctors assuming 1 hr of additional consultation and treatment time per affected individual).

Work Productivity. Impacts were assessed based on workers who suffer additional allergenic symptoms due to ragweed losing 1.5% of their work productivity, valued according to their national average Gross Value Added per worker.

Monitoring and control effort. Controls were modelled through: i) increased use of herbicides (assuming one additional herbicide application yr^{-1} for the crop area invaded by ragweed as for the farming impacts, with costs reflecting chemicals used and cost of application) and urban controls in the most vulnerable areas to Ragweed colonisation. Monitoring costs involve information campaigns and establishing reporting via the internet.

The current costs associated with ragweed impacts on farming and human health are estimated to be of the order of billions of Euros per year. Current estimated total agricultural, work productivity and human health costs were estimated as being €4.5bn per year, within a likely range of €2.95bn - €9.02bn. This range reflects the significant uncertainties in the analysis; the proportion of the human population affected by ragweed allergies (estimated at 2% - 10%), the residual loss of crops after herbicide applications (estimated at 15% - 35%), and the loss of productivity for symptomatic workers (estimated at 1.5% - 5% of the working year).

When expected climate change is included in the analysis, the economic impacts of ragweed in 2032 rise slightly. **When controls are also included in the analysis, the future impacts are reduced.** Economic impacts of ragweed in 20 years time with climate change rise slightly (by around 3%) compared to a scenario without climate change. When controls are introduced, there is a significant decrease (over 25%) in the impacts following climate change, as controls limit ragweed shifting its range to follow its 'climate space' across the study area. Nevertheless, the distribution of costs within the study area is predicted to shift northwards with climate change, with substantial cost increases in some areas (e.g. Germany, France, Poland).

The future economic impacts of ragweed could be substantially reduced – by approximately 50% – with appropriate strategies involving agricultural and urban plant control efforts and improved biosecurity. Controls costing under €400m yr^{-1} (plus the impacts of seed trade regulations) could reduce impacts by €1,500m yr^{-1} in 2032. Despite the uncertainties in the modelling giving a broad range of results, they suggest that control efforts could be cost-effective in the face of the substantial current and future costs related to ragweed. A control strategy would restrict the ability of ragweed to colonise, and cause negative impacts in, new areas of climatic suitability. Within the study area, the main locations vulnerable to this climate-change impact are within the EU.

There are several limitations in terms of data availability and knowledge of the assumptions necessary to construct the model. Further refinement of this economic model, with more primary data, would give better insights into optimal approaches for the management of ragweed. However, this is, to our knowledge, the first attempt to assess or model the economic impacts of an invasive species at this level of detail over such a large geographical area.

Task 6: Modelling the spread and the harmful effects of ragweed across the EU depending on different climatic scenarios and policy scenarios

Temperature-dependent phenology limits the northern and uphill distribution of ragweed. We produced a mechanistic phenology model that predicts the timing of ragweed development from germination to reproduction. The region where the model predicted ragweed cannot produce mature seed before plants are killed by frost corresponded to the northern and high-elevation range margin in both North America and Europe, although populations near the margin are generally casual in Europe. This shows how cool temperatures impose a limit on the native and invasive distribution by preventing completion of the species' annual lifecycle. Warmer summer temperatures and later autumn frosts are therefore expected to push the range margin north, permitting further invasion.

The European invasion can be explained by climate, land use and seed import rates. We developed a model of ragweed's historical spread that accurately predicts the current-day observed distribution within the EU. Modelled dynamics are driven by the climate, land use, localised seed dispersal and introductions of new populations as a contaminant of imported seed. The model suggests that cool temperatures limit ragweed's populations in most of the EU, although drought is more important in Mediterranean countries, and a lack of climatic seasonality is more important in the Atlantic northwest. Where the right combinations of climatic conditions exist the model has ragweed invading cropland and urban areas. Strong populations establish and spread in south east France, north east Italy, the Pannonian lowlands, the eastern Danube basin, Ukraine. Outside of these 'invasion hotspots' ragweed does not readily spread but is regularly introduced as a seed contaminant; as a result it becomes widespread in countries such as Netherlands and Belgium. This suggests that colonisation of northern regions is driven by humans.

The spatial pattern of ragweed's impact is partly decoupled from its distribution. Ragweed impacts on crops and human allergies do not appear to be uniform across its documented distribution. We modelled crop impacts and pollen emission as being severe only where the climate is highly suitable and there is invasion of lots of disturbed habitat. As a result, impacts were only high in the invasion hotspots. Because ragweed has been widely imported into climatically unfavourable areas as a seed contaminant, impacts are very low throughout most of its European distribution, causing a spatial decoupling of the impact and the distribution. A further decoupling arises because of long-distance atmospheric transport of pollen from the invasion hotspots. This means impacts of the species on public health can occur in regions that are not strongly invaded, but are close enough to the invasion hotpots to receive large amounts of pollen. Therefore, although crucial for documenting ongoing spread, monitoring the distribution of ragweed will be insufficient to monitor its impacts.

Climate and land use change will have a large impact on ragweed's distribution in the EU. The modelling suggests that climate change will permit ragweed to spread into cropland and urban habitats in northwest Europe, potentially reaching as far north as the southern Baltic coastline by 2050. Depending on the climate and land use change scenario considered, the model predicts heavy invasion and increased impacts to crops and public health in Germany, Netherlands, Belgium, northeast France, southern UK, Czech Republic, Poland and western Ukraine. The model also suggests that ragweed's population and impacts will decline in the current invasion hotspots, because of a combination of excessively high temperatures and potential abandonment of cropland in eastern Europe. We consider this prediction to be less certain than the northward range expansion since ragweed's response to high temperatures is less well-resolved than its response to cold and there is great uncertainty in the land use change scenarios for some countries.

Targeted eradication and improved biosecurity could be effective in limiting ragweed spread and impacts. We ran model simulation experiments to investigate the possible effects of a Europe-wide control programme beginning in 2013 and running for 20 years. Results suggested that attempting to eradicate ragweed from 5% of Europe's crop area in each year could dramatically reduce its impacts. The effectiveness of the simulated control programme was enhanced by targeting eradication effort towards the areas most climatically suited to ragweed invasion. In particular, the best strategy targets areas predicted to become suitable for invasion over the next 20 years, rather than the areas currently highly suited to ragweed invasion. Furthermore, eliminating the ragweed contamination of imported seeds through improved biosecurity slowed the rate of ragweed spread and approximately doubled the efficacy of the control programme.

Tasks 7 & 9: Current practices to prevent the further introduction and spread of ragweed, to reduce or mitigate its harmful effects and for its eradication

It is not possible to separate eradication from control clearly. During the data collection process it became apparent that it is difficult and artificial to make a clear distinction between the measures to prevent the further introduction and spread of ragweed and to reduce or mitigate its harmful effects; and the current practices for its eradication. Eradication could be seen as one subset of actions in the overall continuum of management and strategy for control. After the realisation that it is no longer possible to eradicate the species, efforts are then dedicated to control. A focus on controlling further spread is increasingly important given the likely expansion of ragweed northwards in Europe due to climate change.

The response to ragweed invasion differs significantly among the European countries. It seems that that there are no control actions being implemented in as many as six countries (Czech Republic, Denmark, Romania, Latvia, Moldova and Poland).

Prevention, eradication, awareness raising and monitoring comprise a possible strategy for control. A potentially successful control strategy should comprise all of the four components. Prevention has to be the first step. If ragweed appears, eradication should preferably occur before the flowering season starts. Once initiated, eradication should be consequent and continuous – without missing a single year. In order to detect the appearance of ragweed in time and react promptly, it is necessary to have a good monitoring system in place, which is also important as a follow-up to the eradication measures to confirm the success of the measures or trigger a repeated eradication action.

Preventative measures aim to stop the spread of ragweed before it becomes established. Such measures are being undertaken in Austria, Bulgaria, Croatia, France, Germany, Italy, Hungary, Serbia, Switzerland and Ukraine. Prevention is the most cost-effective approach to control of ragweed, as current information suggests that once ragweed has become established in an area, it often proves to be very hard, if not impossible, to eradicate it. The most commonly used preventative measures include legal regulation, the control and destruction of contaminated seeds and soil, biological measures such as crop rotation and encouragement of competitive vegetation, chemical measures such as spraying of herbicides and physical measures such as repeated mowing, ploughing, or pulling of ragweed.

Continuous monitoring is needed for any control strategy to be effective. Information about the development of the infestation provides evidence for the success (or failure) of the abatement measures utilized. Monitoring can be organized formally and executed by members of the public (volunteers) or professionals. In countries such as Belgium, Croatia, Czech Republic, Denmark, France, Italy, Hungary, Latvia, Poland, Switzerland and Ukraine, there is a legal obligation for certain landowners and members of the public to conduct monitoring activities, as a part of wider control activities.

Social media, such as Facebook and Twitter; and smartphones apps are very useful tools for monitoring. Social networks and the growing usage of smartphones and their apps have become the latest tools to link scientists with the public, empowering people to act on their own behalf and actively participate in monitoring and reporting on invasive species.

There are three forms of eradication: biological, physical and chemical. Biological eradication (e.g. by grazing or using competitive plants) is being undertaken for example in Austria, Germany and Hungary. There are currently no effective biological control agents available in Europe. Physical eradication (e.g. by mowing, mulching, burning or pulling) is being undertaken in Austria, Croatia, Germany, Hungary, Serbia and Switzerland; but are work-intensive and therefore costly. Chemical eradication (using herbicides, generally: glyphosate, mesotrione, clopyralid, MCPP, or florasulam) is being undertaken in Austria, (Eastern) Croatia, Germany, Hungary and Serbia; and is very effective and the most commonly used approach.

A well-targeted intensive awareness raising campaign is a key to success of control strategies. It will lead to both an increase the number of people that can contribute to tackling the issue (e.g. citizens, volunteers, farmers, landowners), often at low or no further costs, as well as building their capacity. Examples of good awareness raising campaigns are known from Switzerland and Germany; in the latter, the countrywide Action Program Ragweed, the Bavarian Action Program Ragweed, and a General information campaign in Hesse.

Relevant sectors have an important role in the control strategies for ragweed. Certain industries are closely linked to the spread of ragweed – agro-industry, construction, transport, gardens and parks, and management of natural habitats. People working in these sectors should be made aware of their potential roles in the spread of ragweed, and their roles and responsibilities in controlling it. These parties are in an ideal position to do monitoring, without a large additional work load for them and with relatively small investment by the Government – mainly for awareness raising, capacity building and coordination.

Task 8: The necessary elements for an European Early Warning System

Early warning and rapid response systems are developed at national levels. Responses to a Europe-wide questionnaire demonstrate that in at least 13 European countries (sub)national structures have been set up to detect ragweed presence, to assess risks, to report observations, and to take follow up actions. The level of organisation of these structures varies from formal and strictly organized to informal on-line observation portals. In most cases early warning for ragweed is embedded in wider early warning and rapid response (EWRR) systems for invasive alien species (IAS). Well-developed examples of EWRR are also found outside Europe. We describe some European networks and structures that already function as an EWRR for (aspects of) IAS, in certain cases including ragweed.

Managing ragweed involves many different actors. Our survey identified a wide range of actors at the national level that are involved in ragweed management in some way. We distinguish three major groups on the basis of their connection to ragweed. *Contributing parties* are those actors that – mostly unintentionally – enable the introduction and spread of ragweed (e.g. bird feed producers and construction companies). *Affected parties* directly or indirectly experience the impacts of presence of ragweed (e.g. citizens with allergic reactions, or a farmer with a weed problem). *Responding parties* have a direct or indirect role in contributing to control and eradication (e.g. gardeners reporting observations or public authorities developing awareness campaigns). An individual actor may fall into more than one of these groups.

A number of European databases and information networks have been developed. We identified a number of well-developed European and global databases and information networks covering IAS, in most cases including common ragweed. Some of these databases (e.g. DAISIE) were developed on a project basis and are not updated regularly. Others (e.g. EPPO PQR database) are embedded into intergovernmental structures and therefore have a longer future horizon. Each of the identified databases has strengths and weaknesses in supporting an EWRR for ragweed. Jointly they make an excellent basis for a common European information network.

Development of observation portals supports monitoring of ragweed. There is an increasing number of national, easy-access, observation portals, using user-friendly geographical layers (such as Google Earth). In most cases such observation portals cover all species groups, including ragweed. Some examples focus on ragweed as part of a selected set of species in connection to phenology and allergy prediction. Some developments at international level offer opportunities for Europe-wide online reporting of observations of ragweed, such as the NatureWatch component of EEA's Eye on Earth. The observation portals are a useful aid but cannot be considered monitoring programmes *per se*. We found no monitoring programmes focussed on ragweed trends. For pollen, however, monitoring programmes of ragweed pollen concentration have been institutionalized at European level. Detection and monitoring of fruits is largely done at national level in some countries, as part of control of seed mixtures and bird feed.

National communication campaigns are well developed. We found extensive evidence of well-developed awareness raising campaigns and communication actions at national level. We suggest there is no need for a Europe-wide communication campaign on ragweed. Instead, we propose stronger European coordination in exchanging best practices, filling communication gaps, and translating existing materials to all relevant languages.

New technologies offer excellent support to ragweed control. The identified online observation portals, together with mobile technology (particularly apps and Twitter), could allow wide-scale reporting of ragweed infestations across Europe. Social media and online sharing platforms (e.g. YouTube) offer unique platforms for awareness raising and alerting to large audiences. Remote sensing might be used to identify ragweed populations, although further research is needed. The same holds true for DNA barcoding techniques that might provide tools for border control in the medium term.

A European EWRR structure should build on existing networks and focus on coordination and facilitation. On the basis of existing European platforms, networks and organisations we propose the creation of a European coordinating centre on IAS. Such coordinating centre should build as much as possible on existing networks, such as EPPO, EEA/Eionet, EFSA, NOBANIS, and DAISIE, and develop further to fill existing gaps in capacity. The recently established European Alien Species Information Network (EASIN) is expected to provide the basis in terms of an information network. Most of the roles with regard to early warning and rapid response are already taken up effectively at national level. A European coordination centre should therefore focus on facilitation, coordination, and harmonisation of efforts. We propose an organisational structure with identified roles and responsibilities.

Glossary

In this section we supply definitions of terms used widely in this report that are technical and/or are used with a specific meaning. Related terms with the same base definition are given in parentheses.

Term	Definition
Additionality	In economics, the extent to which a new activity (action or item) adds to existing activities (instead of replacing any of them) and results in a greater aggregate impact or cost
Administrative cost	Costs of activities that are required to comply with the information requirements imposed by actions and the management of actions. They exclude the costs of undertaking the actions themselve
Alien (see also non-native)	A species or race that does not occur naturally in a region, i.e. it has not previously occurred there, or its dispersal into the area has been mediated by humans
Allergen	An environmental substance that can produce a hypersensitive reaction (an allergy) in the body but may not be intrinsically harmful. Common allergens include pollen, house dust, and various foods
Atopic	Pertaining to atopy – a hereditary predisposition to experience allergic reactions in response to certain allergens
Biodiversity	Biological diversity at all scales: the variety of ecosystems in a landscape; the number and relative abundance of species in an ecosystem; and genetic diversity within and between populations
Biological control	The regulation or eradication of a pest species by one or more introduced natural enemies. The pest species is frequently, although not always, an introduced alien species
Casual	Non-natives that may grow and even reproduce outside cultivation in a region, but that eventually die out because they do not form self-sustaining populations, and rely on repeated introductions for persistence
Contamination (contaminant)	The presence in a product or other material of an undesirable extraneous substance
Control (control strategy)	An action or set of actions to reduce the numbers or distribution of a species, or to eradicate it, in an invaded area. An overarching control strategy often includes the set of actions for mitigation of harmful effects, awareness raising, and monitoring
Control cost	The costs of undertaking control actions, including equipment, materials, labour to undertake the actions, and their planning and management
Dispersal	The complete lifetime movement of an individual away from its parent
Ecosystem services	The benefits people obtain from ecosystem processes and functions

Eradication	Actions to remove a species completely from a region
Early Warning and Rapid Response system - EWRR (EWS)	A framework designed to respond to biological invasions through a system of surveillance and monitoring activities; diagnosis of invading species; assessment of risks; circulation of information, including reporting to competent authorities; and identification and enforcement of appropriate responses. The terms EWRR and Early Warning Systems (EWS) are interchangeable, although an EWRR adds an element of response to an EWS.
IgE	Immunoglobulin E, a protein in blood plasma that activates allergic reactions
Introduction	The deliberate or accidental release of an organism(s) into the wild in regions where the species or race is not native
Invasion	The spread of a non-native species into a new region
Invasive	Naturalised non-natives that have the potential to spread over a large area and, usually, to form large populations
Naturalised	A non-native species or race which, after escape or release, has become established in the wild in self-maintained populations
Non-native	The same definition as for 'alien'
Pest	Any organism (not necessarily alien) that is found in locations where it is not wanted and which has economic and/or environmental impacts
Phenology	The timing of growth and developmental stages of an organism through the year in relation to environmental phenomena
Pollinosis	An allergic reaction to pollen = hayfever
Prevention	Actions to stop the introduction of a non-native into regions where it is not yet present. This can also include measures for containment to avert the spread of the species from local invasion foci
Ragweed (common ragweed)	All mention of ragweed in this report, unless qualified, refers to common ragweed *Ambrosia artemisiifolia* (also know as short ragweed)
Rhinitis	Infection or irritation of the nasal mucous membranes leading to discharge, congestion, and swelling of the tissues. Allergic rhinitis is caused by allergens
Ruderal	A ruderal species is generally confined to frequently disturbed habitats, and these habitats are defined as ruderal themselves. Disturbance may be anthropogenic (e,.g, cultivation) or natural (e.g. flooding)
Sensitisation (sensitise)	A reaction in which specific IgE antibodies develop in response to a stimulus. Allergic reactions result from excess sensitisation
Spread	The extension of a species' range into a unoccupied region by the establishment of new populations
Weed	Plants (not necessarily alien) growing in locations where they are u and which have economic and/or environmental impacts (see Pest)

Introduction and general methodology

Background

Common ragweed *Ambrosia artemisiifolia* L. (Asteraceae) is an annual species, native to North America, which has been introduced and subsequently naturalized in many countries including a large part of Europe. It's highly allergenic pollen causes hayfever, asthma and other reactions; and it is a significant crop weed. These harmful effects, combined with its potential for rapid spread has caused ragweed to be considered among the most dangerous invasive non-native species in Europe[1]. The European Commission[2] has identified the species as a significant problem to many Member States of the EU and a very serious threat to others; and that, whilst there is good information available on the health effects of *A. artemisiifolia*, there is a gap in the knowledge on the direct and indirect effects on the wider environment and economic sectors.

In order to advance knowledge about ragweed in Europe and to aid planning for future actions, the European Commission let this project titled: "*Assessing and controlling the spread and the effects of common ragweed in Europe* (ENV.B.2/ETU/2010/0037)". This project has the aim to synthesise and systematically review information, highlight knowledge gaps and utilise modern modelling methods to allow: an understanding of the current extent of ragweed infestation in Europe; the development of measures to control ragweed spread and introduction (now and in future climates); economic, social and environmental quantification of direct and indirect harmful effects in all sectors; and the dissemination of accurate and up-to-date scientifically-based evidence to stakeholders.

General methodology

The project was broken down into a number of Tasks (as specified in the original tender), each with a specific aim.

Task 1: Determine the spreading mechanisms

We aimed to assess and rank the spreading mechanisms of common ragweed in the EU over the last 30 years, by undertaking a thorough review of existing literature and other sources of information. Where pertinent, we also took account of the situation in neighbouring countries (Moldova, Ukraine and Belarus) as potential sources of re-invasion or risk for undermining control measures.

Task 2: Establish the conditions and vectors that favour the spreading of ragweed

[1] http://www.efsa.europa.eu/fr/scdocs/doc/1566.pdf
[2] http://ec.europa.eu/environment/funding/pdf/calls2010/specifications_en_10037.pdf

We aimed to establish the conditions, vectors and drivers of the past, current and possible future spread of ragweed by undertaking a thorough review of the literature and other sources of information compiled in Task 1.

Task 3: Establish a thorough and accurate mapping of the infected areas in the EU27

We undertook to map, in as much detail as the available data permits, the current spatial distribution and occurrence of ragweed in the EU27; other European countries were included as data were available. The outputs for this Task included a georeferenced database and distribution maps.

Task 4: Establish a general systematic methodology to assess the social, environmental and economic impacts of invasive species and then provide a very thorough qualitative assessment as of the current and probable future harmful effects of ragweed

We developed a systematic review methodology to collate and analyse all relevant data concerning the social, environmental and economic impacts of ragweed, which would be applicable to other invasive species. We then applied this methodology to particular questions concerning human and animal health, biodiversity, the wider environment, production systems, and transport and built infrastructure.

Task 5: Based on Task 4, carry out a very detailed quantitative and costs analysis of the effects detailed above, based on the countries most affected within and beyond the EU

The aim was to provide economic data to support policy-making in relation to management of ragweed. To provide this data we did a detailed analysis of the different costs arising from the effects of ragweed identified under Task 4, in relation to the distribution of ragweed established in Task 3 and modelled in Task 6. In this context costs are defined as both the value of financial costs and losses of value to humans, with 'value' understood from an economic perspective to include all welfare changing impacts, expressed in monetary terms where possible.

Task 6: Develop two models: one that would allow estimating the spread and another the harmful effects of common ragweed across the EU depending on different climatic scenarios and policy scenarios including a no action scenario

To predict the future spread and impact of ragweed within the EU we modelled climatic, land use and policy influences on both its spatial range dynamics and the production and atmospheric transport of its pollen. Because ragweed pollen can be transported over large distances a model of population spread will not fully indicate the area at risk because pollen will move beyond that area. Fortunately there is a large body of data and literature on ragweed that allowed us to develop very detailed and accurate models for both of these processes.

Task 7: Overview of the current practices in Member States to prevent the further introduction and spread of ragweed and to reduce or mitigate its harmful effects

A literature review was conducted, compiling and comparing existing systems to prevent the further introduction and spread of common ragweed, as well as to reduce and mitigate its harmful effects once the invasion has occurred. The study was be focused on EU27 Member States. Nevertheless, other highly affected European countries such as Switzerland, Croatia, Serbia, Ukraine, Moldova and Belarus were included.

Task 8: Establish the necessary elements for a European early warning system

The structure of an early warning system for common ragweed was elaborated in this Task; control of invasive species once they are established is often extremely difficult and costly, while prevention and early intervention have been shown to be more successful and cost-effective approaches. Indeed, it is now widely acknowledged that effective global early warning and rapid response systems are crucial for mitigating the impacts of biological invasions.

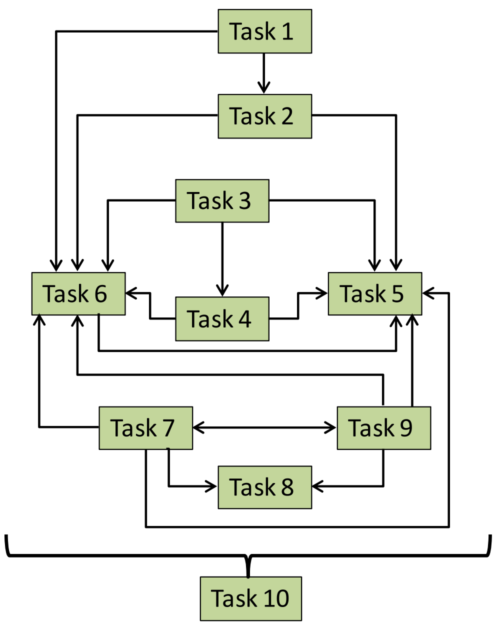
Task 9: Overview of the current practices for eradication in Member States and in other affected European countries (e.g. Switzerland and Croatia)

This Task compiled and compared existing measures and current practices used to eradicate common ragweed. The study was be focused on EU27 Member States. Other highly affected European countries such as Switzerland, Croatia, Ukraine, Moldova and Belarus were included. Because it is difficult in practice to separate eradication measures from more general control measures, Tasks 7 and 9 were conducted in tandem and are reported together

Task 10: Organise a workshop of experts to present the findings of the study and to disseminate the information gathered

A one-day workshop was organised to discuss the contents of the draft final report – to inform this final report – and disseminate the project outputs.

Flows among the Tasks



These Tasks fed into each other as is shown in the diagram above and elaborated in the Task reports. Each Task was tackled using appropriate methods, which are also described in the Task reports. Literature searches were common to several Tasks and all other information sources were stored a Mendeley bibliographic database which allowed sharing among project members.

Because ragweed is a problem throughout Europe, there are many papers, reports and other sources of information only available locally. A critical element of this project was therefore to be able to access and analyse, synthesise and extract data from documents originating from a wide range of countries and languages. This required not only good knowledge of the languages, but understanding of national policies and approaches and access to local data sources. To this end, we recruited 'national experts' employed for the European countries most affected by ragweed. These national experts were selected on the basis of their local expertise regarding *A. artemisiifolia* and other invasive species. The national experts are listed below and are cited in the Task reports either by name or as the national expert for the relevant country. We would like to take this opportunity to thank these national experts for their invaluable contributions to this project.

These national experts were provided with Excel-based questionnaires linked to the aims of each Task; Annex 1 lists the questions asked. This ensured consistency and compatibility of responses and the provision of information considered most relevant for the completion of each Task. The national experts filled in the questionnaires based on the information available in national reports, publications, studies, research projects, scientific articles and personal communication with (other) national experts in fields relevant to the study (e.g. scientists, medical experts, governmental institutions officials, etc.).

Country	**Name**
Austria	Gerhard Gawalowski
Belgium	Tim Adriaens
Bulgaria	Rossen Vassilev
Croatia	Kristijan Čivić
Czech Republic	Miroslav Zeidler
Denmark	Claus Goldberg
France	Isabelle Mandon-Dalger
Germany	Rosemarie Siebert
Hungary	Anikó Csecserits
Italy	Riccardo Scalera
Latvia	Edgars Bojars
Poland	Teresa Nowak
Romania and Moldova	Marin Andrei
Serbia	Aleksandra Mladenovic
Switzerland	Jenny Heap
Ukraine and Belarus	Olga Umanets

Tasks 1,2: A review of information on *Ambrosia artemisiifolia* L. (Asteraceae) spreading mechanisms, and the conditions, vectors and drivers that favour its spread

1 Introduction

This report fulfils Task 1 (Determine the spreading mechanisms) and Task 2 (Establish the conditions and vectors that favour the spreading of ragweed)

Ragweed *Ambrosia artemisiifolia* has shown remarkable persistence and spread in Europe over the last few decades. The aim of Tasks 1 and 2 was to examine the mechanisms of this spread. In this report we will assess the spread of ragweed in the EU over the past 30 years and establish and rank the spreading mechanisms of common ragweed by undertaking a thorough review of existing literature and other sources of information. Where pertinent, we will also take account of the situation in neighbouring countries (Moldova, Ukraine and Belarus) as potential sources of re-invasion or risk for undermining control measures. Secondly, we will assess current knowledge about the conditions, vectors and drivers of the past, current and possible future spread of ragweed by undertaking a thorough review of the literature and other sources of information compiled in the previous Task.

2 Sources of information

A list of scientific and grey literature prioritized for review was compiled, and this formed the main body of evidence used to address the areas of research requested. These included all journal and conference papers, and other literature identified (e.g. government fact sheets, internet publications) identified on available literature databases that made reference to the two key areas of research presented in this review. The publications catalogues of the Wiley Interscience service, Science Direct, Ingenta Connect and Google Scholar were searched using various search terms including *Ambrosia artemisiifolia*; + dispersal, + spread, + invasion, + ecology, and + seed. Non-English language papers were reviewed by a panel of 'National Experts' with expertise on the species in Europe, who also provided their own unpublished observations on the species where available literature was sparse. Additionally, many papers reviewed cited earlier work, providing valuable information on *A. artemisiifolia* not found elsewhere; the full transcripts of some papers were not available for this study but they have been cited where appropriate and indicated in the reference list as 'unreviewed'. Careful attention was paid to the quality of literature reviewed, in terms of both the reliability of the evidence and the relevance of the data presented, and gaps in the research on a given topic were identified as far as possible. The majority of the literature reviewed here is from peer-reviewed journals and the proceedings of symposiums and workshops. These include internationally available English-language journals and numerous journals published in other European languages. Several reports that were included for review could not be assumed to have been peer-reviewed; these were generally by authors with peer-reviewed papers on the species published in one of the journals mentioned above. In short, the general quality and reliability of the evidence available for review was considered to be good. Several papers, which present very thorough investigations of a particular aspect of the history, biology, ecology or genetics of *A. artemisiifolia* are referred to repeatedly in the following report as they hold valuable information that supports multiple areas of investigation presented here; these include Bazzaz (1974), Bassett & Crompton (1979); Fumanal *et al.* (2007a; 2008a,b), Genton *et al.* (2005a), Lavoie *et al*. (2007), Brandes & Nitsche (2006), Kazinczi *et al*. (2008a), Chauvel *et al*. (2006) and Gaudel *et al*. (2011).

A panel of 'National Experts' (see General Methodology) were commissioned to provide literature reviews of non-English-language papers and to assist with observations and interpretations of the behaviour of *A. artemisiifolia* in the European countries most affected by *A. artemisiifolia*. These National Experts are referred to throughout the text when their personal observations and comments are referred to.

3 The spreading mechanisms of Ambrosia artemisiifolia (Task 1)

3.1 Introduction

Information on first records of *A. artemisiifolia* in countries in which it is not native is available in many papers; for example the species was recorded[1] in Germany in 1863 (Heigi, 1906 in Kazinczi *et al*., 2008a), in France in 1870 (Chauvel *et al*., 2006), in Austria in 1883 (Essl *et al*., 2009), in Russia in 1918 (Reznik, 2009), in Hungary in the early part of the twentieth century (Török *et al*., 2003) and possibly as early as 1888 (Kazinczi *et al*., 2008a).

Some invasive non-native species in Europe are the result of a single action, perhaps the most famous (and equally problematic) being the collection and subsequent cloning of a single female Japanese knotweed *Fallopia japonica* plant for commercial ornamental use. However, analysis of *A. artemisiifolia* herbarium specimens (Chauvel *at al.*, 2006) and molecular studies (Genton *et al.*, 2005a; Chun *et al*., 2010; Gaudel *et al*. 2011) suggest multiple introduction events over time within affected countries, rather than an initial introduction and subsequent colonization of neighbouring areas by progressive range expansion. This subject will be returned to in the second part of this review but it is of relevance here because if this is the case, then the initial mode of arrival of *A. artemisiifolia* into a country is of less importance than recent and current routes of introduction, and the current vectors of spread facilitating colonization within and between 'host' countries.

Most documents reviewed report a similar list of dispersal mechanisms for ragweed seeds in host countries and whilst the most frequent dispersal method appears to vary over time and among countries, the vectors of dispersal proposed for the species remain largely the same and include, in no particular order; (1) natural seed dispersal, (2) dispersal of seeds in imported seed for crops and food, (3) contaminated animal fodder including bird feed, (4) the spread of seed along transport routes including movement by vehicles along roads, and by accidental release from road and rail freight of contaminated seed, (5) in transported soil and other organic matter, including on agricultural machinery such as harvesters and mowing machines, and (6) by floods affecting rivers

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[1] As an introduced or naturalized plant in the wild. Cultivated specimens in botanic or private gardens occurred earlier.

and roads. The evidence for these vectors of spread is reviewed below, with particular regard to the quality and quantity of evidence and the relative importance of proposed vectors of spread.

3.2 Natural seed dispersal including barochory, anemochory and hydrochory

Bassett & Crompton (1975) state that *A. artemisiifolia* is primarily wind-pollinated but that the resulting seed is not thought to be adapted specifically for dispersal by wind or animals. A study by Dickerson (Dickerson, 1968 in Bassett & Crompton, 1975) found no *A. artemisiifolia* seeds greater than a 2-m distance from experimental plants. This PhD thesis was unavailable to this study and the conditions under which the experimental plants were grown could not be ascertained, but no evidence in support of dispersal of seed by wind (anemochory) was found. In the Czech Republic it is proposed that natural seed dispersal (by gravity alone – barochory) is 'facilitated by wind' (Miroslav Zeidler, pers. comm.), whilst in Moldova/Romania there is a suggestion that 'the weight of seeds allows spreading by wind' (Marin Andrei, pers. comm.), but these are anecdotal ideas. Fumanal *et al*. (2007a) found that the achenes of *A. artemisiifolia* were heavy relative to other weedy species in the Asteraceae but, as is found in many species (e.g. Michaels *et al.*, 1988), there was a high degree of plasticity in seed mass. Wind dispersed seeds are either small and light (e.g. seeds of the Orchidaceae) or have structures to facilitate flight such as the feathery pappus of dandelions (*Taraxacum* spp.) or the wings of maple seeds (*Acer* spp.) (Hughes *et al.*, 1994). *A. artemisiifolia* has none of these characteristics but, as has been found for other invasive species (von der Lippe & Kowarik, 2007), fast-moving traffic along major roads may enhance dispersal distances, particularly of smaller, lighter seeds. However, the effect of elevated wind currents created by fast moving traffic or trains is largely untested on *A. artemisiifolia* (although see Vitalos & Karrer, 2009). This is investigated further in section 3.5.1.

The high degree of plasticity in seed mass (Fumanal *et al.*, 2007a) in *A. artemisiifolia* is important in another natural method of seed dispersal, hydrochory or dispersal by water, with lighter floating and heavier non-floating achenes produced by the same individual plant. Fumanal *et al.* (2007a) found that floating achenes display longer dormancy, germinate more quickly (although overall % germination success was lower), and attain greater plant heights and shoot dry mass than their non-floating counterparts (Fumanal *et al.*, 2007a). These findings provide evidence of hydrochory as a potential vector of spread for *A. artemisiifolia* and the authors propose hydrochory as a partial explanation for the recent expansion of *A. artemisiifolia* in southern France. Rivers and lakes therefore may be an important vector of spread for *A. artemisiifolia* and this is discussed in section 3.7. Roads are also subject to flooding, particularly during snowmelt, and even under normal precipitation water can flow quite freely along some stretches. Roads have been identified as frequent habitat for *A. artemisiifolia* (section 3.5.1); there is therefore the potential for the dispersal of seeds in floodwater during heavy rain and snowmelt in roadside drainage channels.

3.3 Dispersal by animals (zoochory)

Evidence for dispersal of seed by zoochory in *A. artemisiifolia* is limited. The seeds of many species are predated by faunal species particularly birds and small mammals, some of which pass through the gut intact and seed is dispersed in this way (endozoochory). The spread of *A. artemisiifolia* through cattle slurry is reported (Lesnik, 2001, in Kazinczi *et al*., 2008a) in Slovenia where slurry is considered an important vector of spread; *A. artemisiifolia* is reported to be spreading rapidly in areas of intensive livestock farming that are heavily fertilized with organic manures. Lesnik's (2001) study investigates the changes in germinability of *A. artemisiifolia* seed stored in maize silage and cattle slurry, but the paper was unavailable for this report. However, further evidence from the Czech Republic supports this research (Lhotská & Holub, 1989). Stall dung used to fertilize potato crops near Kolin in the Czech Republic contained viable seed of *A. artemisiifolia*, which would probably have originated from contaminated fodder (see Section 3.4.2).

Seeds may also be dispersed by external attachment to animals (ectozoochory), by adhering to fur, feathers, or feet. There is no direct evidence of this in *A. artemisiifolia* but the presence of hooks on the seeds has been suggested to facilitate accidental spread by animals, including birds and people (Alleva, 2009; Marza, 2010; also pers. comm. from Riccardo Scalera, Aleksandra Mladenovic, Marin Andrei).

The seed of some species may also be collected and stored for later consumption by wild animals ('caching'), some of which may never be retrieved. In Bulgaria, Senka Milanova of the Plant Protection Institute (Kostinbrod, Bulgaria) has observed rodents collecting seeds from cultivation experiments (Rossen Vassilev, pers. comm) and in Serbia this mechanism of spread is reported in the literature, although as an observation only (Mladenovic Aleksandra, pers. comm; Jovanović *et al.*, 2007). Caching of giant ragweed *A. trifida* seeds by earthworms has been reported in the USA (Regnier *et al.* 2008), although the small distances involved make this process unlikely to be of major importance in the dispersal of any ragweed species.

3.4 Agro-industry – human-mediated dispersal

3.4.1 Contamination of grain and other agricultural produce

There seems to be little doubt that early introductions of *A. artemisiifolia* seed into most invaded countries occurred through the import of contaminated seed and grain, although direct evidence of this is lacking due to the long time since these introductions. Most reviewed documents on the spread of *A. artemisiifolia* within a geographic area name various cereal and other commercial seed sources as the historical route of entry, such as: the commercial exchanges of wheat *Triticum aestivum* L. in the 1800s, and red clover seed *Trifolium pratense* L., both of North American origin, mentioned in Chauvel *et al*. (2006); the import of 'American corn' (no further species detail given) and 'clover' seed in Brandes & Nitzsche (2006); and the potato plant route into 1930s France put forward by Kazinczi *et al*. (2008a). The records and reports of *A. artemisiifolia* in arable fields across most of its invasive range (Bassett & Crompton, 1975; Török *et al*., 2003; Brandes & Nitzsche, 2006; Kiss & Béres, 2006; Chauvel *et al.*, 2006; Lavoie *et al.*, 2007; Kazinczi *et al*., 2008a) also correlate with an initial introduction through contaminated cereal and other crops, and the occurrence of the species as a casual around harbours and ports (Brandes & Nitzsche, 2006; Chauvel *et al.*, 2006; Reznick, 2009) in the early years of invasion certainly lends weight to the import of seed and grain as the invasion route.

In Belgium *A. artemisiifolia* is still reported as a casual in harbour areas where oil-seeds and other grain are stored and shipped (Verloove, 2006) and in the Czech Republic it is documented from harbours of the Labe-Vltava and Danube waterways where grain shipments are transferred (Jehlík, 1985). Reznik (2009) observed that in 2005–2007 in central and northern Russia *A. artemisiifolia* plants were found 'mostly along railways and highways' but that none of the plants found were able to produce ripe seed. There are several progressive inferences to be drawn here.

1. Seed ripening is limited by environmental conditions in this area, probably mean temperature (which will be explored in more detail later in section 4.2.2).
2. These plants are not the result of a naturalized colony spreading through natural dispersal along the road and rail route as plants in this area are functionally infertile.
3. These plants must therefore be a result of accidental deposition from a contaminated source, the most likely of which is the transport of contaminated grain.
4. As *A. artemisiifolia* has been known from Russia since the late 1930s, these infertile colonies must be the result of recent, i.e. repeated, introductions and not a one-off introduction.

The levels of contamination of grain and oil-seed by *A. artemisiifolia* are difficult to ascertain. Kazinczi *et al.* (2008a) state that 'fruits' of *A. artemisiifolia* have been 'intercepted' in grain (cereals, maize and soya bean) imported into Poland, and the colonization of western Ukraine occurred through infested grain, but quantitative data are not provided. Song & Prots (1998) state that 2.2–10% of imported grain from Hungary, Slovakia and the Czech Republic during 1986–1992 was contaminated with *A. artemisiifolia* seed (source: Transcarpathian Quarantine Inspection data), but do not give further details such as origin and number of seeds per kg grain. In France and Austria *A. artemisiifolia* plants have also appeared in sown game cover crops. The relationship between grain stores and treatment plants has been investigated more fully in the Czech Republic where *ca.* 9% of 47 grain warehouse, silos and mills surveyed supported *A. artemisiifolia* in their adventitious flora (Jehlík, 1982, 1998). It is also reported as frequent in the flora around oil-seed processing plants in the Czech Republic (Jehlík, 1988, 1994). The inference is that the plant originates from contaminated grain.

A study directly investigating the occurrence of *A. artemisiifolia* seed in commercial grain was carried out by Chauvel *et al.* (2004). *Ambrosia artemisiifolia* is mentioned as a pest in sunflower (*Helianthus annuus* L.) crops (Chauvel *et al*., 2004; Galzina *et al*., 2010), a species to which is more closely related to *A. artemisiifolia* than many other commercial crop species, but little evidence was found of *A. artemisiifolia* contamination of the sunflower seed sold in the Dijon area of France certified for cultivation. Dijon is situated to the north of the Rhône valley; the area in France said to suffer the worst invasion by *A. artemisiifolia*. However, only a single *A. artemisiifolia* seed was found by Chauvel *at al.* (2004) in 16 samples (2 replicates of 8 brands/varieties; 150,000-seed packages), which compared favourably with the much higher contamination found in seed for the bird feed market (see 3.4.2). The exact source of the sunflower seed in this rather limited study is not provided, but the suggestion is that sunflower seed for agricultural use is subject to stricter processing (cleaning) prior to sale. It must also be said that sunflower seed, as a large seeded species, is easier to sort from smaller seeded species such as *A. artemisiifolia* than some other crops.

As *A. artemisiifolia* is known to be a pest in arable fields (e.g. Novák *et al.*, 2009) in many countries outside its native range and is still considered to be increasing in range (Bretagnolle & Chauvel, 2006). It is likely that the plant is still being spread through contaminated grain, and probably also other crops such as tubers where mud sticking to the produce may contain *A. artemisiifolia* seed. *Ambrosia artemisiifolia* is a known pest not just in cereal crops but also tuber and root crops such as carrots and potatoes (Saint-Louis *et al,* 2005; Brandes & Nitzsche, 2006; Lavoie *et al*., 2007; EPPO, 2009). There is little evidence to address the question as to which countries and crops are the most important in movement of *A. artemisiifolia* seed as a contaminant. However, it is clear that this is a major cause of seed transport, which is leading to one or all of the following processes.

1. The repeated introduction of *A. artemisiifolia* through contaminated seed imported from its native range in North America.
2. New introductions of *A. artemisiifolia* within an already colonized country through the transport of contaminated seed from one region to another.
3. New colonies of *A. artemisiifolia* arising due to the transport of contaminated seed between countries in the EU.

Gaudel *et al.* (2011) studied the genetic structure of naturalized colonies of *A. artemisiifolia* in Europe (see section 3.3.1), and found that populations in Central Europe appear to have originated from the eastern part of its native range in North America, whilst western North America appears to be the source of populations in Eastern Europe. These results suggest that these two regions of Europe were initially colonized as a result of quite separate introductions, i.e. separate commercial exchanges. Furthermore, populations in Eastern Europe appear to originate from a variety of native populations, as they display higher genetic variation than Western European populations (Gladieux *et al*., 2011). These findings provide support for processes 1 and 2 above, but give less evidence for scenario 3; i.e. an initial colonization from seed originating in the native range of North America, with range expansion within Western/Central and within Eastern Europe, but little gene flow between Western/Central and Eastern Europe subsequent to this, . For example, the populations in the more recently invaded Burgundy and Provence–Alpes–Côte–d'Azur regions of France show: a) higher within-population levels of genetic variability than that of native populations in North America, indicating a number of separate colonisations; b) but reduced diversity in populations distant from the original area of introduction (the Rhône Valley), indicating sequential bottlenecks rather than new introductions (Genton *et al.*, 2005a).

3.4.2 Animal feed including bird feed

Feed for birds and other small domestic pets

The spread of *A. artemisiifolia* through commercial bird feed for aviaries and garden feeders has been investigated in several studies (e.g. Hanson & Mason, 1985; Chauvel *et al*., 2004; Alexandre-Bird, 2005; Brandes & Nitzsche, 2006; Vitalos & Karrer, 2008). The study by Hanson & Mason (1985) is one of the earliest references to *A. artemisiifolia* contamination of bird feed, although such contamination by non-native plants in general has long been known (ESFA, 2009). Hanson & Mason (1985) identified *A. artemisiifolia* seed in bird feed samples in the UK, stating that it is 'regularly introduced with millet seed from the USA', however they did not quantify their findings. *A. artemisiifolia* is still a casual in the UK although introduced colonies do not persist (Rich, 1994).

A more detailed study of bird feed as a dispersal mechanism is presented in Chauvel *et al*. (2004). This study found *A. artemisiifolia* in 71% of their samples (7 samples, 3 replicates of each) of sunflower seed sold for bird feed by different outlets in the Dijon area of France (at the northern end of France's area of heavy colonization). The highest density of seeds was found in a French brand with a mean of 251 seeds, representing *c.* 2,700 *A. artemisiifolia* seeds kg^{-1} sunflower seed. This is almost equal to the expected seed output from a single, small flowering plant of *A. artemisiifolia* (*ca.* 3,000 seeds per small plant, Bassett & Crompton, 1975; mean 2,518 ± 271 seeds per plant, Fumanal *et al*., 2007b). Bird feed is readily available to consumers in many countries in bags ranging in weight from about 1–20 kg; so a 20-kg bag could hold the same volume of seed as a small colony of around 20 flowering *A. artemisiifolia* plants. With regard to the source of the seed in Chauvel *et al*.'s (2004) study, of the seven samples, six were of French origin and the seventh was Russian. The Russian seed had low levels of contamination (a mean of 3.6 seeds per sample), but the potential dispersal of this seed sourced outside the existing French population would presumably add to the gene flow and population admixture, which has been identified as increasing genetic diversity and aiding the response by the species to novel selection pressures encountered in countries outside its native range (Chun *et al*., 2010). The viability of the seed was not investigated in this study.

Contaminated bird seed is considered to be the dominant reason for the spread of *A. artemisiifolia* in Denmark, where the species is associated mainly with gardens and ruderal habitats including harbours (Claus Goldberg, pers. comm.), and highly important in Germany (Albertenst *et al*., 2006; Nawrath & Albertenst, 2008, 2009) and Serbia (Jovanović *et al.*, 2006). German research has found *A. artemisiifolia* seed in 23 of 33 bird feed samples during winter 2004–5 (at a rate of 1–374 seeds kg^{-1}); Alberternst *et al.*, 2006) and in a nationwide survey 75% of all German counties contaminated mentioned bird feed as a spreading mechanism (Otto *et al*., 2008).

A report by the European Food Safety Authority (ESFA), dealing specifically with the effects on public and animal health of *Ambrosia* spp.[2] contamination of bird feed (ESFA, 2009), summarizes data from 12 recent studies (Chauvel *et al*., 2004; *et al*., 2005; Brandes & Nitzsche, 2006; Albertenst *et al*., 2006; Klein, 2007; Albertenst & Nawrath, 2008; German Govt. Fact sheet, 2008; Jørgensen, 2008; Lauerer *et al*., 2008; Thommes, 2008, Vitalos & Karrer, 2008) on the degree of contamination of bird feed by *A. artemisiifolia* (Table 1 in ESFA, 2009). The combined data from each of these studies showed 58% of samples contaminated with *A. artemisiifolia* (range 20–91%), and a mean of 85.7 ragweed seeds kg^{-1} of bird feed for all samples (with or without contamination) or of 142.1 ragweed seeds kg^{-1} (range 1–531) for samples with one or more ragweed seed. The food type sampled in the 12 studies are given in the ESFA report, they included 'bird seed', 'sunflower seed', 'single variety seeds', 'mixed bird seed', 'fatball' and 'other animal feed'.

These high levels of contamination of *A. artemisiifolia* seed contrast with the low level of *A. artemisiifolia* contamination of sunflower seed found by Chauvel *et al*. (2004) in seed aimed at the agricultural market for cultivation, rather than bird feed. What is unclear from the study is whether the sunflower seed destined for crops comes from a different geographic area than that destined for bird seed. If the seed for both markets comes from the same area and/or crops which are equally infested with *A. artemisiifolia*, then the inference is that it is the sorting (sieving) process which differs between the two markets. This would be entirely expected as food destined for human consumption is under stricter quality control than animal fodder. Additionally, sunflower seed is much larger than *A. artemisiifolia* seed and sieving (e.g. 3 mm mesh) would remove *A. artemisiifolia* seed effectively (other 'mixed bird seed' products may be harder to sort if they included smaller seeded species). It appears likely from Chauvel *et al*.'s (2004) study that producers are paying more attention to contamination of seed for sunflower crops than to seed for bird food. Bird feed is therefore an important vehicle for dispersal of *A. artemisiifolia* locally (by seed falling from seed feeders) into private gardens, parks where birds are fed and locations with aviaries. Indirect dispersal into the wider environment could also occur through seed taken then discarded by birds and by seeds passing unharmed through the guts of seed eaters (endozoochory by birds, arboreal mammals, rodents etc.; see section 3.3).

In Switzerland, where the use of bird feed contaminated with *A. artemisiifolia* seed has been prohibited since 2006, reported occurrences of *A. artemisiifolia* in domestic gardens fell from 397 in 2006 to 19 in 2008 (ESFA, 2009).This points to a successful method of control, at least for this vector of spread. It is reported that bird and animal seed merchants have responded well to requests to ensure that seed is free from *A. artemisiifolia* seed and the Department of Agriculture Import

[2] The ESFA (2009) report refers to *Ambrosia* spp. in general but all studies cited in Table 3.1 are specifically on *A. artemisiifolia*.

Section (ALP) block imports if the content of *A. artemisiifolia* seed is considered to be over 0.2 g ha^{-1} (*ca.* 10 seeds kg^{-1}) (Jenny Heap, pers. comm).

In Essl *et al*.'s (2009) study of *A. artemisiifolia* invasion in Austria 'bird feeding places and gardens' are mentioned as a habitat associated with *A. artemisiifolia* during the period 1950–1974, but they comment that this habitat has since decreased in importance and Vitalos & Karrer (2008) reported low (2%) germination success in *A. artemisiifolia* seed found in bird feed and considered this mechanism of spread as overestimated. Additionally, observations of bird feeding places in Vienna over 15 years show that although *A. artemisiifolia,* like many other neophytes, does germinate in such places, their populations are periodically destroyed by gardening activities (i.e. weed control; Rolf Diran, Lacon, Landschaftsplanung Consulting, Ledergasse, Austria, unpublished data; Gerhard Gawalowski, pers. comm.).

It should be noted that in addition to bird seed aimed at the domestic market, rabbit and hamster feed are also implicated in Switzerland (Jenny Heap, pers. comm.).

Animal feed; livestock and horses

Fodder for horses imported from North America (together with the horses) during the two World Wars, was cited as one of the main initial introduction routes of *A. artemisiifolia* into France (Chauvel *et al*., 2006) during the first half of the twentieth century, putting *A. artemisiifolia* into the category of polemochorous plants (i.e. spread through war). Animal feed is still proposed as a mechanism of spread for *Ambrosia* spp. The ESFA report (ESFA, 2009) also discusses the occurrence of *Ambrosia* seed in feed material other than bird feed, largely that for livestock. The ESFA report quotes animal feeds including maize, wheat, sunflowers, millet, peanuts, soya bean, peas and beans as potentially contaminated by *Ambrosia* seeds. Lavioe *et al*. (2007) comment that *A. artemisiifolia* is particularly competitive in soya bean crops. Millet and sorghum both have small seeds, so *A. artemisiifolia* seed would be harder to separate through sieving/sorting processes. ESFA (2009) cite a German study (BELV-BLV, 2008; Table 3 in ESFA, 2009) that identified *A. artemisiifolia* seeds in three different seed materials aimed at the livestock market (sunflower, 108 *A. artemisiifolia* seeds kg^{-1}; millet, 418 *A. artemisiifolia* seeds kg^{-1}; sorghum, 27 *A. artemisiifolia* seeds kg^{-1}). There is therefore, potential for spread of *A. artemisiifolia* through animal feed (certainly during the transportation and arrival of the contaminated material, see section 3.5), but this potential is likely to be much lower than for bird feed as many of these seed/grain feed materials are processed on arrival (e.g. grinding, heating, oil extraction) and *A. artemisiifolia* seeds are unlikely to survive this.

3.4.3 Contaminated agricultural machinery

It has been reported that *A. artemisiifolia* seed can be transported directly in the litter and soil deposits on agricultural machinery. For example, *A. artemisiifolia* seed is believed to have been spread initially into Geneva by combine harvesters rented from the heavily invaded area around Lyon (Buttenshøn *et al.*, 2006). The National Experts for many countries report this as an important mechanism of spread, including those for Austria, France, Germany, Hungary, Italy, Romania and Serbia.

Evidence of *A. artemisiifolia* seed on agricultural machinery is presented in Karrer (2010) in which the levels of contamination of several different types of machinery used in the harvesting of pumpkin (*Cucurbita* spp.) and soya bean (*Glycine max*) crops in Styria, south-east Austria, are presented. On some machines, heavy levels of contamination were noted, although levels differed between machines. For example, the number of seeds sticking to combination shredder/plough machines used for pumpkins was 24,000 seeds (on average), and seeds on adapted combine harvesters used for soya varied between 32–31,133 seeds. Conversely, a German multi-purpose harvester used for pumpkin crops, when tested showed little contamination (averaging about 60 seeds). Such contamination would lead to the spread of the species between fields within already infected farms, or between farms where machinery is shared or work is done by contractors. In rural France, where harvesting and other agricultural machinery is often shared between different farms (within formal or informal farming co-operatives), the shared use of contaminated machinery is highly likely to be spreading *A. artemisiifolia* from infested to non-infested parcels of land (Bruzeau, 2007). It has been suggested that this is the main vector of spread in rural areas in France (Isabelle Mandon-Dalger, pers. comm.).

3.5 Road and rail transport networks – human mediated dispersal

3.5.1 Vectors of dispersal along transport routes

Rail and road networks have been suggested by many authors as a spreading mechanism for *A. artemisiifolia* (Protopopov, 1991; Song & Prots, 1998; Chauvel *et al*., 2006; Lavoie *et al*., 2007; Essl *et al*., 2009; Kazinczi *et al*., 2008a; Dullinger *et al*., 2009; Vitalos & Karrer, 2009). The weight of evidence for transport corridors as highly important habitat for *A. artemisiifolia* is relatively good and most studies show road and rail corridors comprising large proportions of the habitats invaded, with some evidence about the timescales over which this habitat was or has become, important. There are numerous references in the literature of first records of *A. artemisiifolia* in an area next to a road or railway. For example, in Bulgaria nearly half of the known localities for this species are along roads and nearly half are along railroads (Vladimir Vladimiriov, Institute of Biodiversity and Ecosystem Research). In Croatia roads are thought to facilitate the spread of the species across geographical features that would otherwise act as a barrier to dispersal, such as mountains (Galzina *et al.*, 2006, 2010). In France transport routes (roads, motorways and railway embankments) are all cited as frequent habitat (Chauvel *et al.*, 2005), and in the southernmost canton in Switzerland (Ticino) the high density of *A. artemisiifolia* appears directly related to the presence of a highway from the heavily infested neighbouring Lombardy region of Italy (Casarini, 2002; Ciotto & Maspoli, 2005; Riccardo Scalera, pers. comm.).

The evidence presented for transport networks as a mechanism of spread is mostly based on the presence of a colony of *A. artemisiifolia* in road or rail habitat, rather than a study monitoring the progression of *A. artemisiifolia* colonies along specific transport corridors over time. Progressive colonization along linear habitat by natural methods of seed dispersal is unlikely to be the source of new colonies (although hydrochory may facilitate spread; see section 3.2); rather sporadic escape or direct accidental deposition of *A. artemisiifolia* seeds are considered the most likely mechanisms through the following vectors moving along transport corridors:

- Seed adhering to the tyre treads of cars or freight that has travelled through infested areas.
- Transport of contaminated goods, e.g. agricultural produce – grain, crops and animal feed (see section 3.4.1, 3.4.2).
- The movement of agricultural machinery or mowing machines contaminated with seed (see section 3.4.3).
- Transport of contaminated soil and aggregates (section 3.6).

Dullinger *et al*. (2009) studied propagule pressure and invasion history of *A. artemisiifolia* in Austria and demonstrated a significant effect of street length on the occurrence of casual populations of *A. artemisiifolia* (although not naturalized populations), which implies the transport of *A. artemisiifolia* seed along major roads. A small study carried out by Vitalos & Karrer (2009) examined the direct dispersal of *A. artemisiifolia* seed along roads through natural seed dispersal (barochory) and the potential movement of seed by vehicular movement, and compared this with seed extracted from material stuck to mowing machines (see section 3.5.2) operating in *A. artemisiifolia* invaded roadsides. 'Naturally' dispersed *A. artemisiifolia* seeds are thought to fall within a few metres of the parent plant (Bassett & Crompton, 1975), whereas Vitalos & Karrer (2009) trapped seeds up to 25 m distance from the edge of a highway population and a rural roadside population of *A. artemisiifolia*, although at very low density (a total of 8 seeds for the study). Whilst the study demonstrates that seed can be moved beyond the expected 2-m distance from the parent plant by traffic or vectors unknown, it is of limited use since it covers only two colonies and gives no information as to the rate of traffic flow or the size of the colonies.

In Québec, where initial dispersal along river corridors has been posited, Lavoie *et al*. (2007) present evidence that the expansion of the road network since the mid-1930s has been important in the subsequent spread and population expansion of *A. artemisiifolia*. Their finding from studies of herbarium specimens was that new records for an area were generally from roads. Subsequent records for the same area were either from roads or agricultural fields, with a trend towards agricultural fields for further repeat records for those same areas. Lavoie *et al.* (2007) conclude that the colonization of fields was most likely to have been accelerated by seed dispersal from *A. artemisiifolia* colonies growing on nearby roadsides. The converse is also possible however, in that roadsides could be subject to repeat invasions by *A. artemisiifolia* due to the movement of agricultural machinery in and out of *A. artemisiifolia* invaded fields.

The evidence is less clear in France, where road and rail networks have not been separated in the available literature. Chauvel *et al*. (2006) in their analysis of habitat data, give 'lines of communication' as the main habitat (50%) of *A. artemisiifolia* records from 1951–2003 (with records from fields representing 34% during the same period). Their conclusion on the spread of *A. artemisiifolia* in France is that repeated introductions of *A. artemisiifolia* occurred over time, rather than a naturalized population radiating out from a single or a few initial introductions, as no single front of invasion could be identified. This still supports the spread of *A. artemisiifolia* along transport corridors, but suggests the species has radiated out from a number of introduction sites along available dispersal routes, presumably from freight of contaminated grain (sections 3.4.1) or contaminated machinery as explored in Vitalos & Karrer (2009).

Evidence from several countries points to a reduction in the importance of railways as a spreading mechanism with an increase in the importance of roads for dispersal. In a study in Austria, Essl *et al*. (2009) observe that until 1950 most records of *A. artemisiifolia* were associated with railways, whereas from 1950–1974 records were from ruderal habitats not associated with the railway infrastructure. From the 1970s onwards roadside records increased and became the dominant habitat, with a sharp increase in the cumulative number of records from roadsides (mainly along major roads) from the year 1995 onwards. This move from railway to roadside habitat over the course of the 20th century is most likely to be due to the shift in many countries from rail to road freight in the latter part of the 20th century in response to enhancement and upgrading of road networks and the advent of more sophisticated road vehicles. In Austria the railway network is now considered a spreading mechanism of moderate importance. In the Czech Republic, despite the documentation of the species at numerous railways (Jehlík, 1988), the importance of railways is now considered lower than roads.

However, there are still countries in which this mechanism of spread is still considered important. In the Republic of Latvia conditions are too cold for naturalization of *A. artemisiifolia,* and it is believed that the species cannot reproduce although casual colonies do appear. It is believed that the import of contaminated seed along the rail network is the most obvious mechanism of spread into this country; 27 out of 33 localities recorded for the species are at, or near to, a railway (Herbarium of the Institute of Biology of the University of Latvia, Edgar Bojars, pers. comm.). Transport networks have also been highlighted as the most frequent habitat of *A. artemisiifolia* colonies in the Ukrainian Carpathian Mountains (railway tracks and embankments) and the Transcarpathian Plain (roadside verges) in a useful study that also provides analysis of rates of spread in these areas (Song & Prots, 1998). Perhaps the most important observation in this study though, is an assertion by the authors that high elevation localities have been colonized due to the existence of a rail transport route used in the circulation of goods between eastern and western regions of Europe (although cf. Gaudel *et al*., 2011; Gladieux *et al*., 2011). As mentioned in section 3.4.1, 2–10% of imported grain from Hungary, Slovakia and the Czech Republic during 1986–1992 was contaminated with *A. artemisiifolia* seed (Song & Prots, 1998). Thus, in the Ukraine transport networks (both road and rail) are considered of paramount importance in the spread of the species and many other species of Mediterranean and South American origin (Olga Umanets, pers. comm.)

3.5.2 Contaminated mowing machinery

The capacity for spread of *A. artemisiifolia* seed through the contamination of other types of machinery, notably on mowing machines used to cut roadside verges, is also considered an important mechanism of spread in some countries such as Germany and Austria.

A study by Vitalos & Karrer (2009) investigated the levels of contaminated material stuck to mowing machinery used to cut verges already supporting *A. artemisiifolia* colonies. Samples from the mowing machines yielded a mean of 28 *A. artemisiifolia* seeds $100g^{-1}$ dry matter, with a mean weight of 179.4g dry matter per machine. The germination rate of seed was 66%. The same mowing machinery is likely to be used to cut extensive stretches of roadside habitat (each machine covers a region of several hundred kilometres). This study was very limited in scope but does provide evidence for direct transport of *A. artemisiifolia* seed on mowing machinery, with the capacity to cover great distances. In Austria this is considered the most important dispersal mechanism.

Research carried out in Germany, particularly the states of Bavaria and Hesse, also points to this mechanism as important in the spread of the species (Alberternst *et al*., 2006; Alberternst & Nawrath, 2009; Heudorf *et al*., 2008; Nawrath & Alberternst, 2008; Nawrath & Alberternst, 2009; Otto *et al*., 2008).

3.6 Construction industry; contaminated materials and landfill waste

The import of contaminated construction materials within and between countries, and the transport and deposition of landfill waste must also be considered. Several authors list construction sites as one of the habitats invaded by A*. artemisiifolia* (Greppo, 2003; Chauvel *et al.*, 2004; Buttenshøn *et al.*, 2006; Holst, 2008; Gaudel *et al*., 2011); in France a link has been highlighted between the arrival of *A. artemisiifolia* and the translocation of soils and gravels for construction sites, particularly materials originating in the heavily infested Lyon area and arriving in previously uninfested regions (Isabelle Mandon-Dalger, pers. comm). Taramarcaz *et al*. (2005) cite the transport of soil contaminated with *A. artemisiifolia* seeds for buildings or embankments as an important vector of spread in France and propose the TGV railway Lyon–Marseille as a probable route.

In Serbia, *A. artemisiifolia* has been recorded in the mountain region of Zlatibor at 1000 m a.s.l. where there is extensive construction activity and in Belgrade it is most abundant (100–200 plants per m^2) in recent construction, installation and landfill areas, declining in the years following disturbance (Jovanović *et al.*, 2006; Stavretović *et al.*, 2006). Contamination is likely to originate from movements of both aggregate material and soil, plus movement of machinery – see sections 3.4.3 and 3.5.2. A similar picture emerges from Eastern Austria where *A. artemisiifolia* has been recorded on construction sites at ‘uncommonly high’ elevations and populations are also known from landfill pits (Karrer, 2009; Gerhard Gawalowski and Rolf Diran, unpublished data); both are considered very suitable habitat. In Austria, there is also a suggestion that the regular (approximately every eight years) 'shearing' of road embankments – a process that removes soil and associated plant material – could be promoting spread of *A. artemisiifolia* if the contaminated material is used in the construction of new embankments elsewhere on the road system (Sabine Auer and Klaus Krickl, Government of Lower Austria, pers. comm. to Gerhard Gawalowski).

The transportation of soil, gravel and other construction materials across country borders between France, Switzerland and Italy is also reported to be common practice (Bohren, 2006; Buttenshøn *et al.*, 2006) and may be responsible for the import of seed across borders (both roads and rail) already outlined in section 3.5.

Domestic garden waste is mentioned as a source of *A. artemisiifolia* plants in Switzerland (Jenny Heap, pers. comm.). Communes (municipalities) in Switzerland encourage composting of garden waste at a central point in villages and towns; concentrations of *A. artemisiifolia* have been observed around some of these sites. However, this vector of spread is considered to be of minor importance as compost that is to be sold as a commercial product will undergo sterilization that mostly destroys seed banks. Rich (1994) recorded rubbish tips as the most common habitat for casual *A. artemisiifolia* plants in Britain.

3.7 Rivers and waterways

Ambrosia artemisiifolia has been recorded from riparian habitats in many countries although the importance of this habitat as a migration route varies among countries. Rivers are thought to be of only minor importance for the spread of *A. artemisiifolia* in Germany (Brandes & Nitzsche, 2006) with only a few colonies reported in this habitat, whilst in Québec analysis of herbarium specimens suggested that *A. artemisiifolia* spread along river corridors (Lavoie *et al.*, 2007) in the early years of colonization. Riverside and lakeside habitats can be frequently disturbed through the fluctuating water-levels, and many non-native annual species exploit this (Maskell *et al*., 2006). However, it has also been demonstrated (see section 3.2) that there is high potential for water dispersal (hydrochory) of *A. artemisiifolia* seed (Fumanal, 2007; Fumanal *et al.*, 2007a). Thus, the water body itself could also be contributing to the geographic spread of *A. artemisiifolia* by transporting seed, potentially great distances in the case of river systems. In trials Fumanal *et al.* (2007a) reported the majority of floating achenes sank after 24 h after immersion in water, but seeds could travel a considerable distance in this time especially along rivers (Wadsworth *et al*., 2000). In light of this study Isabelle Mandon-Dalger (pers. comm.) considers that the transport of achenes through the river system in southern France may be a major source of colonization.

There are also indications that hydrochory is an important mechanism of spread in other European countries, although these are mainly from observations rather than scientific study. In Austria, along the New Danube (an artificial waterway in Vienna), seeds are thought to be transported in the water during flooding, and then establish in the disturbed ground once waters recede (Karrer, 2009, 2010); the potential for establishment is viewed as high with eradication problematic (Gerhard Gawalowski, pers. comm.). This is also the case for the Danube River in Bulgaria where periodically flooded areas are colonized (Vladimir Vladimiriov, pers. comm. to Rossen Vassilev). Dispersal through water is mentioned several times in the literature for Italy and it is thought to be a highly important mechanism of spread, with many populations of plants occurring along streams and rivers. Populations along the Ticino and Po rivers in Italy are considered the key factors responsible for the spread of the plant in the Padana Plain (Casarini, 2002; Riccardo Scalera, pers. comm.). There is also mention of this mechanism in Serbia where the species has been recorded along canals and riverbanks (Aleksandra Mladenovic, pers. comm).

3.8 Leisure industry

There is a single reference to the spread of *A. artemisiifolia* in relation to the leisure industry. In Rome, it is reported that the species is only recorded on sites where a visiting circus has erected its tents (Travaglini, 2008). This is an interesting observation which potentially stems from the multitude of conditions and vectors of spread that are provided by this industry. Circuses travel from place-to-place along the road network, involve the transport of heavy vehicles and machinery, they pass through potentially contaminated regions and towns along roads, and generally occupy edge of town sites that are open areas subject to disturbance and they also may include animals and their associated fodder.

3.9 Scoring of A. artemisiifolia dispersal mechanisms by country

The National Experts were asked to score each spreading mechanism identified for *A. artemisiifolia* in their country based on how important they felt that particular mechanism was, using their expert opinion and available literature and research. The scoring system was from 1, being of low importance, to 10, being of very high importance. To discount subjectivity in individual scores, the scores returned were then placed in three bands: scores 1–3 of low importance; scores 4–7 of moderate importance; and scores 8–10 of high importance. On occasion there were omissions in the spreading mechanisms listed or contradictions in the literature with the scores provided. In these few cases the mechanisms and/or scores were altered to accurately reflect the entire breadth of information available. The resulting scores of the importance of mechanisms of spread in each country are presented in Table 1.

The geographic spread of *A. artemisiifolia* through natural dispersal, i.e. the gradual increase in the area occupied by the species through natural population expansion, is not mentioned for most countries but is obviously occurring in arable sites, along roads, railway embankments and riverbanks. Natural dispersal is generally not considered as important in the spread of the species as the human-mediated methods of dispersal that carry seed great distances and to novel areas and habitat. Five countries included the dispersal of seed by animals as a mechanism of spread, with the possible direct transport of seeds attached to faunal species as of moderate importance and the deposition of dung containing seed of minor importance.

Fourteen out of the 16 countries include agricultural practices as a mechanism of spread in their country, and eight of these considered it to be highly important. Part of this industry, the contamination of crops including animal/bird feed was mentioned by 14 counties but the relative importance of this mechanism varied from low to high, whereas six of the seven countries that mentioned the contamination of agricultural machinery as a vector of spread considered it of high importance. Most countries also mentioned the role of roads in this context, as both habitat to fallen seed from this machinery and the facilitator of the transport of such machinery to other farms.

Eleven of 16 countries included the road transport system as a mechanism of spread, with the spread of the species primarily being blamed on the inadvertent transport of soil and litter containing *A. artemisiifolia* seed on vehicles (cars and goods vehicles; low–high importance) and on mowing machines (mostly high importance). The enhanced potential for wind dispersal (anemochory) due to the effect of fast moving traffic was mentioned by some but not considered of primary importance by any. Six countries considered the rail network to be a spreading mechanism of note in their country but in only four countries was this considered of high importance. Rivers and other waterways were mentioned by eight countries, generally as a mechanism of moderate importance, although Serbia, Italy and Moldova believed it to be of high importance. The transport by river of contaminated goods was mentioned but generally the scores were for the long-distance (natural) dispersal and colonization of novel ground by floating seeds (hydrochory).

The construction industry, specifically, the transport and deposition of soil and aggregates for buildings, embankments and other infrastructure was included by eight countries. This was generally a high scoring mechanism with four countries considering it of high importance. Landfill and rubbish tips were also cited by some countries with plants appearing at landfill and composting sites and on rubbish tips. This was considered of minor importance, although it is the most frequent habitat in the British Isles where the species is a casual only.

The scores of the importance of dispersal mechanisms in each country will be used later in this report, in section 5.0, to provide a ranking of *A. artemisiifolia* dispersal mechanisms with additional information on conditions and drivers of spread that may enhance these mechanisms in the future.

Table 1.1 A summary of the level of importance of different dispersal mechanisms of *Ambrosia artemisiifolia* within 15 countries in Europe. A blank space indicates that the mechanism was not mentioned by the 'National Expert' for that country, and is consequently believed to either be of very low importance or not yet documented.

	Austria	**Belgium**	**Bulgaria**	**Croatia**	**Czech Republic**	**Denmark**	**France**	**Germany**	**Great Britain**	**Hungary**	**Italy**	**Latvia**	**Moldova/ Romania**	**Serbia**	**Switzerland**	**Ukraine/ Belarus**	**Total**
Natural seed dispersal					low								**high**				2
Animal dispersal			low		low						mod		mod	mid			5
Zoochory																	
Agro-industry										**high**							14
Grain & other crops	low	mod		**high**	low		mod	**high**	low	mod	**high**		**high**			mod	
Animal fodder/bird seed	low	mod				mod	mod	**high**	mod		**high**			**high**	mod		
Agricultural machinery	**high**						**high**	**high**		**high**			**high**	**high**	mod		
Road network																**high**	11
Natural + anemochory	low										mod			low			
On vehicles	low		**high**	**high**	mod		**high**	**high**		mod				**high**	high		
On mowing machinery	**high**							**high**						**high**	mod		
Rail network	mod			**high**	low							**high**				**high**	6
Wind-tunnel effect																	
On/in trains			**high**														
Rivers & waterways																	8
Natural + Hydrochory	mod		mod	mod	low		**high**				**high**		**high**	low			
Construction & landfill																	8
In soil/aggregates/waste	mod		low				**high**	**high**	mod	mod				**high**	**high**		

3.10 Conclusion

It seems clear from the available literature that the spread of *A. artemisiifolia* outside its native range is more due to anthropogenic factors than natural dispersal mechanisms – the species follows human activity. Interpretation of the evidence presented above suggests the following scenario for the spread of *A. artemisiifolia* throughout its introduced range.

Natural seed dispersal of *A. artemisiifolia* results in slow spatial expansion of populations as, in the absence of strong adaptations for long-distance dispersal of seeds by wind or animals, the seed falls close (2–3 m) to the parent plant (Bassett & Crompton, 1975) and in this way populations could expand only very slowly. This mechanism of spread is thought to be of minor importance in most countries. The case is different for riparian habitats where there is potential for hydrochory (Fumanal *et al.*, 2007a) to enhance spread.

There seems little doubt that seed from infested crops is being harvested with the crop and transported to other geographic areas, by road and rail. The hard evidence for contamination of grain is better represented in studies on bird and animal feed (Hanson & Mason, 1985; Chauvel *et al*., 2004; Brandes & Nitzsche, 2006) but some authors (and national experts) have expressed the opinion that this mechanism of spread is of less importance than crop contamination (Vitalos & Karrer, 2008). The contamination of grain and seed for agricultural use, and the contamination of crops for consumption, is reported by many authors in many countries but investigated in detail by few (e.g. Song & Prots, 1998; EFSA, 2007; Kazinczi *et al.*, 2008a; Essl *et al.*, 2009; Reznik, 2009). Opinion is divided between countries as to the importance of this mechanism with some countries considering contaminated grain of higher importance than others.

New records for *A. artemisiifolia* associated with road and rail habitat in previously uninvaded areas points clearly to *A. artemisiifolia* arriving in novel locations in freight – i.e. the transport of contaminated grain and construction materials – and also by the movement of contaminated machinery, particularly agricultural harvesting machines and mowing machines. Once *A. artemisiifolia* seed has been transported to a new area, potential routes for establishment are: seed falling from grain bags when removed from transport vehicles, establishing colonies *in situ*; seed being sown into agricultural fields with the crop seed; seed being transported to food processing factories and escaping there, or seed germinating in construction materials on construction sites. Seed arriving in agricultural fields through grain for cultivation may further expand its geographical spread by collecting in organic and inorganic matter on agricultural machinery, thus moving from field to field. Seeds arriving along road or rail transport routes achieve further spread via litter collected on mowing machines and are possibly also swept along by fast moving vehicles (Vitalos & Karrer, 2009), and transported by floodwater during heavy rainfall and snowmelt (Fumanal *et al.*, 2007a). The movement of agricultural machinery, such as harvesters, and the movements of mowing machines used to cut roadside verges are considered by many authorities to be the most important mechanisms spreading the species, with the road network facilitating the dispersal of seed in this way to distant locations within and between countries, crossing geographical and climatic barriers to spread.

Rivers are also facilitating spread of the species by providing linear, long-distance corridors of suitable habitat coupled with the dispersal mechanism of hydrochory whereby seeds can be transported potentially long distances downstream before being deposited on the disturbed riverbanks. This method of dispersal is important in at least some countries, and possibly more than are documented. Further research on this mechanism would be advantageous.

Urban renewal is a contributing factor to the spread of *A. artemisiifolia* giving rise to the need to transport potentially contaminated soil and aggregates coupled with the provision of large areas of suitable disturbed habitat. This is an important route into urban environments for the species and although highlighted in several countries, may well be underestimated.

The next section investigates the evidence available for the conditions and drivers that favour the spread and establishment of populations of *A. artemisiifolia* once they have 'arrived' at a potential host site.

4 The conditions and drivers favouring spread of Ambrosia artemisiifolia (Task 2)

4.1 Introduction

Ambrosia artemisiifolia is a pioneer and opportunistic species of early successional ecosystems (Bazzaz, 1974; Fumanal *et al*., 2007b, 2008b). Its spread and the successful establishment of naturalized populations once introduced rely on the correct environmental conditions being met for the reproduction of the species, and as an annual plant these conditions must be maintained over time, or at least return within the timeframe of the longevity of the seedbank. Unlike long-lived perennial species, which can adopt a 'waiting-game' strategy, reproducing only when suitable environmental conditions are met, *A. artemisiifolia* must complete its full life-cycle regularly to maintain populations and replenish the seed bank. Environmental conditions including habitat, temperature, light, CO_2 and the character of the soil are considered here as potential factors for the successful establishment of populations of *A. artemisiifolia*.

The ecophysiological properties and responses of *A. artemisiifolia* to environmental stresses are also investigated using the available literature, concentrating on behaviour of the species that may promote its spread in novel and challenging environments, and increase its competitive ability and chances of survival.

Historic and current anthropogenic drivers that have facilitated or accelerated the spread of *A. artemisiifolia* throughout its invasion range are then considered from available documentation.

Finally, an overview of the mechanisms, vectors and drivers of spread is presented, ranking the mechanisms in order of importance within the EU.

4.2 Conditions; environmental conditions favouring spread

4.2.1 Habitat and vegetation communities

Multivariate analyses of vegetation surveys have shown that *A. artemisiifolia* has a wide ecological tolerance; it colonizes a large range of disturbed habitats differing in terms of vegetation cover, species composition and type of soil (Chauvel, 2008; Fumanal *et al.*, 2008b). It is noted as a component of arable weed floras and ruderal plant communities in the EU countries in which it is recorded, and generally favours sparsely vegetated and frequently disturbed habitat (see section 4.4.1) provided by arable crops, arable field margins (when ploughed), roadside verges, railway embankments, riversides and watercourses, construction sites, landfill and wasteland.

The most frequently mentioned habitats are arable crops and roadside verges. In Serbia, research into the abundance and frequency of *A. artemisiifolia* in land under different use and management (including the type of crop, time of sowing, application of agro-chemicals and technical measures) revealed that the species is at its most abundant in stubble (Stanković-Kalezić *et al.*, 2009).

A French study found that the two most frequent species recorded with *A. artemisiifolia* were fat hen *Chenopodium album* and knotgrass *Polygonum aviculare*; both species are summer annuals of disturbed, open and often nutrient-rich habitat including arable land, waste ground, gardens and soil heaps (Chauvel, 2008; Fumanal *et al.*, 2008b). These species have similar germination periods and tolerance to hydric stress, and are widespread and abundant species in France.

4.2.2 Temperature

Chauvel *et al*. (2006) proposed that climate acts as a strong ecological barrier, and that the cooler summer conditions in the north of France and Europe have prevented the spread of the species. Of the 48 (of 96) départements in France where *A. artemisiifolia* has been recorded, it has not been found in 14 of them subsequent to its first record there, i.e. colonization/naturalization does not always occur. Reznik (2009) also observed that in 2005–2007 in central and northern Russia none of the *A. artemisiifolia* plants found on road and rail transport routes were able to produce ripe seed. Casual populations of the species in cooler Atlantic-climates such as in the UK do not persist (Rich, 1994). In Norway, where *A. artemisiifolia* is frequently reported as an escape through bird feed, it is not naturalized because the plant rarely reaches flowering and has never been found in seed (Kazinczi *et al*., 2008a). As an annual, germinating in spring and completing its lifecycle by flowering and setting viable seed before the end of autumn (and the onset of frosts), the correct temperature regime must be available to *A. artemisiifolia* in order for it to establish colonies and persist. The conditions encountered over much of Europe and southern parts of Russia and China, for example, are similar to those occupied by native populations in North America.

Germination

Bassett & Crompton (1975) state that temperature is the most important factor affecting germination, citing a study by Dickerson (1968). Dickerson (1968) subjected seeds to temperatures of 10, 20, 30 and 40 °C in every available combination for durations of 8, 16 and 24 h; the highest level of germination (of 75%) for all treatments in the trial was achieved at a regime of 10 °C for 16 h: 30 °C for 8 h for each 24 h cycle. This temperature regime is said to closely match the field conditions in southern Ontario and Quebec where *A. artemisiifolia* is most abundant in Canada (Bassett & Crompton, 1975). A slightly lower level of germination (50.1%) was recorded at 20 °C for 16 h: 30 °C for 8h. Higher levels of germination have been recorded by other authors under laboratory conditions (e.g. Fumanal, *et al.*, 2008a; Leiblein & Lösch, 2011).

Ambrosia artemisiifolia certainly requires vernalization (a period of winter cold) prior to germination in the spring; fresh seed shed during the autumn is dormant and not capable of germination under field conditions (Willemsen & Rice, 1972; Baskin & Baskin, 1987). Germination occurs in spring and can occur over a wide amplitude of temperatures; Brandes & Nitsche (2006) report a temperature range of 7–28 °C, with an optimum at 15 °C, whilst Sang *et al.* (2011) report germination success at temperatures ranging from 5 to 40°C, under both a 12-h photoperiod and continuous darkness. The implication therefore, is that germination does not occur at temperatures lower than 5 °C.

Photosynthetic rate

High temperatures are less likely to have a profound effect on performance than low temperatures. Photosynthetic rate reaches a maximum at 20 °C (Bazzaz, 1974) and then declines, with a rate of 50% of the maximum at temperatures of 30 °C. The plant is therefore most likely to perform best in geographical regions with mean daytime temperatures of around 20 °C, but is known from areas that are regularly considerably hotter than this (e.g. the Côte d'Azur in France and Northern Italy) and is therefore able to tolerate high temperatures. In a study conducted by Deen *et al.* (1998) *A. artemisiifolia* development occurred over a temperature range of 8.0 to 31.7 °C; a maximum leaf appearance rate of 1.02 leaves d^{-1} occurred at 31.7 °C. Bazzaz (1974) attributes this tolerance to the high transpiration rates of the species enabling latent heat transfer resulting in leaf temperatures lower than the ambient temperature.

Flowering and seed production

Naturalization is also thought to be limited by a temperature requirement during the flowering and fruiting period at the end of summer. The onset of flowering is generally late summer from late July/early August to September, with seed-set from September to October (or the first frosts). This is dependent upon local climate however. The number of days from emergence to flowering has been shown to vary between countries (section 3.1.2 in Holst, 2008) and presumably also regions and different elevations. In some climates the species will fail to reach flowering size and/or seed set. In Austria, Essl *et al*. (2009) observed that the mean temperature in the month of July predicts the distribution significantly better than the mean annual temperature. A review by Gerhard Gawalowski (pers. comm) of the effects of temperature in Austria (Dullinger *et al.*, 2006; Vogl *et al.*, 2008; Essl *et al.*, 2009) concluded that the minimum necessary mean July temperature for naturalization was between 15 and 20 °C. *A. artemisiifolia* is therefore restricted in Austria to the eastern lowlands and occurs only as a casual in the cool-climate valleys of the northern and central Austrian Alps, where individuals are thought not to set seed (Dullinger *et al.*, 2009).

The effect of global climate warming on the distribution of the species has also been highlighted by experts in several countries and this is discussed in section 4.4.6.

4.2.3 Light

Germination in *A. artemisiifolia* is thought to be light-induced with dormancy broken by light in combination with temperature; seed buried deeper than 4 cm rarely germinate and in the absence of light seed may enter a secondary dormancy (Baskin & Baskin, 1980; Brandes & Nitsche, 2006; Kazinczi *et al*., 2008a; Sang *et al*., 2011). However, in their germination experiments in the laboratory, Sang *et al.* (2011) achieved germination success in continuous darkness, which points to a combination of factors controlling germination.

Ambrosia artemisiifolia plants show extremely high tolerance to light and did not light-saturate even at very high light intensities (Bazzaz, 1974), enabling them to survive the high light intensities encountered in open-field situations. MacDonald (2009) however, reports that the plant growth is strongly suppressed by shade.

4.2.4 CO_2

The effect on *A. artemisiifolia* of elevated levels of CO_2 is of importance in considering the future behaviour of populations of *A. artemisiifolia* under the predicted elevation in CO_2 levels resulting from human activities (section 4.4.6).

Photosynthetic rate in *A. artemisiifolia* seedlings has been demonstrated to increase with CO_2 concentration (Bazzaz, 1974). Photosynthetic rate continued to increase at CO_2 concentrations up to 450 ppm, which is above current normal atmospheric conditions (*ca.* 390 ppm). More recent studies have identified adaptive variation such that certain genotypes become dominant under elevated (doubled) CO_2 levels. Smaller genotypes gain proportionally more above-ground biomass and allocate more resources to reproduction under elevated CO_2 levels than larger genotypes, a finding which reverses the usual size hierarchy in *A. artemisiifolia* populations apparent under normal atmospheric CO_2 levels (Stinson *et al*., 2011). However, biomass gains attributed to urban-induced elevated CO_2 levels may also have a negative effect on temporal population stability. Increased biomass, in the absence of repeated disturbance, can result in increased litter deposition and subsequent reduction in germination success in *A. artemisiifolia* (Ziska *et al.*, 2007).

A positive correlation between CO_2 levels and pollen production has been reported, with a doubling of CO_2 increasing pollen production by 61% (Wayne *et al*., 2002), and whilst reproduction of this wind-pollinated species is not thought to be limited by pollen availability, increased levels of pollen (in addition to having a detrimental effect on human health) may have biological effects such as increasing gene flow between populations.

4.2.5 Soils

Moisture

Whilst it has been demonstrated that *A. artemisiifolia* plants can potentially colonize new areas by hydrochory (sections 3.2, 3.7), and the species has naturalized on riverbanks, the species is not known in heavily waterlogged habitat. The effect of moisture levels on seedling survival and plant growth were investigated in a study on plants from a German naturalized population. Leiblein & Lösch (2011) studied seedling survival and subsequent plant performance under waterlogged, moist and dry soil conditions (39%, 22% and 5% soil water content respectively). Although plant growth (measured by dry biomass) was lower in dry soil than in moist soil, and lower still in waterlogged soil, little difference was recorded in seedling survival between treatments and the plants showed a high level of tolerance to all water conditions. For example, waterlogged plants were able to reach maturity and produce seeds despite reductions in CO_2 uptake (photosynthetic rate) and chlorophyll content. The study suggests the species favours moist conditions but is tolerant of waterlogging, possibly for considerable periods of time. The tolerance of *A. artemisiifolia* to dry conditions has already been identified by Bazzaz (1974); *A. artemisiifolia* rapidly recovers photosynthetically from water stress due to short-term drought.

pH.

In laboratory and greenhouse experiments carried out on seeds collected in China, germination success exceeded 48% in solutions with pH values between 4 and 12, with maximum rates occurring in distilled water at pH 5.57 (Sang *et al*., 2011).

Evidence of the effect of soil pH on *A. artemisiifolia* growth is cited in Bassett & Crompton (1975) from a study presented in Turner (1928) in which plants were more abundant and taller (30–90 cm) at pH 6.0–7.0 than plants grown in acid soils (unspecified pH), which were less abundant and shorter (7.5–15.0 cm).

The inference drawn from the research above is that *A. artemisiifolia* will tolerate more acid conditions but it will show lower fitness than in less acid soils.

Fertility and inorganic content

Little research was discovered regarding the effects of nutrient availability and inorganic content of soils. Pinke *et al.* (2001) report that in investigations into Hungarian populations 'high potassium contents are associated with slightly smaller infection', with a similar result for high sodium and manganese. Several authors mention eutrophic sites for *A. artemisiifolia* and Gerhard Gawalowski (pers. obs) considers it nitrophytic.

4.3 Ecophysiological factors favouring pioneer behaviour, population survival and competitive dominance

4.3.1 Genetic factors

The evidence for repeated introductions over time of *A. artemisiifolia* into countries outside its native range is supported by herbarium studies (Chauvel *et al*, 2006) and molecular studies (Genton *et al.*, 2005a; Chun *et al*., 2010; Gaudel *et al*. 2011). No genetic loss of diversity has been identified between the native North American populations and the introduced populations (Gaudel *et al*., 2011) and the species does not appear to have gone through any genetic bottlenecks within Europe. The French populations studied (Chun *et al*., 2010) demonstrate high genetic diversity with much greater diversity amongst recent French populations than historical populations. The addition of new alleles into introduced populations through repeated introductions (undoubtedly of human-mediated dispersal) is most likely to have a positive effect on the colonizing ability of the species in non-native habitat where it is likely to encounter novel selection pressures and thus a population with a diverse range of genotypes is more likely to survive. This is demonstrated in the high phenotypic plasticity in *A. artemisiifolia*, displaying wide ecological tolerance (see 4.2.1–4.2.5 & 4.3.4–4.3.9).

4.3.2 Allelopathy

Allelopathy – the release of biochemicals (allelochemicals) from a plant that has harmful effects on another plant – has been indicated for *A. artmesiifolia* (Tóth *et al.*, 2001; Kazinczi *et al.*, 2008b). In laboratory trials allelochemicals extracted from *A. artemisiifolia* were found to have: an inhibitory effect on amaranth, winter wheat, *Trifolium* sp. and white mustard; a detrimental effect on the germination rate of several crop species (soya bean, maize, pea and bean); and affected fungi, bacteria and algae (which may themselves be harmful to *A. artemisiifolia*)(Kazinczi *et al.*, 2008b and references therein). The effects of leaf and flower extracts were similar, with leaf extract exhibiting the strongest effect (Brückner 1998, 2001 in Kazinczi *et al.,* 2008b).

The allelopathic effect of *A. artemisiifolia* on crop species and potential pathogens (fungi etc.) may give the species a competitive advantage and will assist in its successful colonization and establishment in agricultural environments. Its effect on other, non-crop species, has not been determined but allelopathy may also play a role in the invasion of ruderal habitat amongst competitive and aggressive weedy species. Such possibilities relate to the 'novel weapons hypothesis', which suggest that non-native species may produce allelopathic chemicals which are highly inhibitory to newly encountered plants in invaded communities (Callaway & Ridenour 2004).

4.3.3 Reproductive output and seed bank dynamics

Ambrosia artemisiifolia has high potential fecundity; an individual plant can produce several thousand seeds with larger individuals capable of very high levels of seed production. Fumanal *et al.* (2007b) recorded a mean of 2,518 ± 271 seeds plant^{-1}, with a maximum of 18,605 (although some authors have claimed considerably more). Seed viability under laboratory or greenhouse conditions has been demonstrated to be high; Fumanal *et al.* (2008a) recorded 82–100% germination success of seeds sampled after winter, although natural seedling recruitment was lower (< 36%).

The seed bank is thought to be long-lived (> 35 yrs, Telewski & Zeevart 2002; Brandes & Nitzsche, 2006) and burial of seed to depths at which germination is inhibited (> 5 cm, Baskin & Baskin, 1980; Sang *et al.*, 2011) due to light limitation (section 4.2.3) does not result in a loss of viability of the seed. Fumanal *et al.* (2008a) found living seed buried up to 20 cm deep with densities of seeds from 536 to 4,477 seeds per m^2 depending on habitat type (field crops, set-asides and wastelands in France). This study presents much additional information on seed bank dynamics but the general conclusion is clear; reproductive output of *A. artemisiifolia* is high and is a contributory and important factor in its invasion success. The high density of viable seeds at lower soil depths in field crops and set-aside, where later ploughing is likely to bring viable seed to the surface, is of particular relevance in the potential spread of the species.

4.3.4 Arbuscular mycorrhizal fungi

Ambrosia artemisiifolia has been shown to be mycorrhizal (Crowell & Boerner, 1988, in Brandes & Nitzsche, 2006), with three species of arbuscular mycorrhizal fungus (AMF) identified from naturalized plants in France and around 94% of 35 populations studied were mycorrhizal (Fumanal *et al*., 2006). Field investigations by Fumanal *et al*. (2006) identified plants in roadside habitats as the most heavily colonized by AMF with other natural habitats such as wasteland and riparian habitat the next highly colonized and agricultural land such as arable crops and orchard habitat as the least colonized. (The lower colonization by AMF in agricultural habitats may be due to the use of fungicide or repeated ploughing, or other unknown factors.) They conducted further studies of the effects on the growth of *A. artemisiifolia* of inoculation with AMF fungus under greenhouse conditions, which resulted in significantly taller plants with more leaves and higher shoot and root dry mass than those not inoculated. This corresponds with the findings of Crowell & Boerner (1988) reported in Brandes & Nitzsche (2006) who also noted an increase in dry biomass in inoculated plants, and the observation by MacKay & Kotanen (2008) that cultivated plants performed better when inoculated with soil from established populations of *A. artemisiifolia*, suggesting a benefit from natural soil biota, such as mycorrhizae.

4.3.5 Enemy release

Species removed from their native range to new regions may gain an advantage because their natural enemies (e.g. pathogens, herbivores, seed predators) may be absent from the new habitat –

a phenomenon known as Enemy Release. Evidence of enemy release has been demonstrated in *A. artemisiifolia* in French populations. Plants from invasive French populations have been shown to suffer less herbivore and pathogen damage than plants from established Canadian populations that share similar flowering phenologies (Genton *et al.*, 2005), but in transplant experiments displayed no loss of defence, suffering no greater damage than their Canadian counterparts when exposed to the pathogens and herbivores of that environment. There is also some evidence that enemy release operates even on a very local scale; in North America, populations of *A. artemisiifolia* growing in new locations where it has previously been absent, even if only a short distance away (100 m), performed better and exhibited higher germination success (MacKay & Kotanen, 2008). However, the findings of MacDonald (2009), who lists some of the herbivores known to attack *A. artemisiifolia* in North America, to some extent, contradict the findings of Genton *et al*. (2005) and MacKay & Kotanen (2008) by demonstrating low effects of enemy exclusion on survival and performance of plants and a high tolerance of the species to herbivory (see below).

4.3.6 Mowing tolerance

Ambrosia artemisiifolia displays only weak apical dominance, producing lateral stems and inflorescences; this may lend it a competitive advantage following mowing over neighbouring species that are apically dominant. Plants affected by herbivory and other foliage damage display plasticity in biomass allocation. For example, Brandes & Nitzsche (2006) comment on the ability of *A. artemisiifolia* to tolerate damage due to mowing and trampling; they cite several studies (Armesto & Pickett, 1985; Vincent & Ahmim, 1985; Irwin & Aarson, 1996) that have investigated the species' response to removal of the stem apex and leaves. Removal of the stem in a vegetative plant is reported to delay flowering but does not prevent reproduction as the plant will form new buds from the base, or increase existing lateral stems, whilst removal during flowering has a greater effect on potential reproduction with fewer new inflorescences produced.

4.3.7 Salt tolerance – the role of de-icing salt

Ambrosia artemisiifolia is a successful colonist of roadside habitat, including major roads subject to applications of de-icing salt (sodium chloride, NaCl). A study by DiTommasso (2004) showed that *A. artemisiifolia* in roadside habitats can become locally adapted to withstand seasonal application of de-icing salt. Many roads within the current invasive range of *A. artemisiifolia* have de-icing salt applications during the winter and early spring period. DiTomasso (2004) studied the effect of salt on germination of *A. artemisiifolia* seeds collected from agricultural, rural roadway and highway (major road) sites in Québec. Increasing salinity decreased germination success, which was highest (62–90%) in the absence of salt. Populations from highway sites exhibited significantly higher germination success than the populations at NaCl concentrations of 300 and 400 mM l^{-1} (Figure 3.2 in DiTomasso, 2004). In addition to this, DiTomasso (2004) found that seed from highway populations germinated more rapidly than seed from non-highway habitat. This data is supported by Sang *et al*. (2011) who found that germination exceeded 69% at < 200 mM l^{-1} NaCl, but only reached 8% at 400 mM l^{-1} NaCl.

DiTomasso (2004) observes that *A. artemisiifolia* plants are usually found in the first 0.5 m of the roadside (closest to the road). Species that would be normal competitors of *A. artemisiifolia* in this environment may be excluded by saline conditions, increasing the competitive advantage of this species. The application of de-icing salt on major roads may therefore be promoting conditions that favour the spread of *A. artemisiifolia*. An earlier study (DiTomasso *et al*., 2000) provided evidence that some members of the Fabaceae and some grasses used in roadside re-vegetation projects in North America exhibit poor or delayed germination under saline conditions and may subsequently fail to establish (potentially paving the way for *A. artemisiifolia*) and that the physical removal of roadside vegetation by snow-removal machinery may also create suitable habitat for the spread of *A. artemisiifolia*.

4.3.8 Herbicide tolerance

Several papers mention the successful control of *A. artemisiifolia* through herbicide use (Taramarcaz *et al*., 2005; EPPO, 2008; Kazinczi *et al.*, 2008c; Reznik, 2009) and a table of systemic and contact herbicides suitable for use in different crops is provided in Appendix 3, Table 1 of the European and Mediterranean Protection Organization paper on *A. artemisiifolia* (EPPO, 2008). The general consensus of papers is that the use of herbicides can be an effective means of control in crop situations (with the exception of closely related species such as sunflowers), or particularly effective when used in conjunction with mowing just prior to flowering in non-crop situations [(See Appendix 3, Table 2 in EPPO (2008) for possible herbicides in sunflower crops)].

However, a developing tolerance by some populations to herbicide treatment has been identified [(Ballard *et al.*, 1996; Leif *et al.*, 2000; both in Brandes & Nitzsche, 2006); Saint-Louis *et al*., 2005]. In Québec and Ontario *A. artemisiifolia* is successfully controlled using herbicides 2,4-D, atrazine, bentazon, dicamba, diuron, linuron and MCPA, but few of these are registered as safe to use in carrot crops – a crop in which *A. artemisiifolia* is an extremely invasive and problematic plant (Saint-Louis *et al*., 2005). Linuron has been used in carrot crops since the 1960s, particularly in fields where soil conditions preclude the effective use of other ‘safe’ herbicides. Saint-Louis *et al*. (2005) collected *A. artemisiifolia* plants from fields where they appeared to show a degree of resistance to linuron (R-plants) and *A. artemisiifolia* plants from fields where linuron had never been used and were considered susceptible to linuron (S-plants). In an experiment 100% of S-plants were killed by linuron but R-plants showed only 30% mortality at the recommended linuron rate. Furthermore, the biomass of some *A. artemisiifolia* plants increased when stressed by linuron, achieving greater heights and a greater number of staminate (male) inflorescences. These latter effects may increase the reproductive effort of the plant and increase the capacity for spread. Linuron is used not only with carrot crops, but also cabbage, onion, cereal and potato crops (Saint-Louis *et al*., 2005; EPPO, 2008).

Saint-Louis *et al*. (2005) note that *A. artemisiifolia* has also developed resistance to S-triazine herbicides such as atrazine, loransulam-methyl, cyanazine, simazine, and many Group 2 herbicides (Heap, 2004; Patzoldt *et al*. 2001). Detailed information on *A. artemisiifolia* biotypes in USA and

Canada resistant to herbicides, the geographic area and the herbicide involved can be found at www.weedscience.org (Heap, 2004). Within Europe, such resistance to S-triazine herbicides has also been documented. In the Somogy county of Hungary nearly half of the naturalized populations of *A. artemisiifolia* have developed a resistance to atrazine (Hartmann *et al.*, 2003), apparently due to the intensive use of this herbicide since the 1960s, and further atrazine-resistant plants have been recorded in Vas, Tolna and Békés counties (Kazinczi *et al.*, 2008c and references therein). Kazinczi *et al.* (2008c) summarize some of the research that has been undertaken in Hungary with the aims of identifying herbicides that would be effective at controlling *A. artemisiifolia* and investigating the specific mutation controlling herbicide resistance; a photosystem II (PSII) chloroplast-encoded (*psb*A) gene was isolated where a mutation affects the triazine-binding site. Metribuzin was also highlighted as an effective herbicide against atrazine-resistant genotypes (Hartmann *et al.*, 2005) but much further data is presented in Kazinczi *et al.* (2008c) on herbicide control plus valuable information relating to biological and mechanical control.

It should also be noted that in Hungary, in addition to the development of herbicide-tolerant genotypes of *A. artemisiifolia*, changes in the legislation governing herbicide use may have inadvertently promoted the spread of the species. Preplant Incorporated (PPI) application (mechanical incorporation of herbicides into the soil prior to planting) is now prohibited, which was an effective means of control in sunflower and maize crops; this is thought to be of high importance in explaining the increased spread of *A. artemisiifolia* in Hungary (Novák *et al*., 2009; Kukorelli *et al.*, 2011; Anikó Csecserits, pers. comm.).

4.3.9 Lead tolerance

Ambrosia artemisiifolia has demonstrated a high tolerance to the accumulation of lead in its roots (Pitchel *et al*., 2000, in Brandes & Nitzsche, 2006). This result may have given *A. artemisiifolia* a competitive advantage over other species in roadside habitat in the mid-20th century when traffic volume increased and leaded fuel was still widely used.

4.4 Anthropogenic factors favouring spread

4.4.1 Disturbance

Bazzaz (1974), who studied the species in its native range in eastern United States, considered *A. artemisiifolia* to be an anthropogenic species. *Ambrosia* spp. appear in the pollen record in post-glacial prairie pollen profiles, indicating species colonizing open habitat following tree-clearance by indigenous people. If agricultural expansion and forest clearance were the initial causes of spread within its native range, the rapid colonization of countries outside its native range is also probably through human activity. Human-mediated disturbance is likely to be a strong contributing factor to the spread of this species.

Disturbed habitat is well documented as a habitat for *A. artemisiifolia* in Europe (Bazzaz, 1974; Basset & Crompton, 1975; Chauvel *et al*., 2006; Lavoie *et al*., 2007; Ziska *et al.*, 2007; Fumanal *et al.*, 2008b; Martin & Lambion, 2008; Chytrý, 2009). The requirement of light for germination (an adaptation allowing the seed to detect when it is in open habitat that favours growth) is probably the pivotal environmental variable met in disturbed habitat where seeds remain close to the soil surface (section 4.2.3) and are free of litter accumulation. Certainly in France the species is known from fallow fields in the early years (recent disturbance) but it does not persist due to the increasing shade and competition (Fumanal & Chauvel, 2007). A study carried out by Bazzaz (1968) documented a very marked reduction in frequency of the plant in a field abandoned after corn cultivation from dominance to low importance over a 4-year period following abandonment. Plants are most likely to encounter repeated disturbance in agricultural (i.e. rural), road and rail habitat. Urban environments provide disturbed habitat of shorter duration. In an interesting study of urban-induced elevated CO_2 and temperature (Ziska *et al.*, 2007) the increases in biomass associated with increased CO_2 (section 4.2.4) had a negative effect on the temporal stability of populations of *A. artemisiifolia*; increased biomass in the absence of repeated disturbance can be translated into increases in litter deposition which was shown to have a negative effect on germination success. In support of these findings, Fumanal *et al.* (2008a) demonstrated a positive effect of soil disturbance and the removal of vegetation on seedling recruitment.

The inference from these studies is that for successful naturalization, *A. artemisiifolia* requires repeated disturbance, although longevity of the seed bank will also play a role in this. Habitats which experience fluxes in levels of disturbance (e.g. rotational land-use) may allow *A. artemisiifolia* to persist over time through periodic recruitment from the seed bank.

4.4.2 International trade

It has been demonstrated in section 3.4 that the initial colonization of Europe by *A. artemisiifolia* probably occurred through the import of contaminated seed and grain, and there is much evidence that contaminated commercial products (grain etc.) are still being imported into and within Europe. Evidence is both direct (e.g. the discovery of *A. artemisifiifolia* seed in imported grain in Eastern European countries; Song & Prots, 1998; Kazinczi *et* al., 2008a) and indirect, but still compelling (*A. artemisiifolia* is still reported as a casual in harbour areas where grain shipments are transferred; Jehlík, 1985; Verloove, 2006). It is clear from this evidence that international trade can still be viewed as a current and future driver of spread in the EU, whether from repeated accidental imports of seed from countries in the native range of *A. artemisiifolia* or in contaminated produce traded between countries within the invaded territory in the EU.

4.4.3 Political change and war as drivers of spread

The import of grain into France during the First World War triggered the first main invasion of *A. artemisiifolia* into that country (Chauvel *et al.*, 2006) but further wars and political change can also be seen as drivers of other invasions and population expansion in Europe and elsewhere. Kiss & Béres (2006) point to political transitions that may have indirectly favoured the spread of *A.*

artemisiifolia in Eastern Europe, and assisted the rapid range expansion in populations in the latter part of the 20th century.

After the collapse of communism, agricultural land previously owned by socialist co-operatives was sub-divided and ownership redistributed, with land often returning to small private farms. In many cases agricultural land was abandoned and uncultivated for many years (Makra *et al*., 2005) and in others, a lack of farming knowledge and/or financial resources led to a lack of weed control and poor field management such as few crop rotations (e.g. Hungary, Czech Republic, Slovenia). Reportedly these fields were colonized by *A. artemisiifolia* (Makra *et al*., 2005; Kiss & Béres, 2006; Novák *et al.*, 2009). Although *A. artemisiifolia* favours disturbed ground, it seems that the absence of regular tilling of the soil coupled with poor weed control will lead to expansions in the populations of *A. artemisiifolia*, at least initially (see also 4.4.1). Conversely, poor crop rotation leads to the overuse of the same herbicides and this is likely to have added to the development of herbicide resistant genotypes (see section 4.3.8).

Interestingly, the very formation of these co-operatives or 'collective farms' during the communist era is also proposed as facilitating the spread of *A. artemisiifolia* in post-First World War Russia (Reznik, 2009) and post-Second World War Eastern Europe (Kiss & Béres, 2006), when fields appropriated from farmers obviously saw changes in management including neglect. Kiss & Béres (2006) quote 'Stalin weed' as a popular name for *A. artemisiifolia* in Hungary at this time.

Wars in the late 20th century have also been drivers of the expansion of *A. artemisiifolia*. In the war-torn countries of former Yugoslavia, population expansion was almost certainly aided by the sudden availability of large areas of waste and fallow land as a direct effect of bombing, and the abandonment of fields by displaced (or deceased) former owners (Taramarcaz *et al*., 2005; Bohren, 2006). For example, in Croatia, abandoned settlements and large areas of land affected by landmines were colonised by *A. artemisiifolia* populations in the 1990s – especially in Slavonia in the easternmost part of Croatia – and although they are largely undocumented these populations are believed to still persist (Mrkobrad, 2006; Galzina *et al.*, 2010; Kristijan Civic, pers. comm.).

4.4.4 Urban renewal and infrastructure growth

During the latter part of the 20th century population expansion and political change (including war) has led to urban renewal and expansion, and improved transport links. Construction sites are named by many authors as a frequent habitat invaded by A*. artemisiifolia* (Greppo, 2003; Chauvel *et al.*, 2004; Buttenshøn *et al.*, 2006; Holst, 2008; Gaudel *et al*., 2011). Road networks have been improved over time to accommodate more vehicles for a more mobile society (Kiss & Béres, 2006; Lavoie *et al*., 2007). Road and rail freight, transport goods across country borders (Song & Prots, 1998; Buttensschøn *et al.,* 2009). Rural-village and urban expansions, to accommodate growing populations has necessitated housing and commercial developments. Buildings require the transport of aggregates and soil that may be contaminated by *A. artemisiifolia* (section 3.6; Taramarcaz *et al*., 2005), and create localized areas of heavily disturbed ground that are readily colonized by ruderals such as *A. artemisiifolia*.

4.4.5 Agricultural policy

Section 4.3.8 reported that changes in legislation in Hungary governing the use of PPI herbicide application may have inadvertently promoted the spread of the *A. artemisiifolia* in sunflower and maize crops. In France changes in agricultural practice brought about by the Common Agricultural Policy (CAP) in 1994 have also been highlighted as a driver of *A. artemisiifolia* expansion, particularly in the Rhône département. The increase in set-aside (leaving arable land fallow) and the subsidization of sunflower crops (a frequent host of *A. artemisiifolia*) is thought to have contributed to population expansion. In a study by AFEDA[1] on the increase in *A. artemisiifolia* following CAP reforms, measured during the years 1994–1999, a doubling (in the Rhône) of the *A. artemisiifolia* pollen count was observed (from the previous maximum of 330 grains m^{-3} air to 660 grains m^{-3}). Approximately 10% (*ca.* 33,000 ha) of the total land area of the Rhône département was either fallow or under sunflower crops during this study and there were strong positive correlations between pollen counts and fallow areas (r = 0.97, P = 0.001) and between pollen counts and sunflower areas (r = 0.93, P=0.006)(AFEDA; Isabelle Mandon-Dalger, pers. comm.).

Large-scale set-aside has also been indicated as of importance in Italy (Ciotto & Maspoli, 2005; Alleva, 2009).

4.4.6 Climate change

A recent range expansion in *A. artemisiifolia* populations in relation to increases in temperature has been noted in several countries in the EU. The heightened effects of predicted temperature increases for the future have also been noted as of high importance in the spread of the species. See also section 4.2.4.

Research on the composition of the arable weed and ruderal flora (*A. artemisiifolia* habitat) of Serbia during the period 1949–2005 demonstrated that growing seasons in Serbia are now warmer and drier, with an upward (linear) trend in the length of the vegetative period of plants, with plants appearing earlier in the season (Radičevic *et al*., 2008). Recent observations in Austria have also shown the spreading of *A. artemisiifolia* in higher regions of Austria and this is thought to reflect the global rise in temperature (Dullinger *et al.*, 2006; Vogl *et al.*, 2008; Essl *et al.*, 2009; Gerhard Gawalowski, pers. comm.). The possible effect of global warming has also been highlighted in the

[1] AFEDA, Association Française d'Etude Des Ambroisies; http://assoc.orange.fr/afeda/politique_agricole_commune.htm

Czech Republic where the species is currently restricted to warmer districts (Misoslav Zeidler, pers. comm.).

4.4.7 Absence of control measures

In Switzerland the use of bird feed contaminated with *A. artemisiifolia* seed has been prohibited since 2006 and the Department of Agriculture Import Section block imports if the content of *A. artemisiifolia* seed is considered too high (section 3.4.2). There are also legislative measures to control the accidental import of unwanted species in Russia and Ukraine (Paul Goriup, pers. comm.). However, there are numerous mechanisms of spread for *A. artemisiifolia* in Europe that appear largely uncontrolled. For example, there is no evidence of cleaning potentially contaminated machinery (harvesters, mowing machines, construction plant) prior to transport from infected to non-infected areas; measures to contain the species within infected sites are largely lacking (e.g. the promotion of good farming practice such as wide arable headlands supporting perennial closed-canopy vegetation); or the use of herbicides along infected riverbanks.

4.5 Conclusion

The conditions and drivers that favour the spread of *A. artemisiifolia* comprise the wide tolerance of the species to a range of climatic and environmental conditions, phenotypic plasticity that enables the species to respond to a variety of environments and novel selection pressures, and anthropogenic factors that create disturbed habitat suitable for this annual, ruderal plant. The greatest limiting factor on the spread of *A. artemisiifolia* seems to be climate; the species cannot establish naturalized populations in climates too cold for flowering and successful fruiting. Other than this the densely populated countries of Europe, with mobile and expanding populations reliant on greater infrastructure and a large food supply, provide ideal conditions for this opportunistic species with a high capacity to adapt. The species is tolerant of such factors as mowing, elevated salinity, waterlogging, drought, herbicides, periods of low disturbance and elevated light levels and CO_2 concentrations with an increased biomass.

5 Overview; Current and future mechanisms, vectors and drivers of spread ranked in order of importance

5.1 Introduction – two approaches to ranking spread

The spreading mechanisms and the associated vectors by which *A. artemisiifolia* is spread have been covered in detail in section 3. The mechanisms (the processes and pathways involved) and the vectors (the carriers) are inextricably linked and are for the most-part human-mediated. There are two different approaches which may be taken when assessing the relative importance of spreading mechanisms, required in order to produce a ranking system of mechanisms.

Firstly, one may take a broad, holistic, view of those industries or systems as a whole that result in the spread of this invasive species within Europe. This approach is taken in section 5.2. Secondly, one may look at the individual carriers of seed (organic litter, soil, contaminated crop seed etc.) and rank these in terms of their relative importance in the spread of the seed. This information is presented in section 5.3.

5.2 Ranking broad-scale systems and industries responsible for spread

Six distinct subjects arose repeatedly in the literature on *A. artemisiifolia* and in the personal observations made on the spread of the species by the national experts. These involved large-scale systems that integrate numerous mechanisms of spread. These can be classified as: 1) farming and food production – the agro-industry, 2) the road transport system, 3) the construction industry, 4) the rail transport system, 5) waterways, and 6) natural dispersal by animals. We considered it useful to rank these large-scale systems in addition to ranking individual mechanisms. It may be that individual industries should be made aware of their roles and potential roles in the spread of the species.

The order presented above, is the order in which these systems have been ranked in Table 2, although agro-industry and the road systems are considered of equal importance, with the construction industry only slightly less important. Railways and waterways are considered to be important in some countries but less so in others, and so are ranked as of moderate importance. Natural seed dispersal by animals is considered to be of least importance in the wide-scale geographic spread of *A. artemisiifolia*.

The mechanisms/ vectors and the anthropogenic drivers for each system ranked in Table 2 are expanded upon below. This is not an exhaustive discussion, but aims to demonstrate how each system facilitates the colonisation, persistence and expansion of *A. artemisiifolia*. The individual steps (for example, 1.1–1.6) are not strictly hierarchical but demonstrate possible pathways through various processes and drivers to further population expansion. Potential knock-on effects within each step are indicated (1.1.1, 1.1.2 etc. and further subdivisions). Some indication of the conditions favouring spread is also provided.

Table 1.2 Broad-scale systems responsible for the spread of *Ambrosia artemisiifolia* ranked in terms of their relative importance (1 highest, 6 lowest) in the spread of the species beyond its native range.

Rank	System	Level
1	Agro-industry	Highly important
2	Road transport system	Highly important
3	Construction industry	Important
4	Rail transport system	Moderately important
5	River and waterway system	Moderately important
6	Animal dispersal	Low importance

1) AGRO-INDUSTRY – HIGHLY IMPORTANT

A. *A. artemisiifolia* seed is introduced to arable land through the driver of international trade i.e. imported contaminated seed. Conditions favouring successful establishment and persistence in arable fields include suitable environmental conditions, genetic factors, allelopathy, enemy release and herbicide tolerance

i. Ineffective weed control in crops leads to establishment of *A. artemisiifolia* in crops.

ii. Ineffective cleaning of harvesting and other agricultural machines leads to contaminated machinery leaving infested sites and arriving in novel, uninfested sites – generally by roads and other crop fields.

iii. Ineffective weed control in crops leads to contaminated produce (grain, crops etc.) arriving at processing plants.

iv. *A. artemisiifolia* becomes part of the adventitious flora around processing plants.

v. Ineffective cleaning and sorting of harvest at processing stage leads to contaminated produce (grain, crops etc.) leaving processing plants and being sold on.

Vehicles leaving processing plants become contaminated with seed

vi. Contaminated fodder results in *A. artemisiifolia* seed in stall dung / cattle slurry spread on arable land (endozoochory).

vii. Seed is introduced to gardens, parks and urban areas through feeding birds with contaminated seed.

viii. Contaminated grain is transported across regions and country borders.

ix. Contaminated seed (re-)enters arable fields.

B. Poor farming practice favours spread including.

i. Lack of herbicide use *or* use of herbicides leading to herbicide tolerance.

ii. Poor crop rotation leading to persistent populations and established seedbank.

iii. Ploughing of arable field margins/loss of arable headlands creating disturbed habitat.

C. Changes in agricultural policy at the national or EU scale lead to.

i. Increases in suitable disturbed arable habitat for colonization/expansion.

ii. Loss of effective weed control measures.

iii. Political change results in altered farming practices leading to the creation of suitable disturbed arable habitat for colonization/expansion.

2) THE ROAD TRANSPORT SYSTEM AND ITS MAINTENANCE – HIGHLY IMPORTANT

A) Seed is deposited on and beside roads. Conditions favouring successful establishment and persistence on roadside verges include reproductive output, heavy colonization by beneficial mycorrhizal fungi, mowing tolerance, salt tolerance, herbicide tolerance and lead tolerance.

i. Seed is dispersed though transport losses from contaminated agricultural produce.

ii. Seeds fall from contaminated litter/soil collected on vehicle tyres.
iii. Movement between fields of contaminated agricultural machinery increases geographic spread.
iv. Seed is deposited through losses of contaminated soil and aggregates for construction industry.
v. Natural processes lead to dispersal of seed out of fields and onto roads.

B) Seed on road verges/embankments is collected in litter accumulating on mowing machines and is deposited further along the road.

C) Accelerated geographical dispersal of seed occurs due to heightened effects of wind through movement of vehicles.

3) THE CONSTRUCTION INDUSTRY – IMPORTANT

A. Urban renewal and industrial growth are drivers leading to increases in suitable disturbed habitat on construction sites for colonization/expansion.
i. Populations establish from contaminated soil and aggregates delivered for construction.
ii. Seed collects on construction machinery which is then transported to other construction sites.

4) RAILWAYS – MODERATELY IMPORTANT

A. Seed is deposited on railway embankments. Conditions favouring successful establishment and persistence on railway embankments include reproductive output, heavy colonization by beneficial AM fungi, mowing tolerance, herbicide tolerance and availability of disturbed habitat.
i. Seed spreads through natural seed dispersal along a habitat corridor.
ii. Seed disperses via transport losses from contaminated agricultural produce such as crops and grain.
iii. Seed adheres to the undercarriage of trains.

5) WATER AND WATERWAYS – MODERATELY IMPORTANT

A. Seed is spread along the linear habitat corridor of rivers and other waterways. Conditions favouring successful establishment and persistence on riverbanks include hydrochory, reproductive output, absence of herbicide use near waterways, and availability of disturbed habitat.
i. Seed spreads through natural seed dispersal along disturbed terrestrial habitat bordering lakes and rivers.
ii. Seed from riverside colonies collects in waterbodies during periods of high water and flooding and is carried further downstream (hydrochory)..
iii. Floating seed is deposited on riverbanks.

B. Seed dispersal through hydrochory also when flood water carries seed along roads.

6) ANIMALS AND BIRDS – OF LOW IMPORTANCE

A. Seed from populations in any of the above habitats may be spread by wild and domesticated animals.

i. Seeds collects on the fur, feathers and feet of wild and domesticated animals and is deposited in novel habitat/locations.

ii. Seed is collected for food by wild animals and is abandoned or lost.

iii. Seed ingested by faunal species may re-enter the environment through endochory.

5.3 Ranking of individual mechanisms which facilitate spread

According to the literature review and the opinions of our national experts it is apparent that there are individual mechanisms (or vectors) of spread that are more responsible for geographic or population expansion than others (. These include for example, the contaminated organic litter or soil in which *A. artemisiifolia* seed is found. Seed entering the wider environment by the mechanisms listed in Table 3 transcend the boundaries of the systems outlined in Table 2. For example, organic litter may be generated by the agro-industry, but it enters the road system and possibly the rail system on vehicles and heavy machinery. Contaminated soil enters the road system and the construction industry. Table 3 lists the dispersal mechanisms, which are ranked in order of importance (1, highest) with a break-down of their possible routes into the wider environment (road, rail etc.), the habitats/systems they invade, and the drivers and conditions facilitating that spread.

Table 1.3 Dispersal mechanisms of *Ambrosia artemisiifolia* in Europe ranked in order of importance and frequency (highest = 1) in the literature, and an indication of the current drivers favouring spread. **Dispersal mechanism**, the organic/inorganic material contaminated with *A. artemisiifolia* seed with the vector or carrier which disperses that material; **Habitat invaded***,* the habitats invaded most frequently through this dispersal mechanism,; **Drivers**, current anthropogenic drivers considered most important in facilitating or accelerating dispersal, and ecophysiological properties and responses to environmental stresses that may act as drivers promoting its spread and increasing competitive ability.

DISPERSAL MECHANISM			HABITAT INVADED	DRIVERS	
				ANTHROPOGENIC	ECOPHYSIOLOGICAL
1	**Organic litter**	Harvesting machinery Mowing machinery Tractors Cars	Arable fields Road verges Wasteland Rubbish tips Landfill	Absence of control measures (no cleaning of machines, communal use of machines) International trade	Allelopathy Reproductive output Mycorrhizal fungi Mowing tolerance Salt tolerance
2	**Soil**	Harvesting machinery Tractors Construction equipment Road transport vehicles Cars People	Arable fields Road verges Construction sites Rubbish tips Landfill Industrial sites Wasteland	Absence of control measures (no cleaning of machines, communal use of machines) Urban renewal and infrastructure growth	Allelopathy Reproductive output Mycorrhizal fungi Mowing tolerance Salt tolerance Herbicide tolerance Enemy release
3	**Harvested crop**	Road transport vehicles	Road verges Industrial sites Wasteland	Absence of control measures (poor crop rotation, lack of herbicide use, ploughing arable headlands) Disturbance International trade Changes in agricultural policy	Allelopathy Mycorrhizal fungi Mowing tolerance Herbicide tolerance Enemy release
4	**Production process for human food**	Road transport vehicles Trains Boats	Road verges Railway banks Industrial sites Wasteland	Absence of control measures (ineffective processing) International trade	Allelopathy Mycorrhizal fungi Mowing tolerance Salt tolerance
5	**Aggregates**	Road transport vehicles Trains Construction equipment	Road verges Construction sites Rubbish tips Landfill Industrial sites Wasteland	Urban renewal Absence of control measures (no cleaning of machines, communal use of machines)	Allelopathy Mycorrhizal fungi Mowing tolerance Salt tolerance Herbicide tolerance Enemy release

DISPERSAL MECHANISM			HABITAT INVADED	DRIVERS	
				ANTHROPOGENIC	ECOPHYSIOLOGICAL
6	**Hydrochory (water)**	Floodwater River water	Roads Riverbanks	Absence of control measures (poor flood control, lack of herbicide use) Disturbance	Allelopathy Herbicide tolerance Enemy release
7	**Production process for animal food**	Road transport vehicles Trains Boats Animals People	Road verges Railway banks Industrial sites Wasteland Gardens /Parks	Absence of control measures (ineffective processing) International trade	Allelopathy Mycorrhizal fungi Mowintolerance Salt tolerance
8	**Barochory (Wind)**	Gravity	Arable fields Road verges Riverbanks Rail banks Construction sites Wasteland Industrial sites	Disturbance International trade Political change Urban renewal Agricultural policy Climate change	Allelopathy Reproductive output Mycorrhizal fungi Mowing tolerance Salt tolerance Herbicide tolerance Enemy release
9	**Zoochory (Animals)**	Animal movement	Arable fields Gardens/Parks		

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Task 3: Mapping the distribution of *Ambrosia artemisiifolia* across the EU27

1 Introduction

A critical aspect of assessing current and future threats from ragweed *Ambrosia artemisiifolia* is knowledge about its changing distribution in Europe. Partial maps of ragweed in Europe have been made in projects such as DAISIE (http://www.europe-aliens.org), and the Global Biodiversity Information Facility (GBIF; http://data.gbif.org), but there is much data at national and sub-national scales which has not yet been collated. Our aim is to synthesise existing distribution data to create an accurate representation of the distribution of *A. artemisiifolia* in a GIS database. This data set will subsequently be used in modelling the spread of the species in different climatic scenarios (Task 6). Section 1 provides full details on how all distribution data was collated and mapped using GIS, while Section 2 presents the results of the mapping exercise. In Section 3 the results are discussed in line with current knowledge about the distribution of the species and in Section 4, the future applications of the mapping methodology are described.

2 Mapping methodology

2.1 Project objectives and purpose

The purpose of collecting data and mapping the current distribution of *A. artemisiifolia* in Europe was primarily to show the extent to which the species has invaded EU member states. Understanding the spatial distribution of the species is a key step in predicting its future spread in the region and developing control measures to help prevent this spread.

Confusion with two closely related species (*Ambrosia trifida* and *Ambrosia psilostachya*) is an issue which this research project has addressed. These species may have been misidentified in the field due to their similar appearance, which can distort distribution data. By collecting data for all three species and mapping them separately, our understanding of the potential future spread of *A. artemisiifolia* will be enhanced and also indicate regions where the species may have been misidentified in the past.

Collating data over such a wide area will also identify data gaps and areas where only poor quality data are available. Such information is discussed in Section 3

As part of this project, a series of GIS-based distribution maps were produced based on data collected from sources throughout the EU. The data were standardised and displayed on an easily interpretable map to provide a clear understanding of the current distribution of *A. artemisiifolia*.

The production of higher resolution distribution maps for each country with *A. artemisiifolia* records were also created in order to gain a more detailed understanding of the species' distribution at a local level and thus assist countries to plan for control of the plant in the future.

A map showing the relative abundance of *A. artemisiifolia* across the EU was also created based on the local and EU scale data available (Section 2).

2.2 Existing information

A number of key sources of information were initially reviewed in order to assess the current state of *A. artemisiifolia* distribution in the EU and neighbouring countries to help identify regions and countries where data on the species appeared to be lacking.

Existing distribution maps for *A. artemisiifolia* in Europe were available from the *Delivering Alien Invasive Species Inventories for Europe* (DAISIE) and the Global Biodiversity Information Database (GBIF).

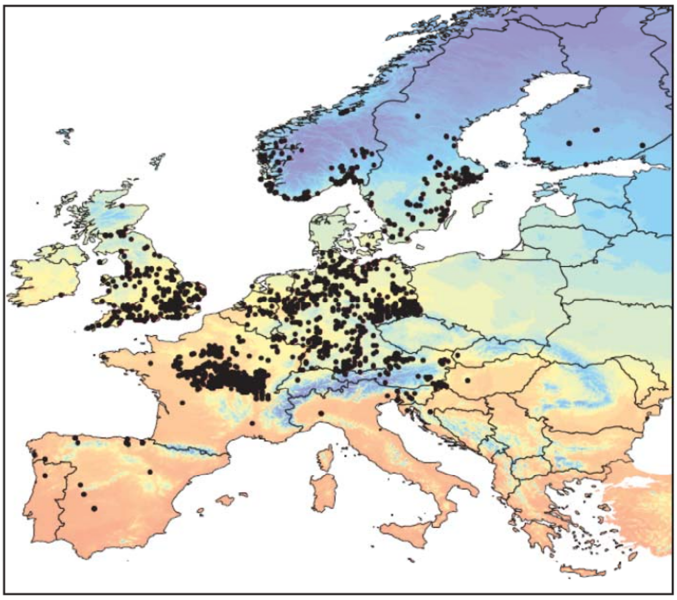


Figure 3.1 - The European distributions of ragweed *Ambrosia artemisiifolia*, according to the Global Biodiversity Information Database (GBIF).

The GBIF and DAISIE distribution maps show similar general patterns of distribution across Europe. The point data displayed in the GBIF map (Figure 1) shows clusters of *A. artemisiifolia* records in the Rhône valley (France), eastern Germany and southern England. Potential data gaps can be clearly seen in Figure 1 with very few or no records displayed for Poland, Czech Republic, Austria and Switzerland despite their proximity to *A. artemisiifolia* population clusters on the GBIF map. Figure 2 - The European distributions of ragweed *Ambrosia artemisiifolia*, according to the DAISIE Invasive Species database.

Moreover, northern Italy and the Carpathian basin (along with the Rhône valley) are known to be the main regions invaded by *A. artemisiifolia* (Kazinczi *et al*., 2008a) and the lack of information for these regions on the GBIF map suggests there are significant gaps in the data set.

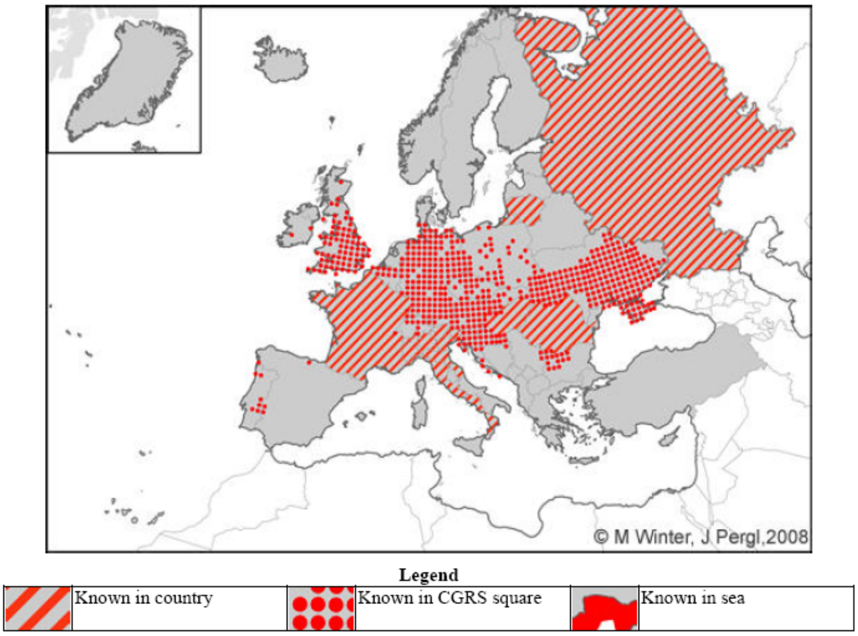


Figure 3.2 - The European distributions of ragweed *Ambrosia artemisiifolia*, according to the DAISIE Invasive Species database.

The DAISIE distribution map (Figure 3.2) shows a wider distribution of *A. artemisiifolia* across Europe and into the Carpathian and Balkan states. However, by displaying entire countries where the species is known to occur rather than specific locations, only very general conclusions about the distribution can be drawn. The DAISIE map utilises the Common European Chorological Grid Reference System (CGRS) but the extent of the grid only covers central Europe, United Kingdom and Ukraine. However, by displaying data for Italy, central Europe, Carpathian basin and Ukraine the DAISIE map proves there are published data available for these regions.

Further information on the current spatial distribution of *A. artemisiifolia* in Europe can be inferred from studying the distribution of *Ambrosia* pollen as mapped by Buttenschøn *et al.* 2009 (Figure 3.3).

In support of Kazinczi *et al* (2008) high or very high pollen counts were mapped in the Rhône valley (France), northern Italy and the Carpathian basin. Whilst the pollen counts are not an accurate record of *A. artemisiifolia* distribution it can be assumed that the highest pollen counts will be recorded in areas in close proximity to *A. artemisiifolia* populations, albeit on a greater spatial scale.

The literature and sources discussed above provided the basis for developing the mapping methodology used here.

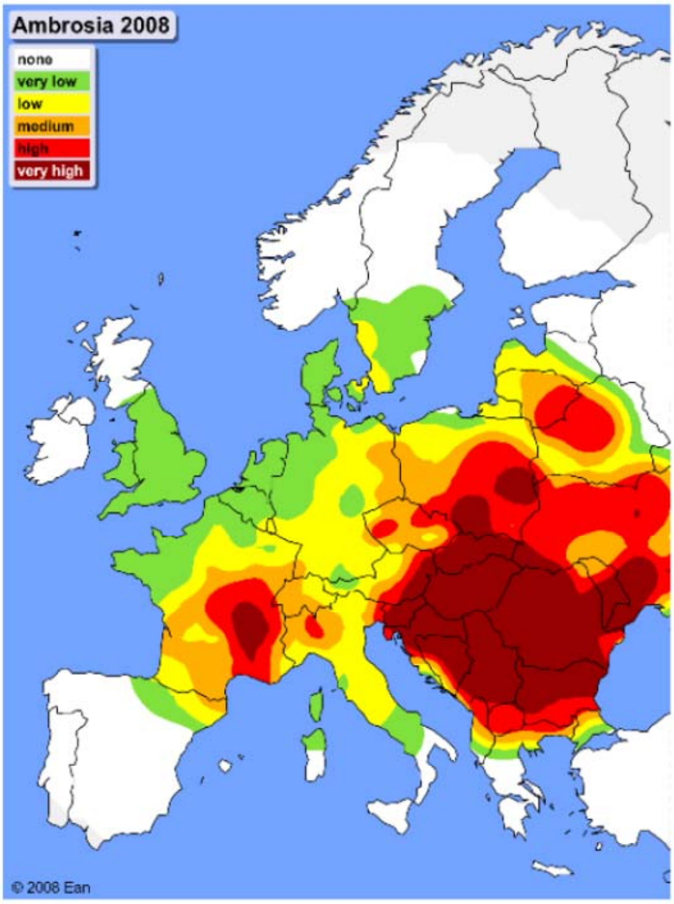


Figure 3.3 - Distribution of *Ambrosia* pollen in 2008 (from Buttenschøn et al. 2009 and based on data from European Aeroallergen Network and European Pollen Information).

2.3 Amendments to the original methodology

The technical document submitted to the European Commission for "*Assessing and controlling the spread and the effects of common ragweed in Europe* (ENV.B.2/ETU/2010/0037)" included a basic description of a methodology that would be applied to mapping the distribution of *A. artemisiifolia* within Europe.

As part of the initial stage of this project the methodology was reviewed and the following amendment made:

Amendments to the grid format

It is important that the requirements of the proceeding modelling exercise are taken into account in the mapping methodology, since the modelling data will be derived from the mapping results. The initial methodology envisaged that the distribution maps would be based on the Common European Chorological Grid Reference System (CGRS) as used by other European biodiversity mapping projects such as DAISIE. However, the mapping grid has been changed to the Lambert Azimuthal Equal Area projection, as an equal area grid system is required for the modelling purposes.

2.4 Data description and specification

In order to create the distribution maps for *A. artemisiifolia,* as many species records as possible were retrieved from various sources throughout the continent. It was expected that this data would be supplied in a variety of different formats which would require standardisation, for example non-digital maps, geo-referenced point data and literature records with vague geographic locations. Furthermore, the potential for confusion with other *Ambrosia* species had to be considered.

The types of data which were expected to be retrieved and their limitations are discussed below:

Geo-referenced Point data

Geo-referenced point data relate to the specific location where a record of *A. artemisiifolia* has been observed. This is the most accurate type of data which can be used as it allows precise locations of *A. artemisiifolia* records to be plotted on a map. The reliability of this type of data is dependent on the instrumentation first used to note the record (GPS etc.) and the various forms of standardisation used by local data collectors. Some geo-referenced points also relate to a notable location nearby (e.g. the centre of the closest town). The range of coordinates systems that such data may be retrieved in meant that a standard system was needed, which all coordinates would need to be converted to.

Grid data

Grid data sets are those where locations of records have been recorded as being present within a given grid square. This method is commonly used in floras and distribution maps of different regions. The accuracy of this type of data is dependent on the resolution of the grid (i.e. 1 x 1 km, 5 x 5 km, etc). Grid data is often provided in one of two formats: firstly grid data supplied as mappable grid files with a notation saying whether a species is present or absent within a square; secondly, grid data that display as points, which have been derived from a grid square. This second format can cause problems in assessing the origin of the original grid, in that the point can be derived from any given point in the square. Such points are often derived from the south-west corner of the grid or the squares centre, but it is important to know which. A method for establishing and standardising these grid data was developed. The coordinate systems that these points are supplied with also required standardisation.

Another limitation of grid data is that grids with a resolution lower than that which is being produced by the project require removal. Therefore the resolution of the grids being produced will need to be set so they include as many data sets as possible whilst still being able to show the finest available distribution patterns. Such a decision on mapping scale can only be made once the data retrieved are assessed.

Images of distribution maps

This type of data are images of distribution maps which have been produced as a result of previous studies (GIS or otherwise) where the original source data is not available for mapping. Such images can vary greatly in quality and accuracy depending on the quality of the original data, the method of representation used to show distribution and the quality of the image supplied. Data supplied in this format will need to be digitised into the GIS system for integration with other data types. It is possible that these images can represent grid data, point data and/or regions within a country (e.g. counties) where *A. artemisiifolia* is present. Therefore a method for standardising and converting this information into points was also developed. To ensure that the digitised images were as accurate as possible, a minimum number of geo-referenced points were applied to the registration of the images within the GIS system. A maximum pixel error limit was also set for the final GIS-registered images.

Anecdotal descriptions of *A. artemisiifolia* occurrences

Anecdotal descriptions of *A. artemisiifolia* records are the least accurate and reliable form of data that is expected to be retrieved from data providers. By lacking any geo-referenced information, there is a significant risk that it will not be possible to map the data to a reasonable level of accuracy. Anecdotal descriptions are most likely to describe a region or country where *A. artemisiifolia* is present and therefore the resolution will be extremely low. This can potentially pose problems when integrating the data as it will show a false distribution pattern compared to higher resolution data (e.g. geo-referenced point data).

Accordingly, data holders were requested to supply all records, as well as geo-referenced data, for the three species.

In order to address the problems associated with standardising large quantities of data from different sources, specifications were set for the data formats and parameters that should be submitting, including:

1. Data retrieved should include as much information as possible on the data's native map projection and coordinate system.
2. The data type (e.g. grid based, geo-referenced point) should be identified
3. Contact details of the data holders should be provided (including phone numbers and email addresses)
4. Map images should be of sufficient quality to allow digitisation and geo-referencing

2.5 Methods for data retrieval

The technical document submitted to the European Commission for ENV.B.2/ETU/2010/0037 included a list of countries where *A. artemisiifolia* was known to occur and/or where further research was required. These countries were:

- Austria
- Bulgaria
- Moldova
- Romania
- France
- Switzerland
- Belgium
- Czech Republic
- Denmark
- Germany
- Hungary
- Italy
- Serbia
- Ukraine
- Latvia
- Croatia
- Poland
- Belarus

To ensure that a comprehensive data trawl was carried out in these countries national experts were employed by NatureBureau and the European Centre for Nature Conservation (ECNC) to retrieve country specific information. The national experts employed for each country were selected based on their local expertise regarding *A. artemisiifolia* and other invasive species. By having experts in each of the key countries it allowed the project consortium to gain access to local information and data sets which otherwise would have been unobtainable. A full list of the national experts is provided in Section 7.

To assist the national experts in their search for data, a questionnaire was supplied outlining the details of the data they should retrieve (Table 3.1). This was done in order to aid in the comparison of data sets at a later date.

Questionnaires completed by national experts were returned and analysed. Any data sets which had not been retrieved by the national experts themselves, but which had been identified as being available were then accessed directly by NatureBureau.

National experts were also required to provide information about the earliest known record and the species historic spread in each country. This information would then be used to create a description of *A. artemisiifolia's* temporal and historic spread (Section 2.1).

Table 3.1 - Example section of the questionnaires provided to the national experts for the retrieval of data

Data details, including region covered	**Source of data**	**Data retrieved?**	**Cartographic projection used in data**	**Georeferenced or grid based data?**	**Data access restrictions**	**Organisation name**	**Contact name**	**Address**	**Tel.**	**Email**	**Website link**
e.g. NBN Distribution Data	*National Biodiversity Network*	*Yes (attached)*	*British National Grid*	*Grid Based*	*NBN needs to be referenced*	*National Biodiversity Network*	*n/a*	*n/a*	*n/a*	-	-
e.g. NBN Distribution Data	*National Biodiversity Network*	*Yes (attached)*	*British National Grid*	*Grid Based*	*NBN needs to be referenced*	*National Biodiversity Network*	*n/a*	*n/a*	*n/a*	-	-

To supplement the data sets obtained by the national experts, an extensive internet search of all potential data holders both within the identified key countries and in other European states was undertaken. This involved collating a list of universities, national biological records centres, flora recording groups, invasive species groups, natural history museums, herbariums and botanical societies within each region. All data holders on the list were contacted and requests for data were submitted. All leads were followed up by email and telephone.

Before any data sets were obtained, data holders were asked to ensure they agreed to share their data and have their data reproduced as part of the current project. When necessary data sets were purchased from data holders and data use agreements signed.

2.6 Results of data retrieval

The extensive trawl of data sets and data holders yielded positive results throughout the EU and for the majority of previously identified key countries. A summary of the data retrieved for all countries is shown in Table 3.2.

All data received from data holders were subjected to a quality control procedure to ensure that they met the required standard for the project. All data sets were assessed against the parameters identified in Section 1.4. Holders of data sets lacking certain information were contacted in order to complete the information required. If sufficient information was not available then the data sets were not considered for the mapping exercise.

2.7 Standardisation of data

All data sets were standardised by georeferencing them to the World Geodetic System version 1984 (WGS84) with the coordinates displayed in decimal degrees. This was chosen as it is an internationally recognised system and is also commonly used in biodiversity recording due to this system being the reference used by the Global Positioning System (GPS).

Table 3.2 –The range and type of data sets retrieved

Country	**Number of Data sets**	**Types of Data Sets**
Austria	3	Point; Image
Belgium	1	Point
Bulgaria	1	Point
Croatia	4	Point; Grid; Image
Czech Republic	4	Image
Denmark	1	Image
Finland	1	Point
France	3	Point; Image
Europe-wide (GBIF)	1	Point; Grid
Germany	2	Point
Greece	1	Anecdotal
Hungary	1	Grid
Ireland (inc. Northern Ireland)	1	Grid
Italy	3	Grid; Image; Anecdotal
Latvia	1	Image
Netherlands	2	Point; Grid
Norway	3	Point
Poland	1	Grid
Romania & Moldova	1	Point
Serbia	2	Point; Image
Slovakia	1	Point
Spain	1	Point
Sweden	1	Point
Switzerland	3	Point; Grid
UK	1	Grid
Ukraine	1	Image

A systematic approach was applied to converting all data sets to the WGS84 standard. The different coordinate systems and projections encountered and the conversion methods applied are detailed below:

Degrees/minutes/seconds

Coordinates supplied in degrees/minutes/second's format were converted in to decimal degrees using the following formula:

(Minutes x 60) + (seconds)
/ 3600
+ Degrees
= Decimal degrees

Example

48° 39' 20.0"
(39x60) + (20.0) = 2360
/3600 = 0.655
+48
= 48.655

Military Grid Reference System (MGRS)

MGRS coordinates were converted using the specifically designed converter available at: http://geographiclib.sourceforge.net/cgi-bin/GeoConvert?input=34WED988418&zone=-3&prec=0&option=Submit)

Distribution Atlas of Vascular Plants in Poland (ATPOL)

This system divides the country of Poland into 100 x 100 km squares which are then subdivided into 10 x 10 km squares. Each square is then given a unique code e.g. DF03.

The ATPOL websites: http://www.ib.uj.edu.pl/chronpol/intro.html; and http://www.ib.uj.edu.pl/chronpol/geo/geo.html provide details of the coordinates for the corners of these squares in minutes/degrees/seconds format. These were then converted into decimal degrees and the central point of each square calculated by finding the mean on the X and Y axis respectively.

Universal Transverse Mercator (UTM)

UTM coordinates were converted using a specially designed converter tool available at: http://www.earthpoint.us/Convert.aspx

Data types

The different data types that were retrieved also required converting to a standard format. Details on how each data type was converted are provided below:

Grid data

Grid data sets were received in two different formats. Those supplied as points based upon a grid did not require standardising to point format. However, it was necessary to discern at which location in a grid square the points were taken from. When this information was not available, the points were assumed to have been taken from the central point of the grid square.

When grid data was supplied as a grid with no points then the central point in the grid square was calculated and the record was taken as being from this point.

Images of distribution maps

Images of distribution maps were digitised into GIS so that they could be displayed alongside other data sets. To ensure maximum accuracy when digitising these images, a maximum error limit of 3 pixels was used and a minimum of 10 geo-referenced points were used to digitise each image.

For digitised images displaying records as points or symbols, the records were taken at the centre of the point or symbol.

Anecdotal

Anecdotal descriptions of records were found to describe regions or counties and therefore the resolution was too low for points to be plotted showing useful information. In these instances it was decided that these records would be mapped as counties/regions showing *A. artemisiifolia* presence/absence during the trial mapping exercise (see Section 1.9) to assess their potential for use in the final distribution maps.

2.8 Quality control

Once all data types and formats had been standardised and plotted, a second phase of quality control was applied to the data sets. The purpose of this second phase was to ensure that no errors had been made in the standardising procedures and that data records had been plotted in the correct places.

Data sets which contained information relating to the specific location of records were overlaid with a GIS layer showing the locations and names of towns, cities and regions. The location data associated with the records was then cross referenced with the GIS layers to ensure records were in the correct locations. If any records were found to be in the incorrect location the data set was reviewed.

Data sets which contained no information regarding the locations of records were plotted on a GIS layer and an image of the GIS layer was created and sent to the data holder to verify the records were in the correct place.

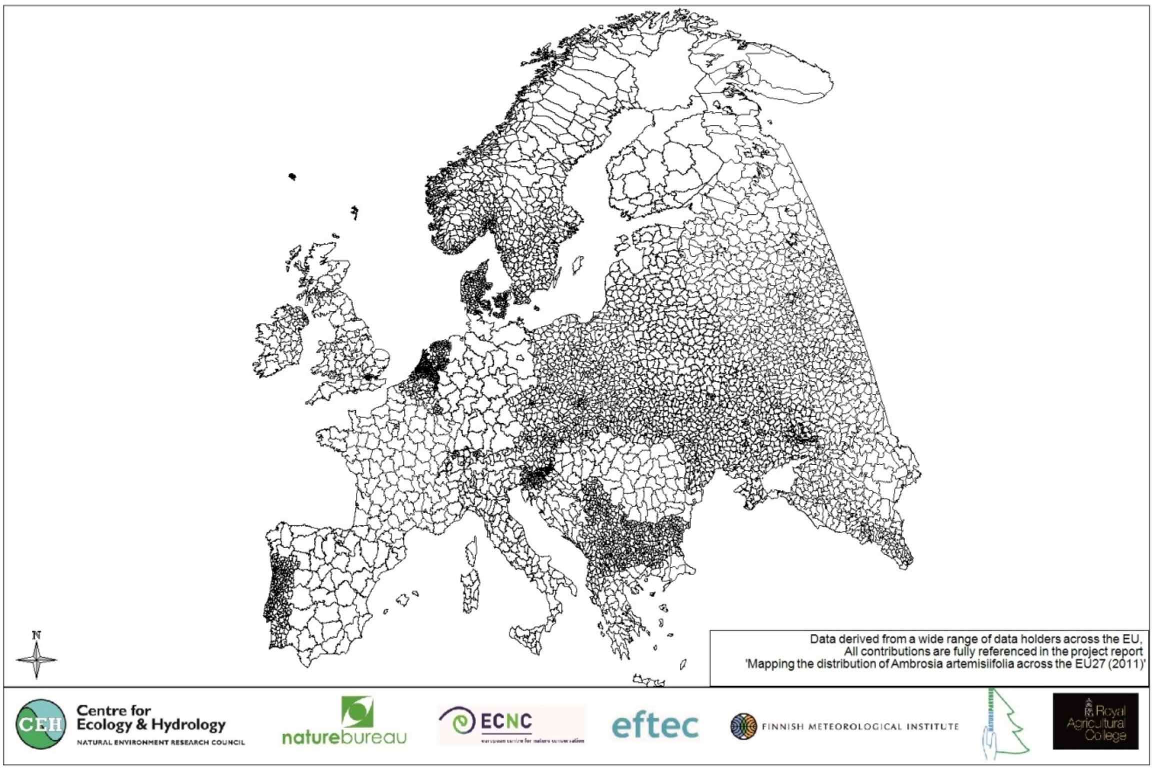
2.9 Trial mapping methodology (county-based map)

In order to develop and test the mapping approach, a trial mapping exercise was carried out. The purpose of carrying out such an exercise was to ensure that the most effective method of integrating the data sets would be applied when creating the final distribution maps. Any issues encountered during the test exercise could then be reviewed and solved prior to developing the final grid based distribution maps.

The aim of the trial map was to show *A. artemisiifolia* distribution throughout Europe at a county level. This was done using a map layer showing European counties with a WGS84 projection (Figure 3.4). The county presence/absence format for the trial map was chosen as data sets were still being retrieved at this time and therefore the resolution of the final distribution grid maps was unknown.

Figure 3.4 - The European county-based map used as the basis for the trial mapping exercise

County and sub-region map used for the trial mapping exercise



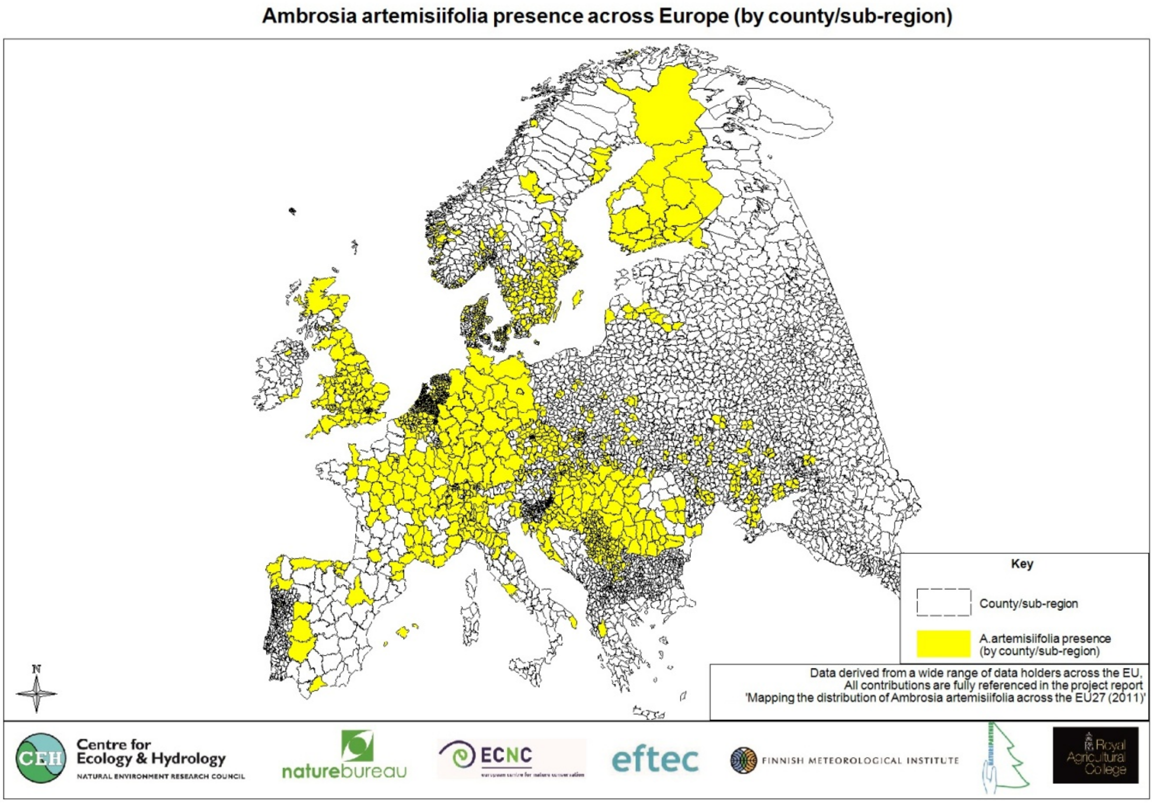
The GIS database for the trial map was created to allow data concerning species presence/absence to be recorded for each county.

To create the trial map all data sets were loaded into MapInfo GIS software (©Pitney Bowes) and overlaid with the county WGS84 map layer. All counties containing records of *A. artemisiifolia* were then selected and assigned as 'present' in the GIS table.

Where data sets were based on grid data the area of grid squares was calculated and any intersecting counties were selected.

2.10 Results of trial mapping exercise

Figure 3.5 - The distribution of *A. artemisiifolia* based on the presence of the species in counties and sub-regions



The results of the trial mapping exercise found that merging the data sets into one GIS layer did not pose any significant problems. However, some issues were highlighted by the exercise and are discussed below:

Data sets originally based on a grid posed a problem when the resolution of the grids was unknown. This meant that the size of the grid squares could not be calculated and therefore the number of intersected counties was unknown. This same problem arose if the location of a point in the square (e.g. centre, south west corner, etc) was unknown and therefore the dimensions of the square could not be calculated.

The borders of the county map used in this exercise were too crude and therefore some records were shown in incorrect counties. This was most noticeable when records in coastal areas appeared in the sea. In these cases another geo-referenced GIS layer showing a map of Europe was overlaid to confirm the location. Where these records were on land the adjacent county was then selected.

The GIS table was not designed to detail information about the data sets. This could become a potential problem if future modification to the GIS map were required.

Data sets which consisted of points derived from a mixture of point and grid data (such as GBIF data sets) were impossible to separate into their constituent types. It was necessary to standardise these data sets by assuming that all records related to precise geo-referenced points.

The method of using counties to show presence/absence clearly distorts the apparent distribution patterns: those countries with larger counties (e.g. Germany, France, UK) appear more heavily infected with Ambrosia than those with smaller counties (e.g. Ukraine, Poland, Hungary). For example Lapland in Finland contained one record on the very southern border of the county. However, this meant that the entire county was selected which gives the false impression that *A. artemisiifolia* was found across the whole county which is not the case (Figure 3.5).

The data sets supplied by GBIF contained no metadata regarding the type of data sets (e.g. point, grids, location of point within a grid, etc). Therefore all data sets obtained via the GBIF portal had to be assumed to be point data where it was not possible to obtain the metadata from the original data holders.

2.11 Revisions to methodology

Based on the findings of the trial mapping exercise the following revisions were made to the methodology before developing the final grid distribution maps:

As not all grid based data contained information regarding the size of the grids and the location of points within grids the true extent of grids containing *Ambrosia spp* could not always be calculated. Therefore it was necessary to try and obtain this information. All data holders who supplied grids of this type were contacted and asked to provide metadata for their data sets. The response from data holders was low, so it was concluded that where no metadata were available, all data sets which were converted to show records as points would be treated as point data and a note explaining this included in the GIS tables.

The ability to identify the original data sets that were used to create the map would be incorporated into the GIS database structure. The table was redesigned so that each data set was provided a reference code within their own column of the GIS database. This allowed full cataloguing of all data sets that could occur in a single grid square.

Where county based presence/absence information would be utilised, a minimal mapping unit would be assigned to each grid resolution. All occupied county/country polygons that occupied below 10% of the area of a grid square were removed from the map.

Grid based data, where the grid resolution was not known, were classed as georeferenced points.

2.12 Development of final distribution maps

The final distribution maps were based on a 50 x 50 km grid (for EU-wide mapping) and a 10 x 10 km grid (for country-wide mapping). Both were equal area grids set to an Azimuthal projection as discussed in Section 1.3.

The GIS tables were constructed so that extra information regarding the total number of records, per 50 km square, could be provided.

The minimum and maximum record dates were also analysed by aggregating the earliest and most recent records for *A. artemisiifolia* in each square. It should be noted that not all records provided date information.

50 x 50 km distribution maps

Separate European distribution maps were created for *A. artemisiifolia*, *A. psilostachya* and *A. trifida.*

All data sets were loaded into MapInfo and overlaid with the grid and all grid squares containing records were selected. Based on this selection the metadata associated with each record was imported into the GIS table to allow cross-referencing with the distribution map.

When data sets were known to be based on grid data this information was included in the table. Otherwise the records were treated as precise locations of records and no calculations were carried out to test if the grids intersected with multiple squares on the grid.

Additional information including 'population' and 'record dates' were provided for *A. artemisiifolia* to support the modelling exercise.

10 x 10 km distribution maps

A 10 x 10 km distribution map was created for each country where records of *A. artemisiifolia* had been retrieved. Distribution maps at this scale were not produced for *A. psilostachya* and *A. trifida*.

10 x 10 km was chosen as the resolution for the local maps as was the finest resolution available that could include the most grid-based data sets.

The grid was produced using the same methodology applied to the 50 x 50 km distribution maps.

Abundance estimate map

An estimate of relative abundance of *A. artemisiifolia* was produced by assessing the number of 10 x 10 km squares within each 50 x 50 km square.

3 Mapping Results

3.1 Historic spread of Ambrosia artemisiifolia

The earliest records of *A. artemisiifolia* date from the 1800s; often being introduced via botanical collections or as a contaminant in agricultural grain and seed imported from the USA (DAISIE, 2011).

United Kingdom

In the UK the species was first recorded as a casual species in 1836. It is considered to be increasing in range and abundance, but most records are still classed as casual (BSBI, 2011)

Austria

The first record of *A. artemisiifolia* in Austria was as a herbarium specimen collected in 1883 (Essl *et al*,. 2009).

The first naturalised populations of the species were discovered during the 1950s in Lower Austria, Gurgenland and Linz (Essl *et al,*. 2009; Fruendorfen, 2009). Since the 1950s, the spread of the species has been exponential with 80 distinct populations recorded in 1980. A study carried out by Essl *et al* (2009) found that nearly one third of all records collected were from the years 2001 - 2005.

In the past 30 years *A. artemisiifolia* has spread throughout the Pannonian region and into areas with cooler temperature regimes. Isolated populations have also begun to occur at higher altitudes (Essl *et al*,. 2009; Karren, 2010).

Bulgaria

The species was first recorded in 1975 on the Danube Plain (Rossen Vassilev). Since this time, *A. artemisiifolia* has extended to numerous locations in the north-west of the country with isolated populations appearing in the north-east and south-west, respectively. The species does not appear to have extended its range greatly since a 2002 study (Dimitrov, 2002). The species is considered established in areas where it is recorded. (V. Vladimirov, *Pers Comm*).

France

A. artemisiifolia was present in at least three botanical gardens in the eighteenth century (Lyons, 1763; Paris, 1775; and Poitiers, 1791) and during the first half of the nineteenth century in at least five gardens in: Alençon; Angers; Avignon; Montpellier; and Strasbourg. The earliest herbarium records are from 1863 (Chauvel, B. *et* al, 2006).

The temporal and spatial spread of the species in France has been extensive in the last 30 years with the number of departments (sub-regions) being free of *A. artemisiifolia* declining dramatically from 54 in 1982; to 38 in 2004; and 9 in 2011 (Chauvel *et al*,. 2005; Pettermann, 2011). The main area of naturalisation has historically been the Rhône valley and the species has proceeded to extend its range from there.

Romania

In Romania the species was first recorded in 1908 in Orsova (western Romania) (Nyarady, 1964). In the past 30 years it has extended its range across the entire country with the exception of the mountainous regions (Hodisan, 2008).

Moldova

A. artemisiifolia was first introduced downstream of the Nistru River (date unknown) (Geidman, 1975). Since being introduced the species has spread in the south-eastern part of the country (Negru, 2007; Marza, 2010).

Switzerland

A. artemisiifolia was introduced into Switzerland in the 1850s in the Geneva and Ticino regions. In the past 30 years the species has continued to spread into the south and east of the country (Christian Bohren, *pers. comm.*).

Ukraine and Belarus

A. artemisiifolia was first recorded in Ukraine in 1925 at an unknown location, probably in the south. It was officially listed in the flora of Ukraine in 1950 (Viznachnik URSR Roslin, 1950). By 1962, it had been recorded from Kiev, Kharkov, Donetsk, Dnepropetrovsk, and Zaporozhye oblasts. It is assumed that the distribution of the species occurred during World War II. In 1987 the species was reported as rare in Kherson oblast and Crimea, but it has since spread to thousands of hectares of land (Olga Umanets, *pers. comm.*). Little information or data were obtained from Belarus and no date of establishment was ascertained.

Belgium

In Belgium the species was first recorded in 1883 and has since become widely spread with most records from the north of the Samber-Meuse river corridor. The majority of records are found in the more urbanised regions (FLORABANK; Martin *et al*, 2008).

Croatia

The first records of *A. artemisiifolia* in Croatia are from the 1940s around Pitomaca in Central Croatia. It is suspected that the species spread from the major sea harbour of Rijeka with clover and grain seed. According to some Hungarian authors, Ragweed spread from Hungary to Croatia as early as 1922 (Béres I., Hunyadi K., 1991). The species has since spread rapidly in Croatia as an agricultural weed (Malceljski, 2003) and is now present in all of inland Croatia. The infestation along coastal areas is not as extensive as inland but it is spreading rapidly (Galinza *et al*, 2008). *A. artemisiifolia* is expanding its range in a westerly direction at a rate of between 6 and 20 km per/year (Galinza *et al*, 2008).

Czech Republic

Within the Czech Republic, the species was first recorded in 1883 in clover fields near Třeboň and a field near Doudlevice u Plzně (Slavík, B. & Štěpánková, J., 2004). Over the past 30 years *A. artemisiifolia* has spread from harbours, grain houses, silos, mills and transport links (Jehlik, 1998) to lowland areas of south Moravia, north east Moravia and along the Elbe valley (Slavík, B. & Štěpánková, J., 2004).

Denmark

The earliest record of *A. artemisiifolia* dates from 1865 but today it has only a limited distribution in the country. However, the species has been noted as spreading from established areas (Nature Agency, DK).

Germany

A. artemisiifolia was first recorded in 1860, in Hamburg. It is believed that *A. artemisiifolia* was inadvertently introduced with grain and seed shipments from the USA. Up until the 1970s, *A. artemisiifolia* was found in only a few places but since the 1990s it has spread eastward. The species is mostly found in the south and east of the country (Alberternst *et al*, 2006) in areas where anthropogenic activity is greatest. The suggested driving vector for the species spread has been the development of road networks (Nawrath *et al*, 2010).

Hungary

A. artemisiifolia was first recorded in Hungary in several places in the south-west, north-east and central regions of the country between 1922 and 1926 (Csontos, 2010). In the last 30 years it has begun to expand its range into the north-east of the country (Novak *et all*, 2009). Since the 1950s the species has been recorded with increasing frequency within the Hungarian National Weed Survey. In the 1950s the species was ranked 21st in the weed list and has since risen to: 8th in the 1970s and to 4th by the 1980's (Novak *et al*, 2009).

Italy

The species was first recorded in 1901 or 1902 from Piedmont. In the past 30 years *A. artemisiifolia* has spread most significantly through the Po valley in northern Italy. It has also begun to spread into central Italy, specifically in the regions of Lazio and Marche. The species appears to be spreading south and the spreading rate of the species has been calculated at 10 km yr^{-1} (Travaglini, 2008) and 6 km yr^{-1} (Lupo *et* al, 2006), respectively.

Latvia

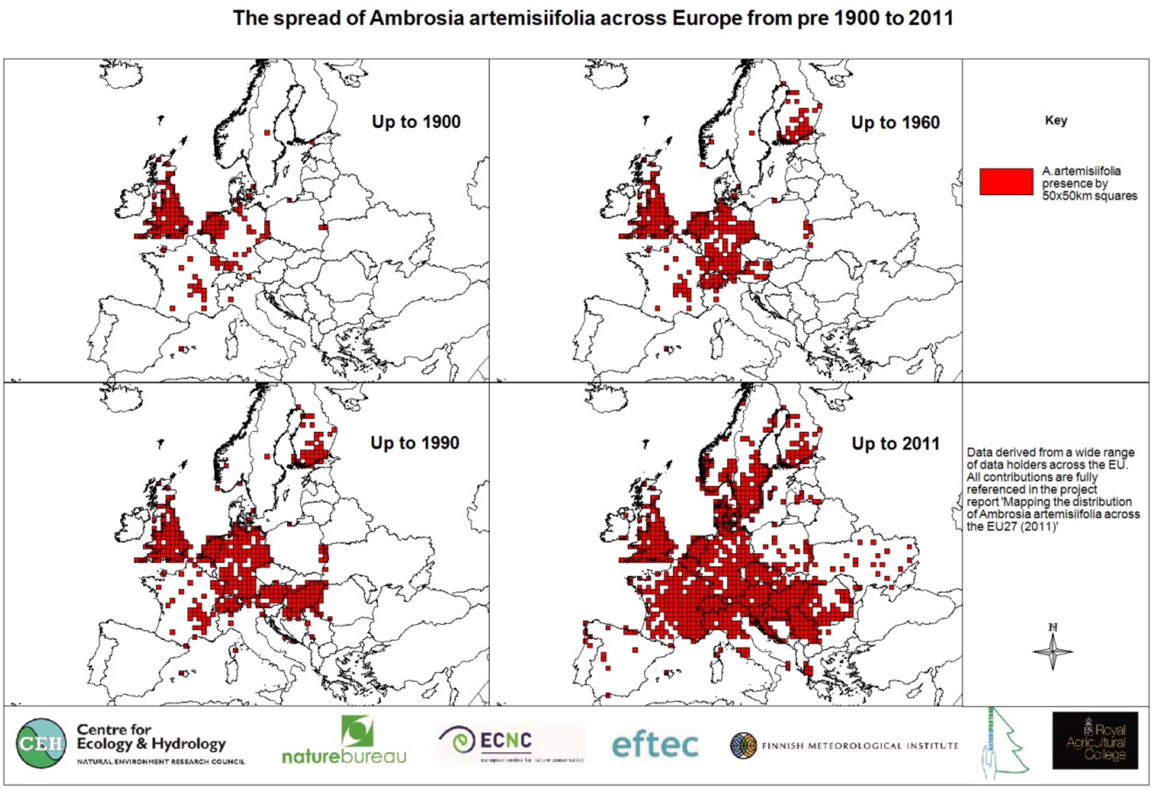
A. artemisiifolia was first recorded in Latvia in 1936 (location unknown). *A. artemisiifolia* is considered a casual species in Latvia and the spreading rate is considered to be very low. *A.*

artemisiifolia is mostly recorded along railways and close to major cities (Herbarium of Institute of Biology of the University of Latvia).

Poland

A. artemisiifolia was first introduced into Szczepanowice (Silesian Lowland - south-western Poland) in 1873. It is also possible that the species may have been introduced as early as 1613 (Tokarska-Guzik, B., 2005). The species has since spread to southern and central/eastern Poland (Chlopek, 2011). The spreading rate is poorly understood because both the species and incidence of biological recording in the country are increasing. However, one study found that in southern Poland *A. artemisiifolia* had spread 30 km between 2007 and 2010 (Chlopek, 2011).

Figure 3.6 - The temporal and spatial spread of *Ambrosia artemisiifolia across Europe*



Serbia

The species was first recorded in Serbia around 1935 in the village of Osojci, near Derventa (Maly, 1940). The species was then recorded in 1953 around Sremski Karlovci, Petrovaradin and Novi Sad. It is believed that the species arrived from Romania on ships that sailed on the Danube (Slavnić, Ž., 1953). From the 1970s to present, *A. artemisiifolia* has spread across a wide area of Serbia and is considered today to be a widespread ruderal weed species in Vojvodina often forming large, compact communities in sandy and ruderal habitats (Konstantinović, 2004).

***A. artemisiifolia* spread map**

Figure 3.6 shows the temporal and spatial spread of *A. artemisiifolia* based on the 'record date' information provided with individual *A. artemisiifolia* records in the GIS database.

The earliest records retrieved are from the UK, Netherlands, France, Germany, Italy, Hungary and Austria. Records from 1900 to 1960 appear to show the species becoming more established in Austria and Finland. The species expands into Hungary, Slovakia and Croatia between 1960 and 1990 and was also present on the borders of Serbia at this time.

The dates provided from the literature described for each country above correspond relatively well with Figure 3.6. The literature notes earlier records for Serbia (1935), Romania (1908) and Croatia (1940s). It is possible that such introductory dates have not been included within the data sets retrieved as part of the mapping exercise.

3.2 Ambrosia artemisiifolia distribution

Figure 3.7 - The distribution of *A. artemisiifolia* based on a 50 x 50 km grid

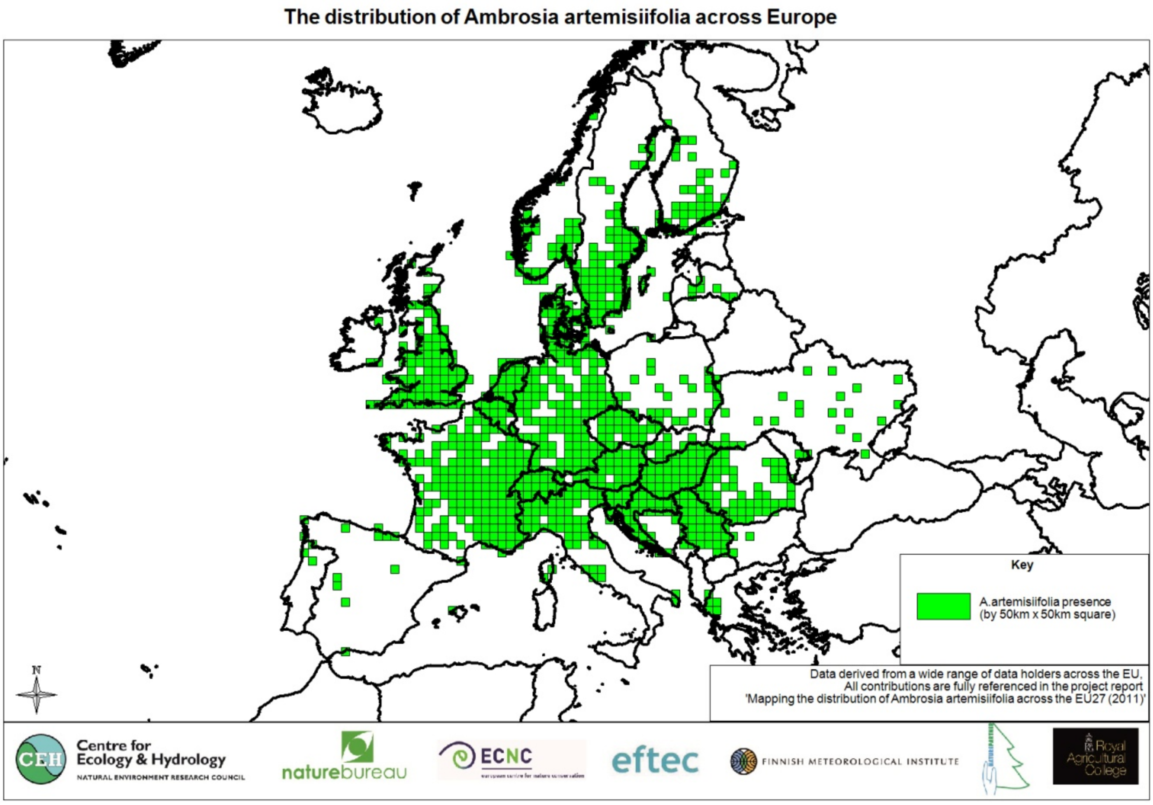


Figure 3.7 shows the distribution of *A. artemisiifolia* using an equal area 50 x 50 km grid. At this resolution it can be seen that *A. artemisiifolia* has a very wide distribution across a significant part of Europe, stretching from the United Kingdom in the west, across central Europe and into the Carpathian basin in the east. The southern and coastal regions of Scandinavia and Finland also show relatively significant populations at this resolution. The southerly limit of the species range currently halts at the Mediterranean region where a record in southern Italy and the Iberian and Balkan Peninsula's become sparse. In Poland and to the east and north of the Carpathian basin, the records also become more sporadic as the species appears to find its eastern and northern limits.

Figure 3.7 shows an interesting relationship between the data sets that were provided for Poland and Ukraine. Here the records were retrieved from different data sets but yet retain a similar density of records over a considerable spatial scale. It is possible that this pattern of distribution is related to a lack of recorder effort within these regions.

Similarly to the 50 x 50 km resolution distribution map, the 10 x 10 km distribution grid maps for individual countries (Figures 8-28) show that the highest number of records of *A. artemisiifolia* occur in: the Rhône valley (France); Hungary; and Serbia. The lowland country of the Netherlands also shows a significantly dense population.

Figure 3.8- The distribution of *A. artemisiifolia* in France based on a 10 x 10 km grid

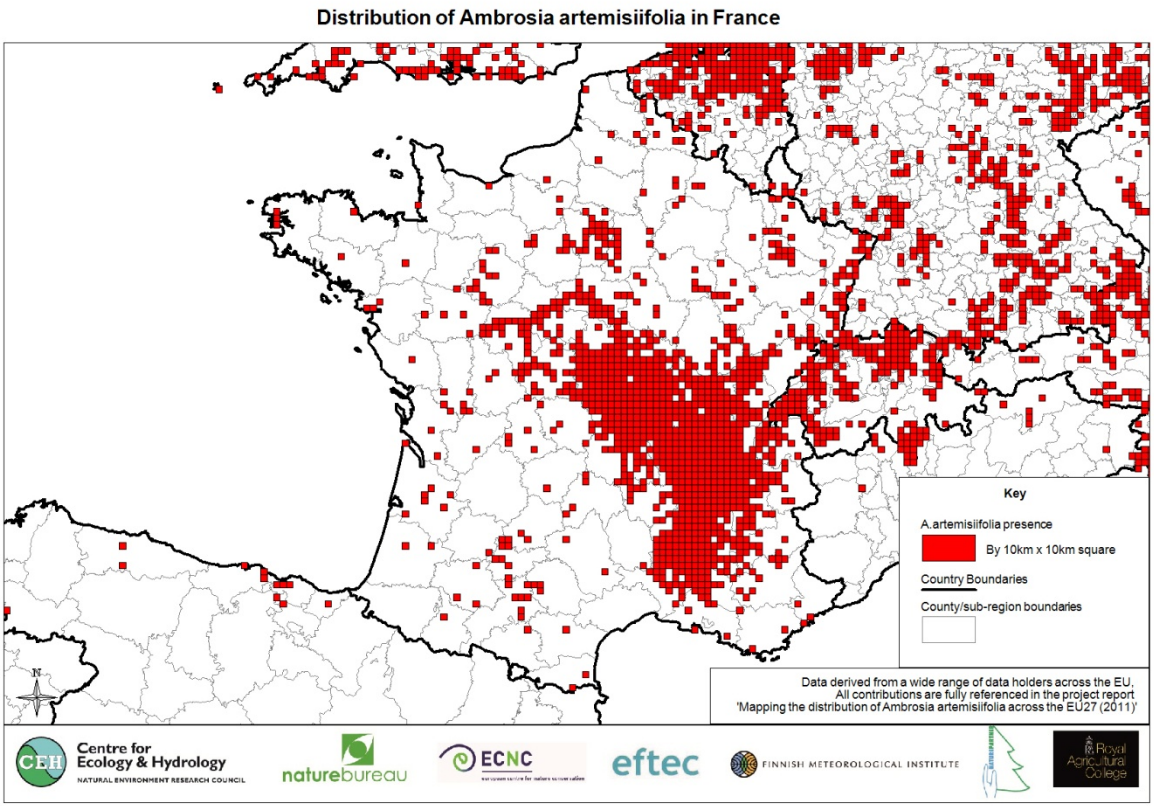


Figure 3.9 - The distribution of *A. artemisiifolia* in Hungary based on a 10 x 10 km grid

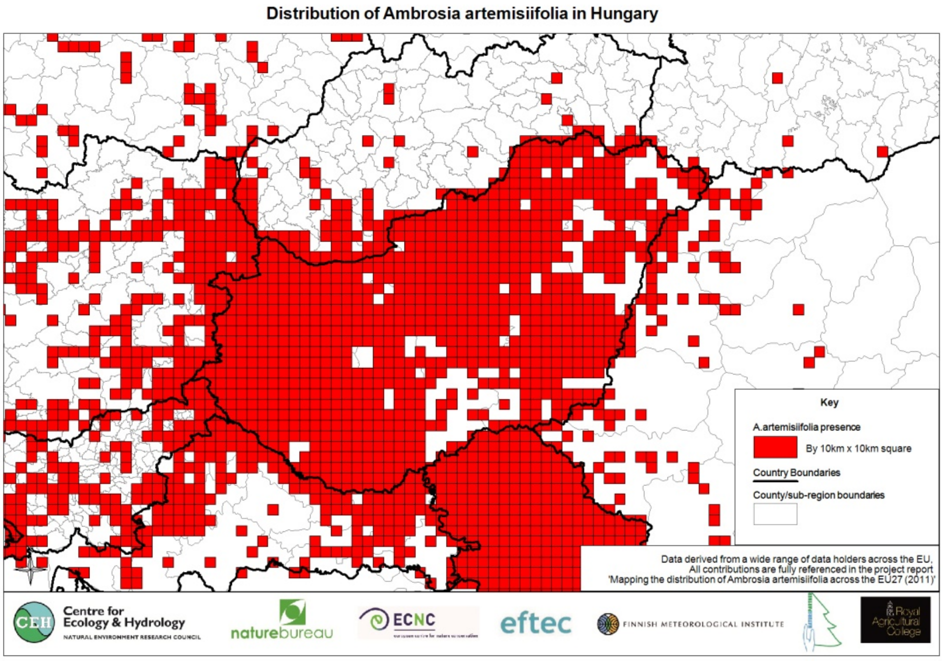


Figure 3.10 - The distribution of *A. artemisiifolia* in Serbia based on a 10 x 10 km grid

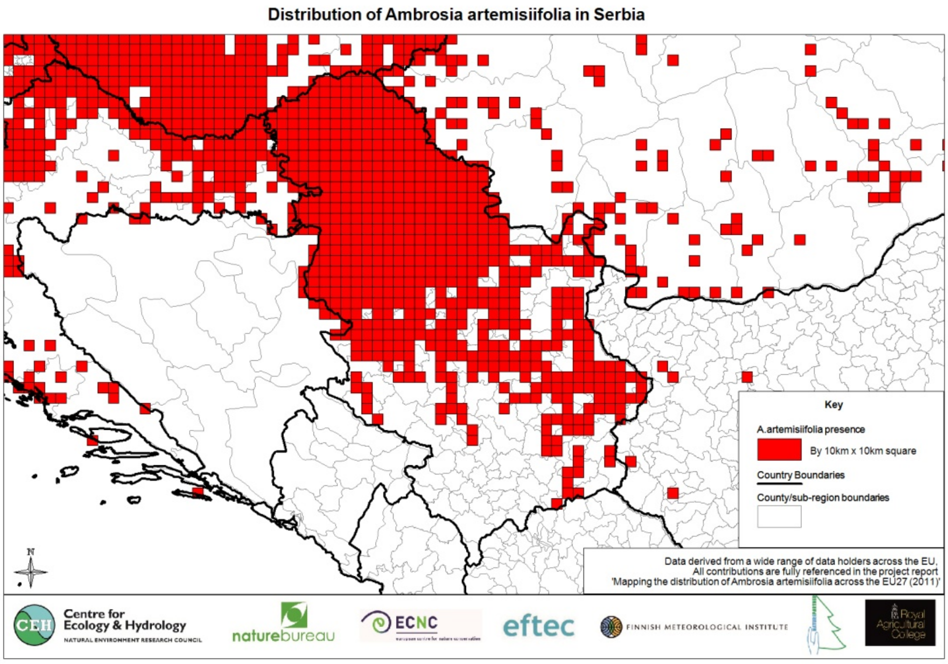


Figure 3.11 - The distribution of *A. artemisiifolia* in Netherlands based on a 10 x 10 km grid

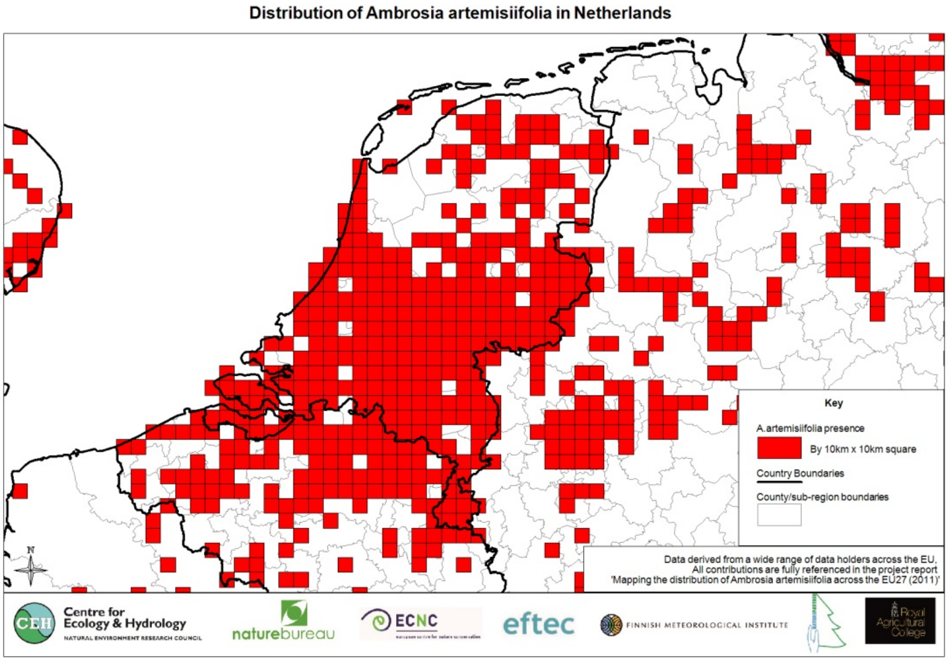


Figure 3.12 - The distribution of *A. artemisiifolia* in Austria based on a 10 x 10 km grid

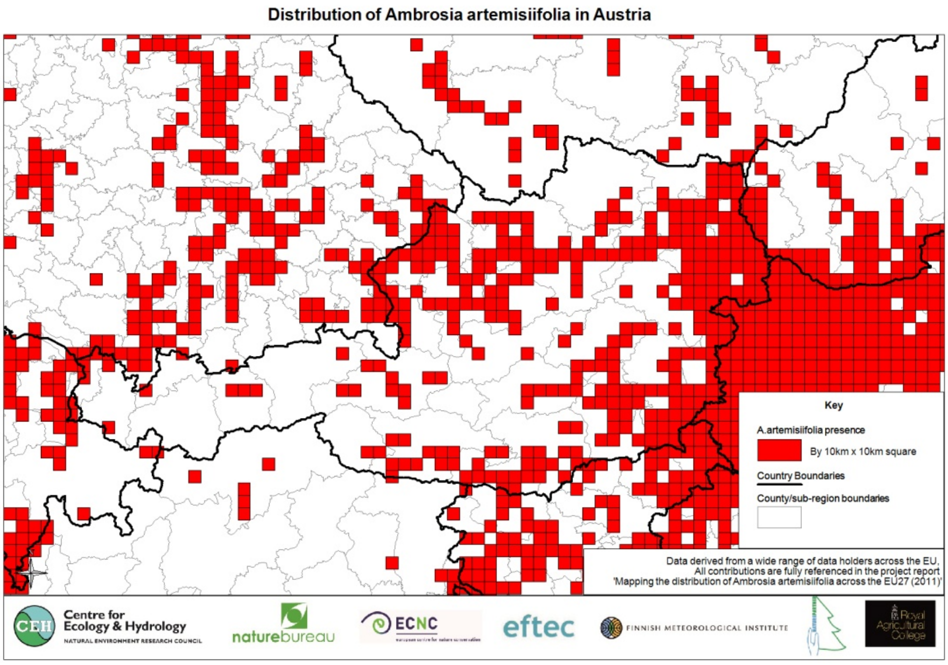


Figure 3.13 - The distribution of *A. artemisiifolia* in Belgium based on a 10 x 10 km grid

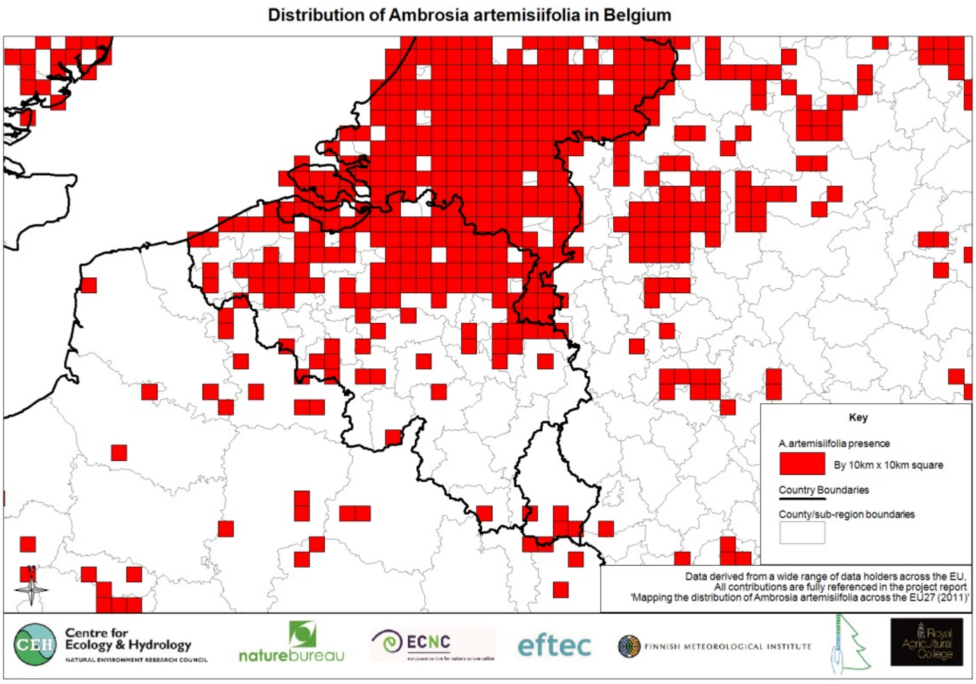


Figure 3.14 - The distribution of *A. artemisiifolia* in Bulgaria based on a 10 x 10 km grid

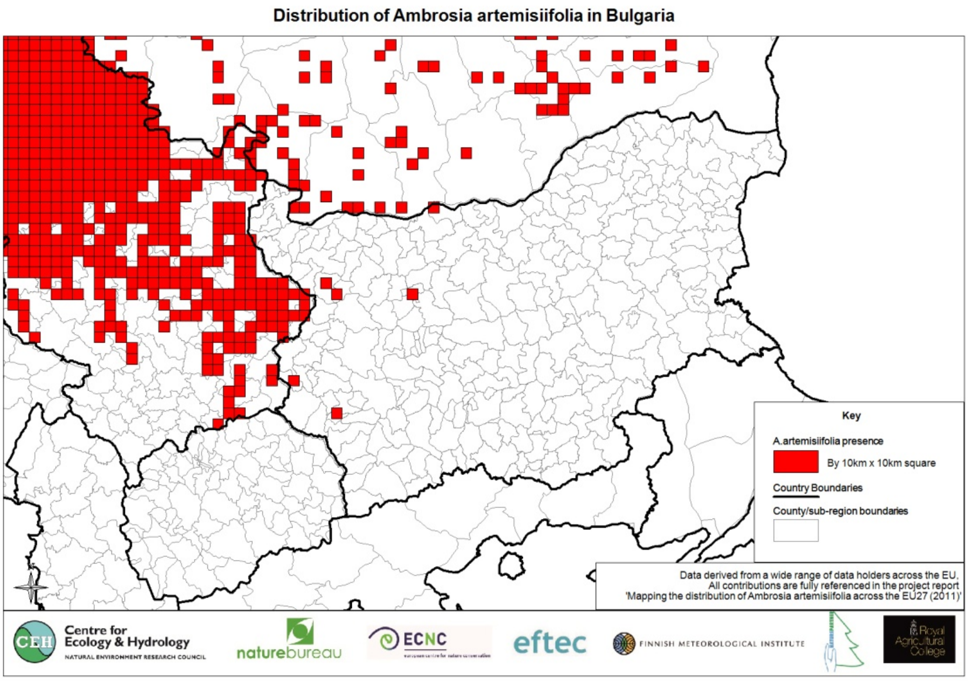


Figure 3.15 - The distribution of *A. artemisiifolia* in Croatia based on a 10 x 10 km grid

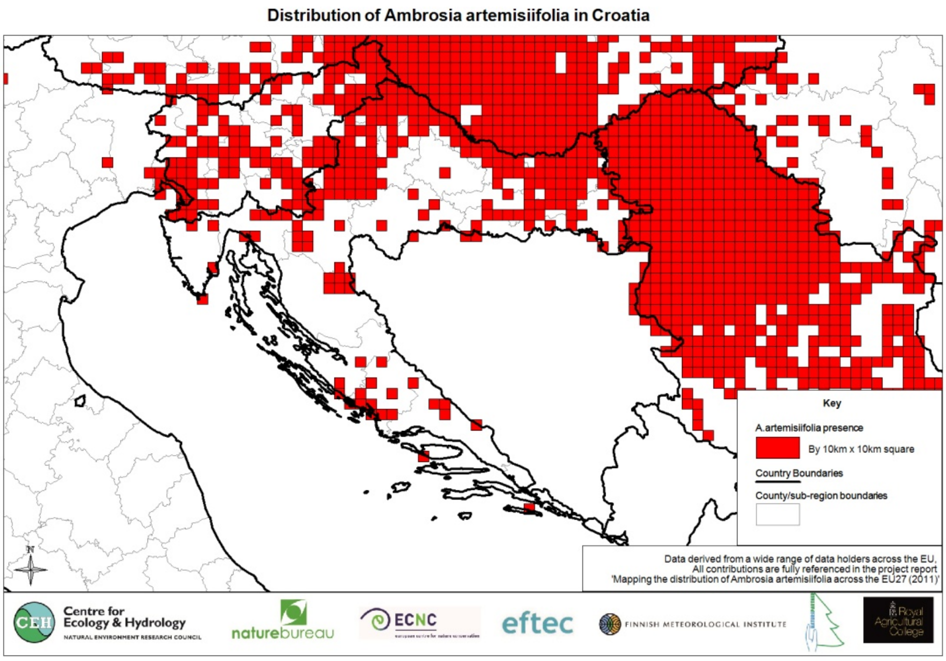


Figure 3.16 - The distribution of *A. artemisiifolia* in Czech Republic based on a 10 x 10 km grid

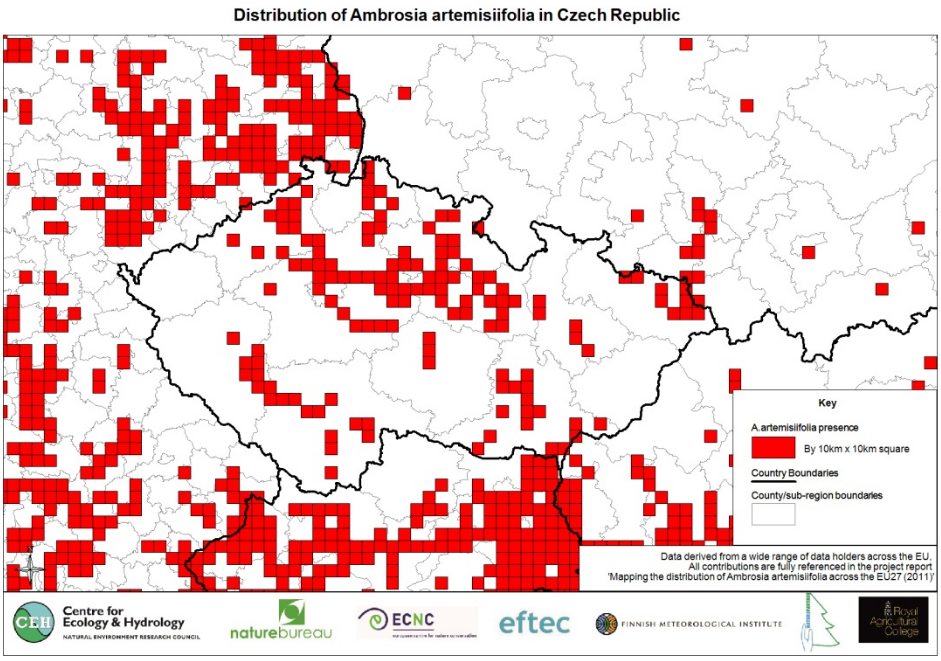


Figure 3.17 - The distribution of *A. artemisiifolia* in Denmark based on a 10 x 10 km grid

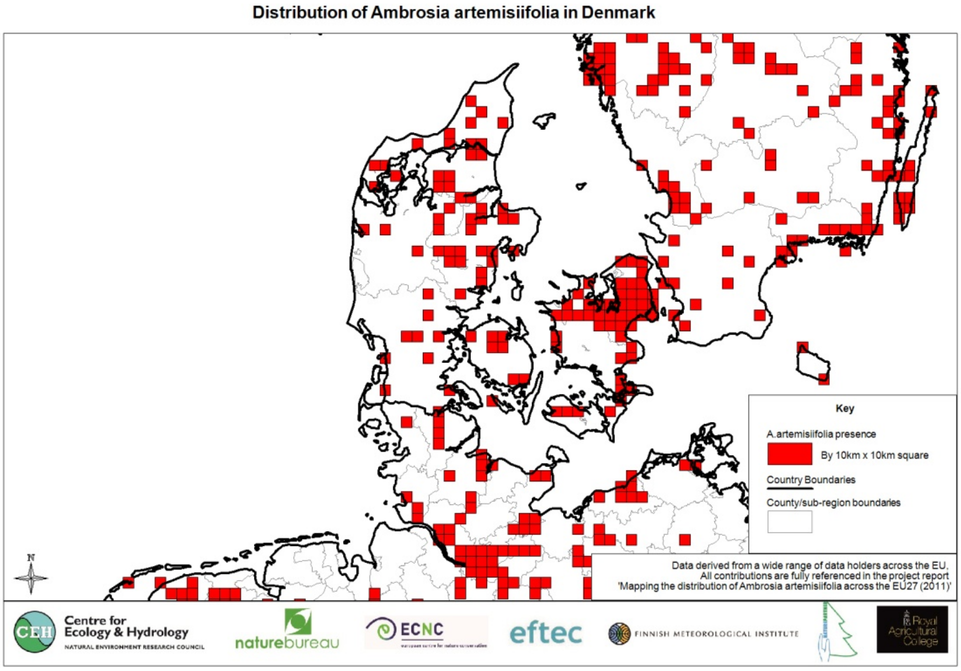


Figure 3.18 - The distribution of *A. artemisiifolia* in Germany based on a 10 x 10 km grid

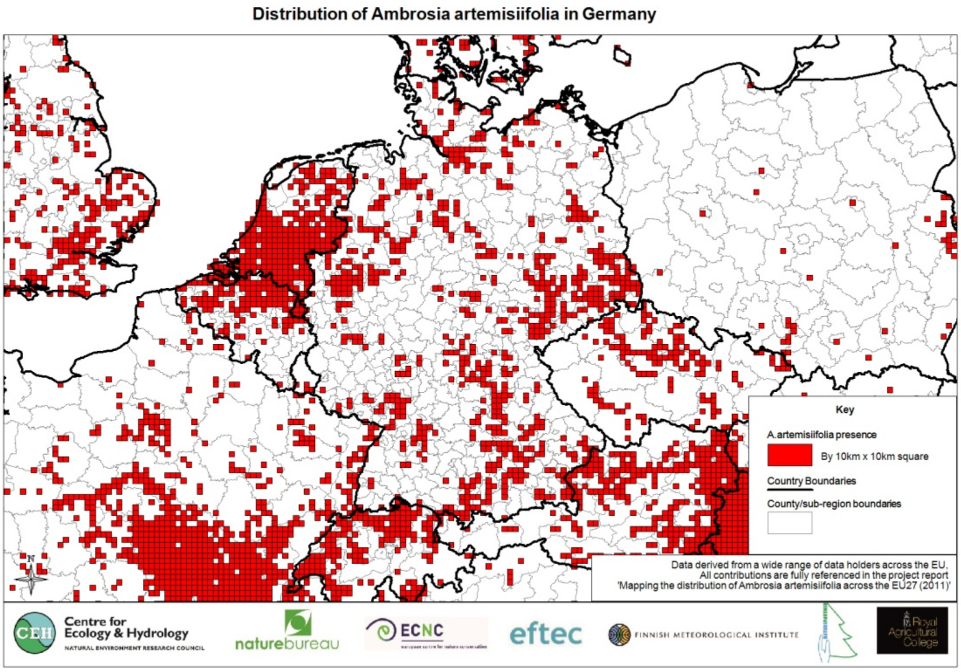


Figure 3.19 - The distribution of *A. artemisiifolia* in Italy and Greece based on county presence

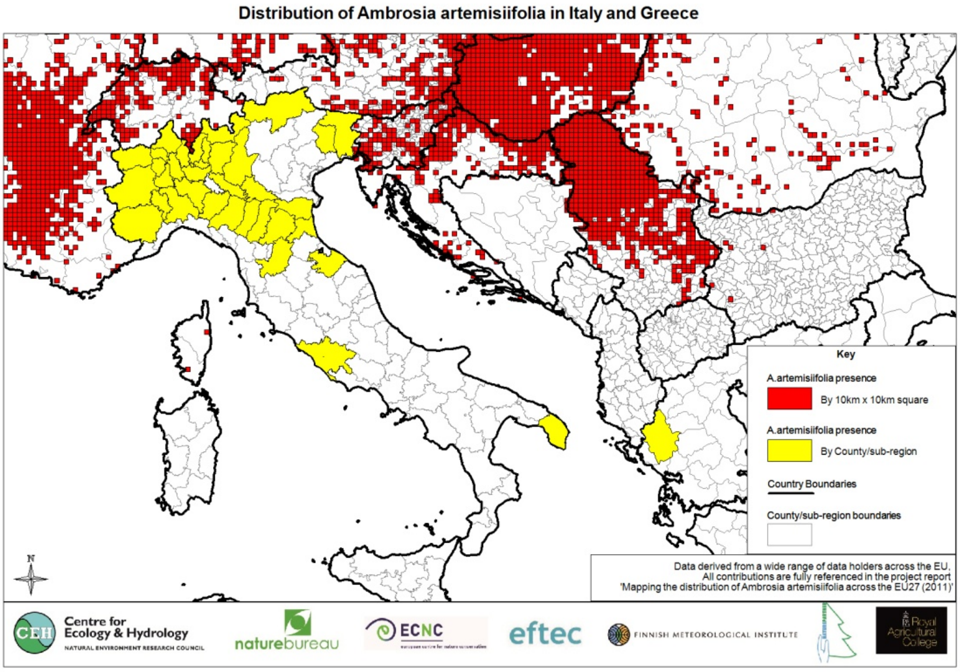


Figure 3.20- The distribution of *A. artemisiifolia* in Latvia based on a 10 x 10 km grid

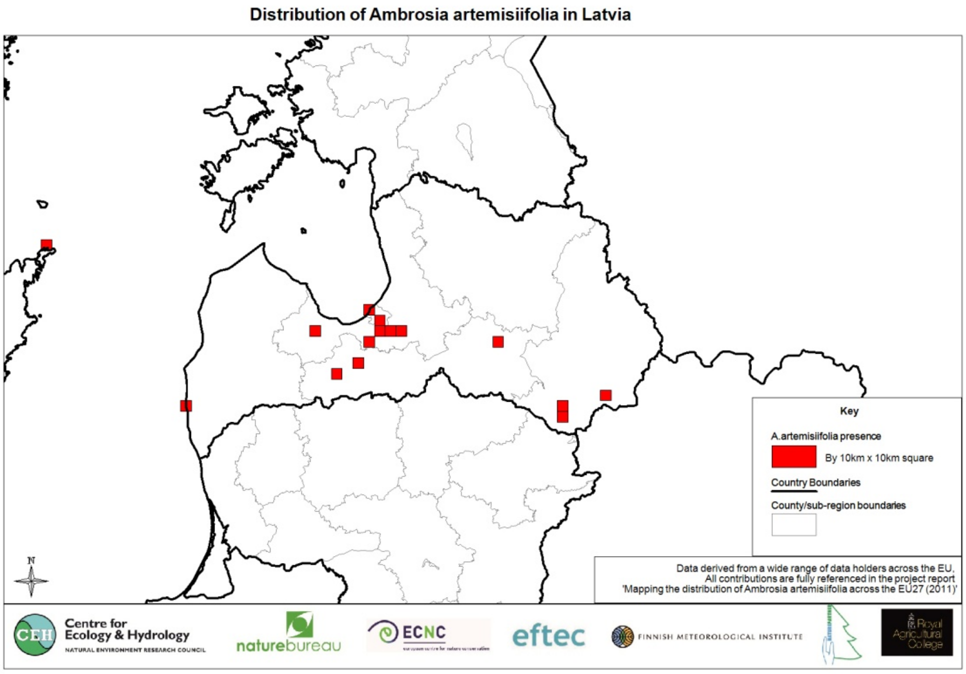


Figure 3.21 - The distribution of *A. artemisiifolia* in Norway, Sweden and Finland based on a 10 x 10 km grid

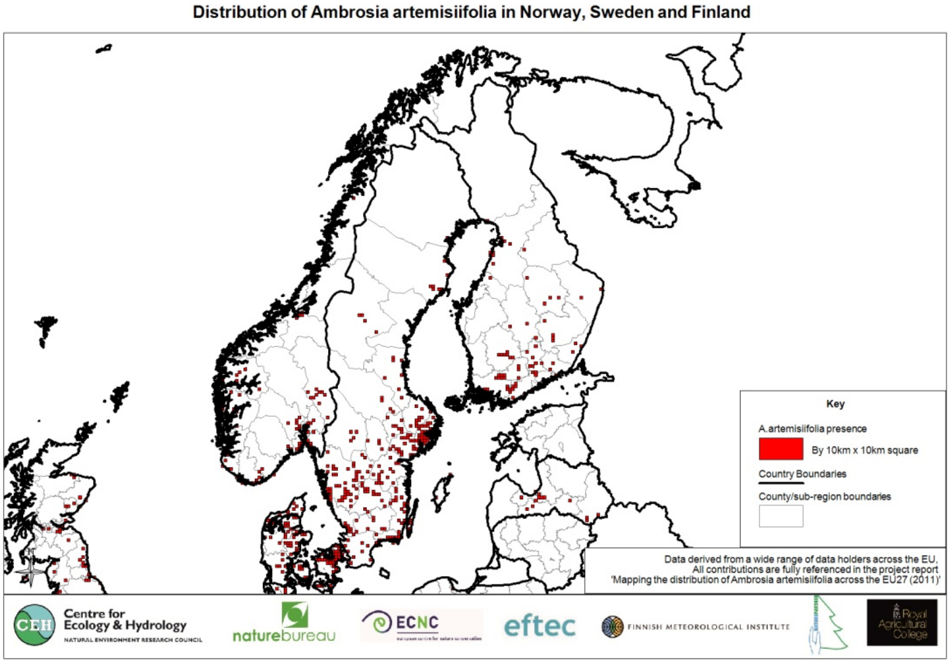


Figure 3.22 - The distribution of *A. artemisiifolia* in Poland based on a 10 x 10 km grid

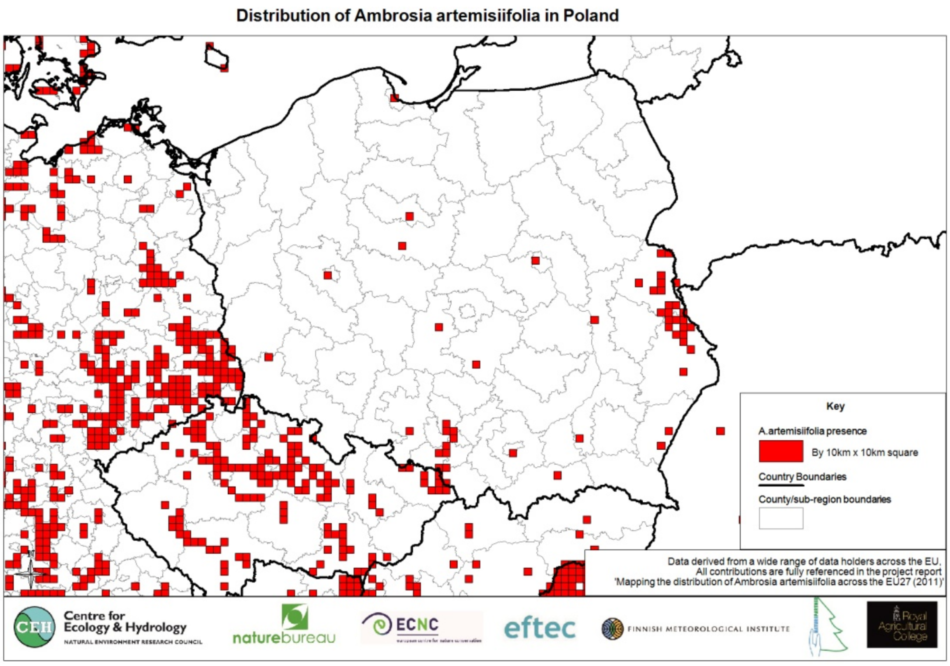


Figure 3.23 - The distribution of *A. artemisiifolia* in Romania based on a 10 x 10 km grid

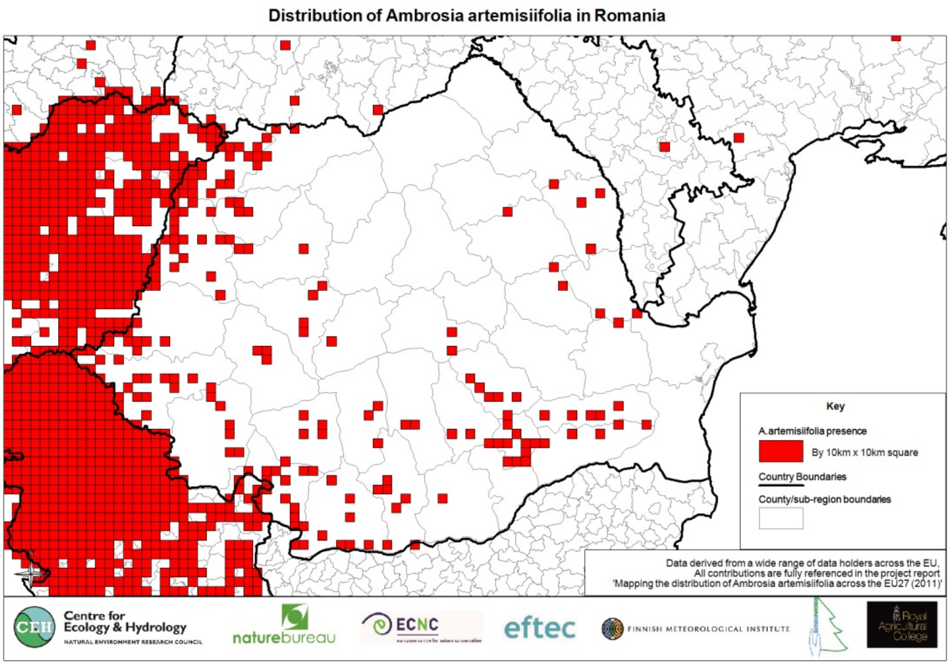


Figure 3.24 - The distribution of *A. artemisiifolia* in Slovenia based on a 10 x 10 km grid

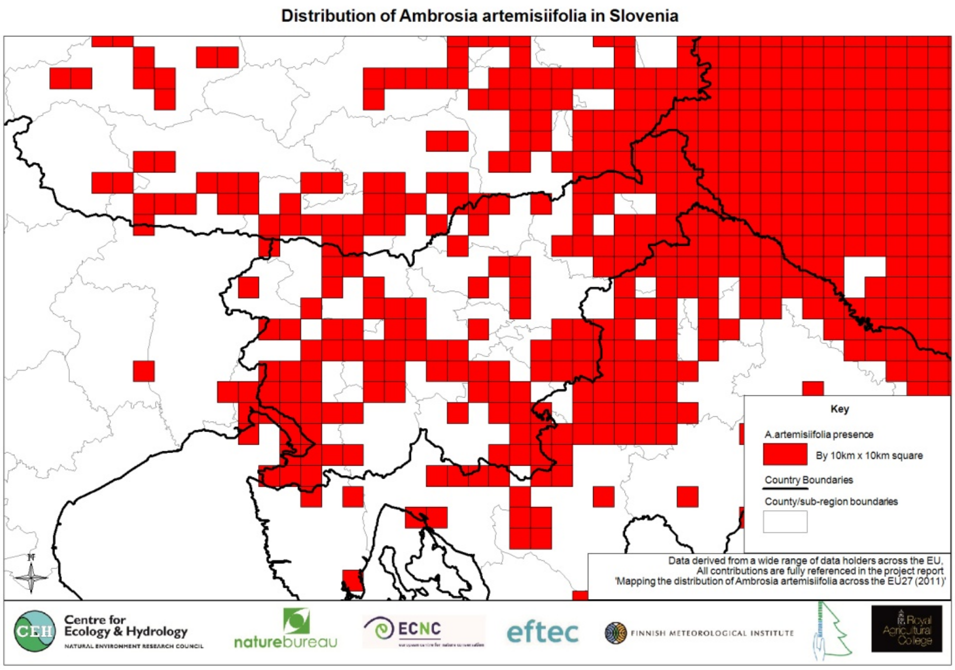


Figure 3.25 - The distribution of *A. artemisiifolia* in Spain and Portugal based on a 10 x 10 km grid

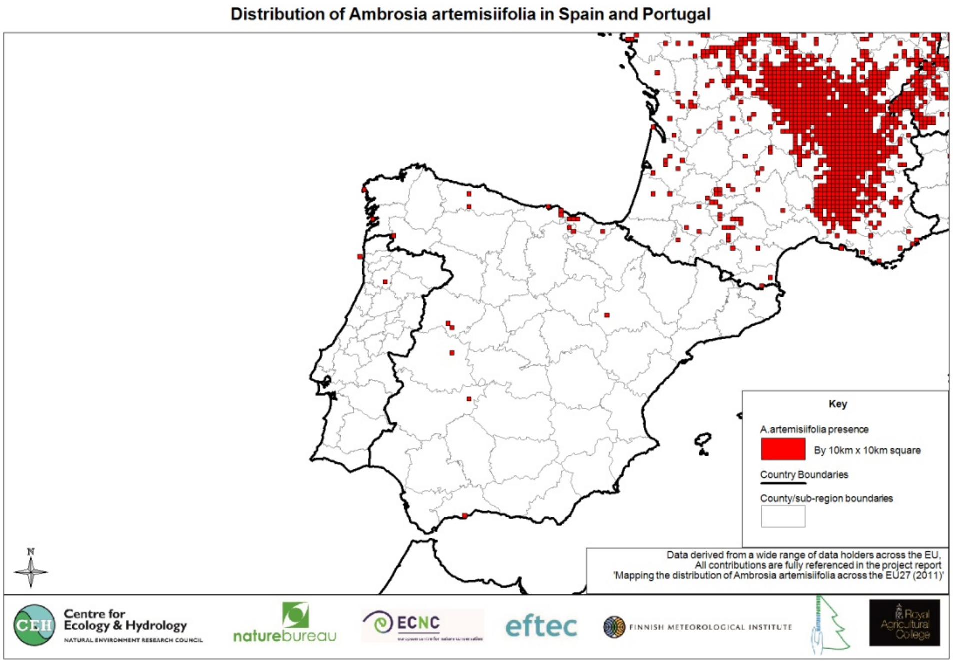


Figure 3.26 - The distribution of *A. artemisiifolia* in Switzerland based on a 10 x 10 km grid

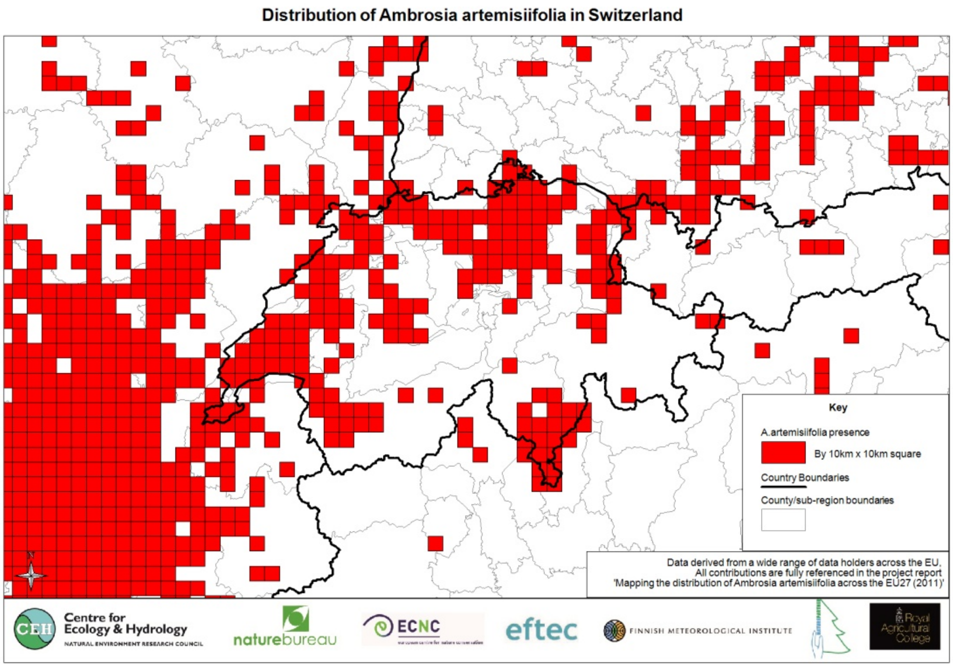


Figure 3.27 - The distribution of *A. artemisiifolia* in Ukraine and Moldova based on a 10 x 10 km grid

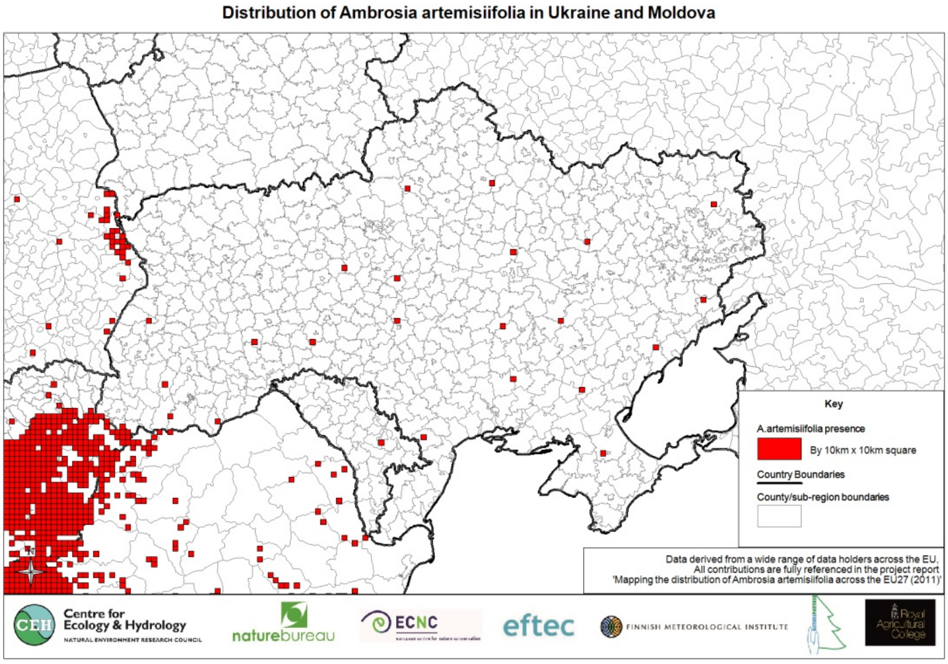
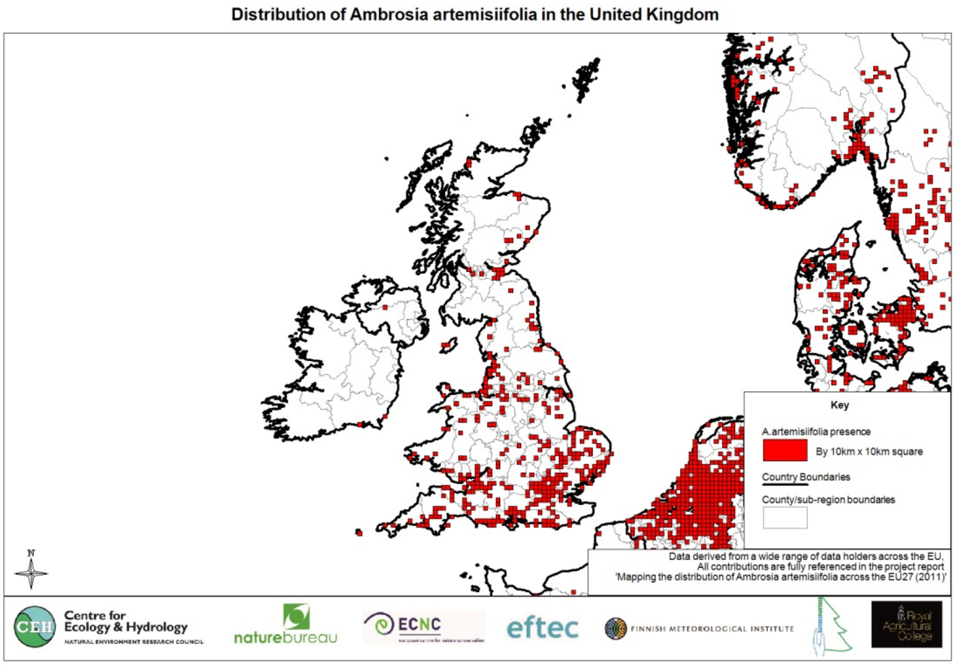


Figure 3.28 - The distribution of *A. artemisiifolia* in United Kingdom based on a 10 x 10 km grid



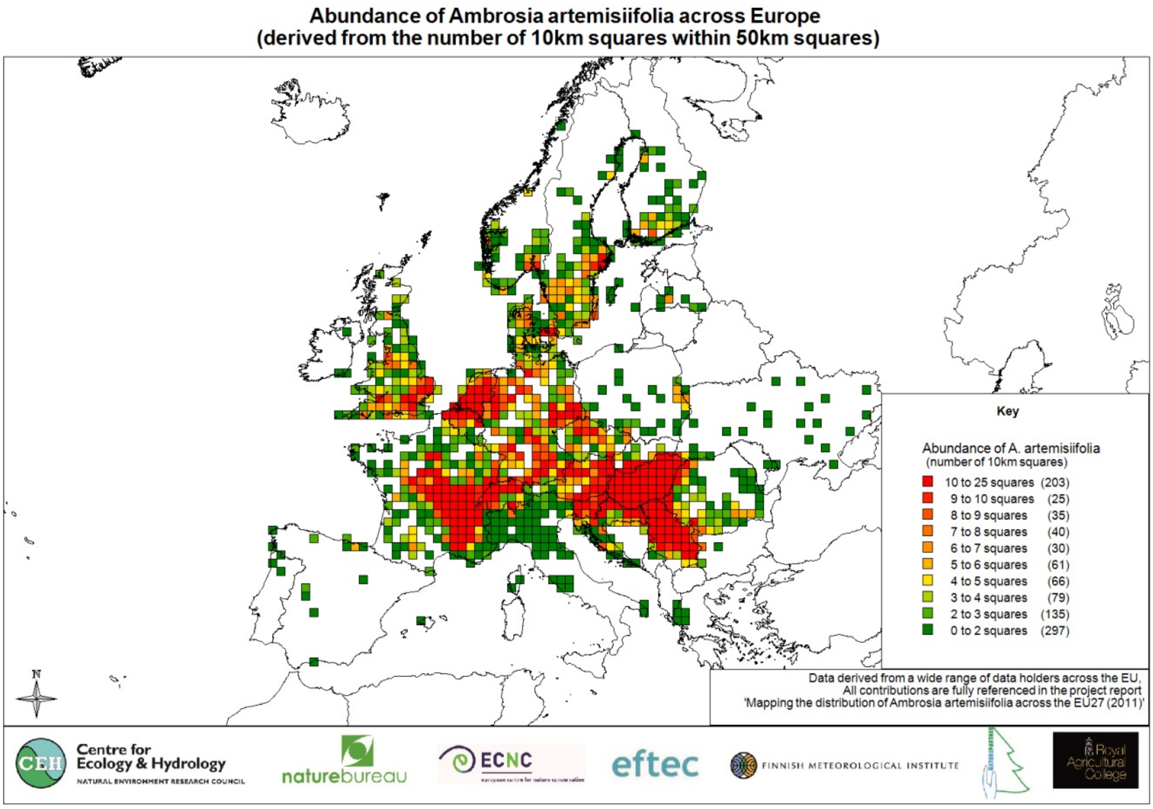
The United Kingdom, Germany, Scandinavia and Finland show less significant records when analysed on the higher resolution 10 x 10 km maps as the records appear more sporadic and less extensive.

Switzerland still shows dense clusters of populations at this resolution along its northern borders but these are neither as dense nor as extensive as the populations in the other previously identified key regions.

The conclusions about the southerly and easterly limits of the species range that were drawn from the lower resolution 50x50 km distribution map are reinforced by the 10x10 km maps with the additional observation that the eastern limit of the species' range, where Hungary and Serbia border Romania, appears more pronounced when viewed at this resolution.

It should also be noted that this finer resolution was not available for Italy and Greece as the data available for these two countries was not sufficiently detailed to produce 10 x 10 km resolution maps. The maps for these countries are instead based on the county distribution map produced as part of the trial mapping exercise (Figure 3.19).

Figure 3.29 - The abundance of *A. artemisiifolia* based on the number of 10 x 10 km grid squares recorded within each 50 x 50km grid square.



3.3 Relative abundance of Ambrosia artemisiifolia

The areas where the abundance of *A. artemisiifolia* can be seen to be highest are the Rhône valley (France), Switzerland, Netherlands, Belgium, Serbia and Hungary. Interestingly, there appears to be areas of eastern Germany where more abundant populations can also be seen, something that was not obvious when analysing the 50 x 50 km and 10 x 10 km distribution maps. Areas of higher abundance may suggest that the species is becoming naturalised and has a high potential spread.

It should be noted that the low abundance presented for Italy and Greece are due to the lack of data available for fine resolution mapping discussed in Section 2.2.

The conclusions that can be drawn from Figure 3.29 support those drawn from both the 50 x 50 km and 10 x 10 km distribution maps for *A. artemisiifolia*.

3.4 Ambrosia trifida distribution

Figure 3.30 - The distribution of *A.trifida* based on a 50 x 50 km grid

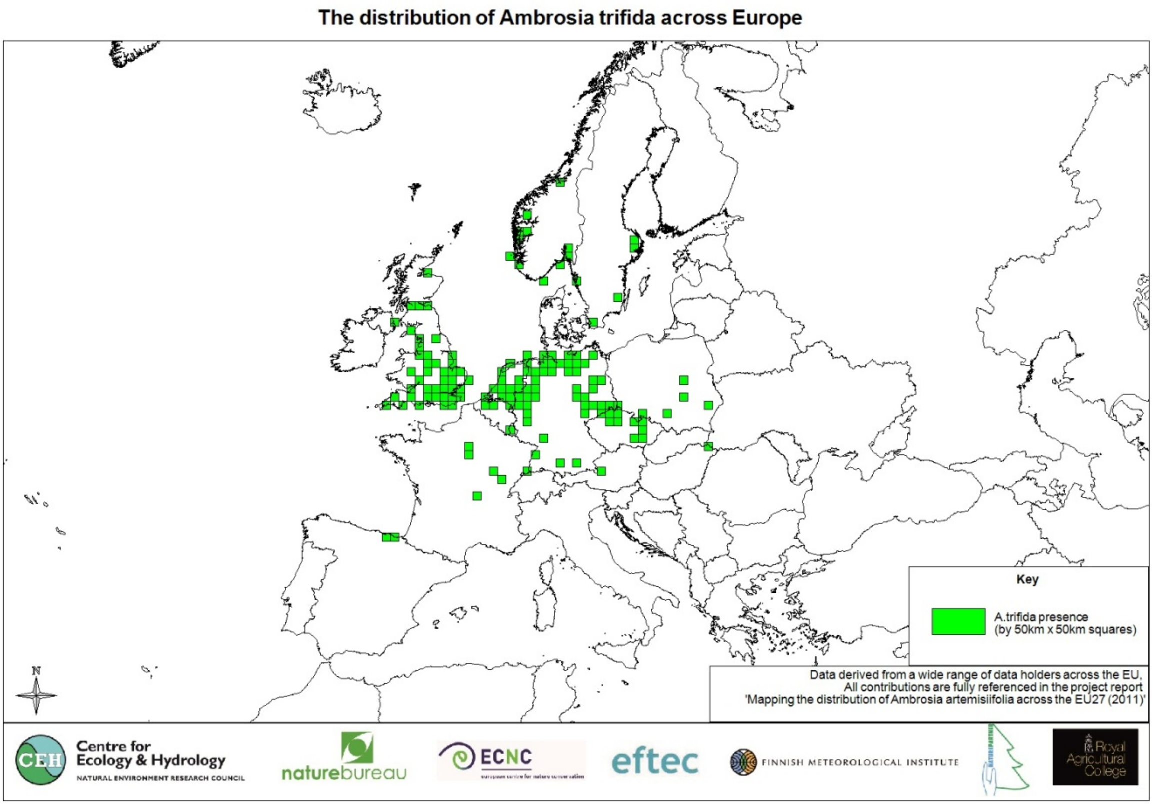


Figure 3.30 shows the distribution of *A.trifida* in Europe as mapped using the 50 x 50 km distribution grid. The number of records retrieved for *A.trifida* was considerably lower than that for *Ambrosia artemisiifolia.* This was expected as the species is not widely reported in Europe.

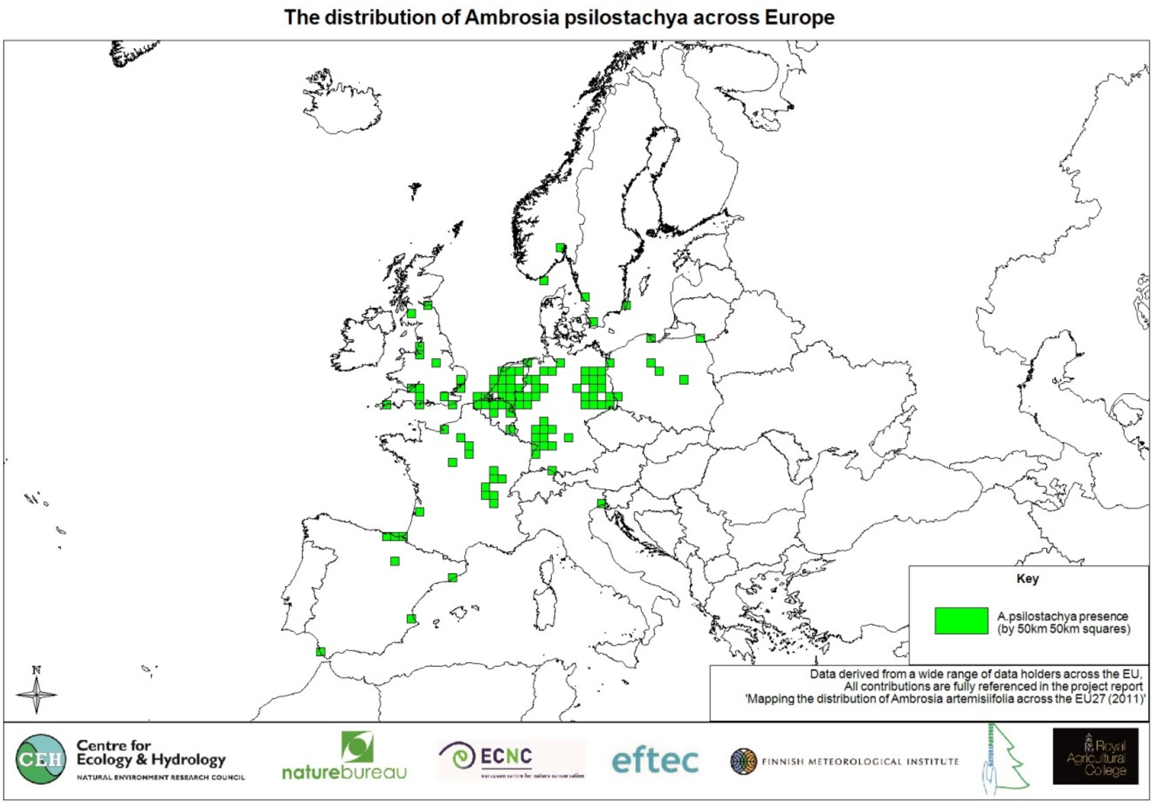
In general *A.trifida* distribution in Europe indicates a species which prefers more northerly climatic conditions than *A. artemisiifolia* as population clusters are centred in the United Kingdom, Belgium, Netherlands and northern Germany.

In the United Kingdom the species is present in all mainland regions with the densest cluster of 50 x 50 km squares occurring in the south east of England. As the distribution spreads west into Wales and north towards Scotland it becomes more sporadic. There are sporadic records in southern Germany, central Europe, France and coastal areas of southern Scandinavia, western Germany and Czech Republic show slightly denser records before becoming sparser into Poland. There are also two records from the Basque coast of northern Spain.

3.5 Ambrosia psilostachya distribution

Figure 3.31 shows the distribution of *A.psilostachya* on a 50 x 50 km grid. *A.psilostachya* is the least common of the three *Ambrosia* species occurring in Europe. The distribution of *A.psilostachya* is more extensive than that of *A.trifida* despite fewer individual records of the species being retrieved. The densest population clusters are shown in Belgium, Netherlands and western and southern Germany. Elsewhere the records are more sporadic although a series of records are displayed along the Rhône valley and in northern France. Sporadic records can be seen on the coast of southern Scandinavia, the Slovenia/Italian border, Poland and Spain's Mediterranean coast, highlighting the extensive range the species appears to have in Europe.

Figure 3.31 - The distribution of *A.psilostachya* based on a 50 x 50 km grid



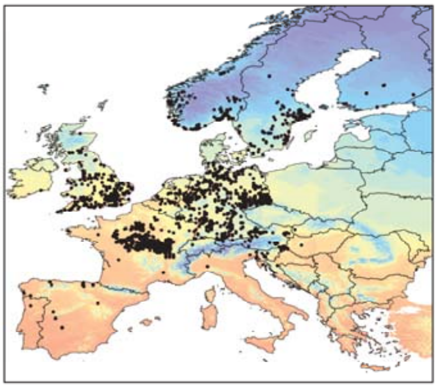
4 Discussion

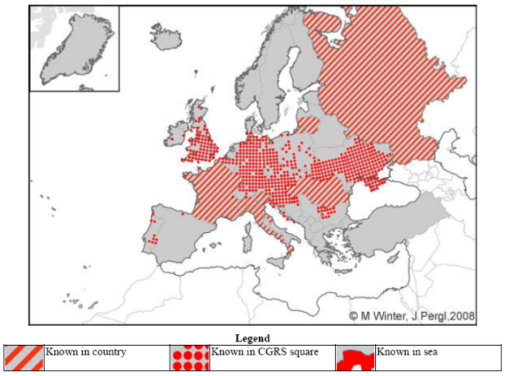
4.1 Relationship with previous research

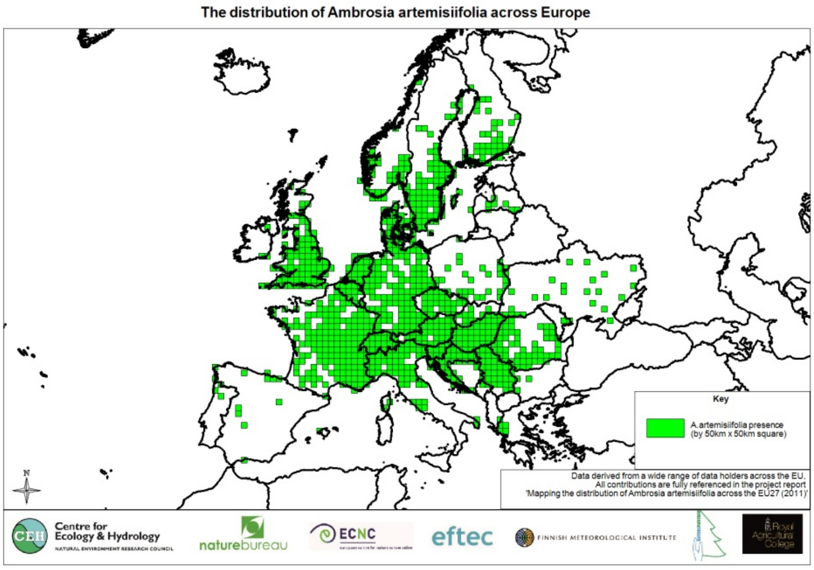
As has already been discussed the distribution maps produced at both 50 x 50 km and 10 x 10 km resolution support the descriptions of Kazinczi *et al* (2008) who stated that the Rhône Valley in France, northern Italy and parts of the Carpathian basin were the three regions in the EU most heavily invaded by *A. artemisiifolia*.

When comparing the 50 x 50 km *A. artemisiifolia* distribution map with those previously produced by DAISIE and GBIF (Figure 3.32) it can be seen that the results of this exercise adds considerably to the recorded distribution of the species.

Figure 3.32- GBIF (top left) and DAISIE (top right) maps of *A. artemisiifolia* distribution compared to the map produced as part of the current project (bottom).





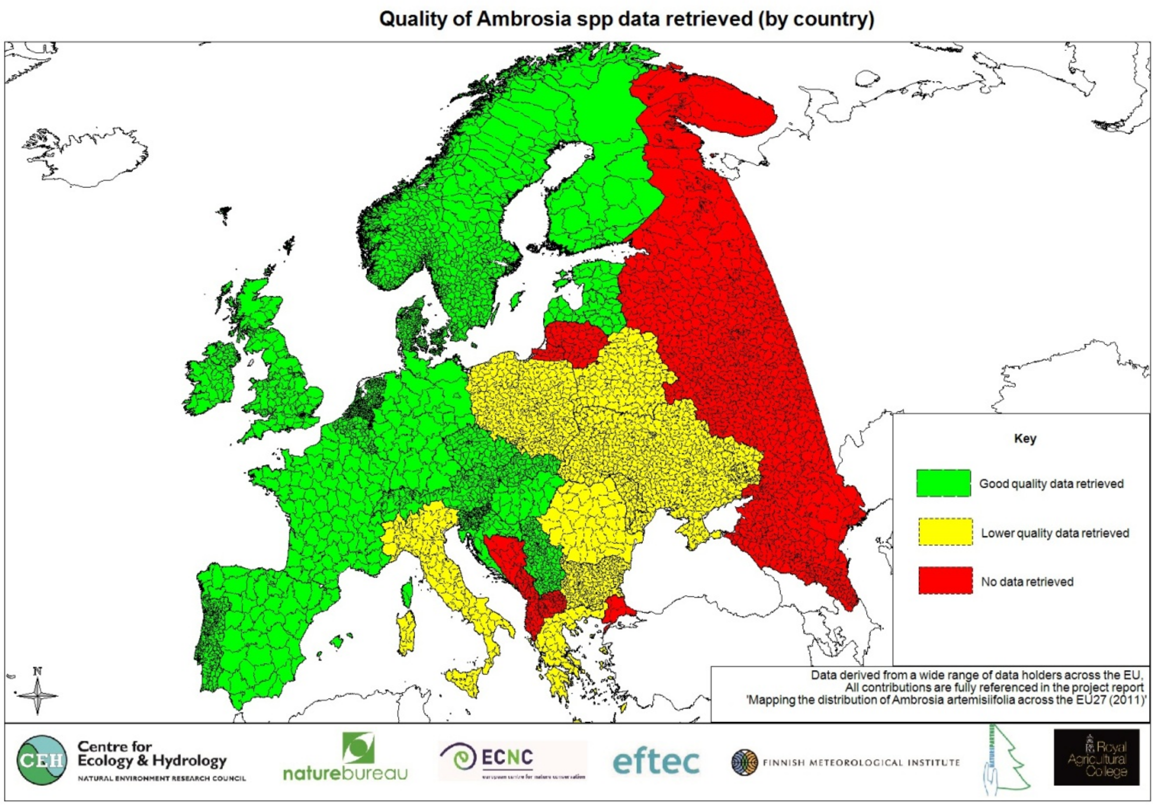


The GBIF distribution map shows very few or no records for northern Italy, Croatia, Serbia and Hungary. These countries were specifically identified as key countries where *A. artemisiifolia* was known to be a serious problem (Section 1.5) and were therefore targeted for data retrieval. The data retrieved for these countries proved that they are some of the most significantly *A. artemisiifolia* populated countries in Europe and has therefore added a considerable amount of information to that which was previously published by GBIF.

When compared to the DAISE distribution map; the additional data can be seen to provide a clearer picture of the actual region-based distribution of the species. The mapping project has retrieved new records for Serbia and Latvia which were previously unmapped, adding greater understanding to the species' range. However, the DAISE map does contain records which were not obtained during this exercise for Poland and Ukraine which were not available within the timeframe of this project.

4.2 Data quality

Figure 3.33 – Map showing the quality of data sets retrieved for *Ambrosia spp*



Despite the extensive network of contacts and organisations contacted for data there were still areas for which it was difficult to retrieve data sets, or where data sets appeared to be incomplete due to less extensive recording networks. Figure 3.33 displays geographically the quality of data retrieved based on the following criteria:

- **Good quality data** was considered to be from: multiple data providers; georeferenced point data; and/or well defined grid systems; and/or high resolution imagery.
- **Lower quality data** was considered to be often limited to one data source or individual records retrieved from a number of studies; have limited georeferencing or a lower resolution grid; and/or lower resolution imagery.
- **No data** was indicated where data sets were not available for those regions/countries.

Figure 3.33 shows a significant data gap for Bosnia and Herzegovina which is particularly obvious due to it being surrounded by some of Europe's most heavily infected states (Croatia and Serbia). No data was retrievable for Bosnia and Herzegovina despite efforts being made.

No data were available for Albania and Former Yugoslav Republic of Macedonia (FYROM). It is possible that the species is not prevalent here as Figure 3.7 shows the records become more sporadic as the range spreads through southern Serbia towards these countries. It is also possible that biological recording in these countries has not been carried out as extensively as other European countries and therefore the species remains under-studied.

Figure 3.7 shows a definite border to *A. artemisiifolia's* range on the Germany, Hungarian and Czech Republic borders with Poland; however these areas are also recorded as areas with lower quality data (Figure 3.33). It is possible that the climatic conditions and geographical barriers (Sudeten and Carpathian mountain ranges) may contribute to this but it is also possible that the data sets received for Poland are incomplete and there exists a greater population than the records obtained show.

Romania, Moldova and Bulgaria all report presence of *A. artemisiifolia* but due to their proximity to the heavily infested countries of Serbia and Hungary it is suspected that the species is under recorded in these countries and further research is required to understand the true extent of the species range in these areas.

Records of *A. artemisiifolia* occurrences in Slovenia were retrieved but it's proximity to Croatia and Hungary suggests the species may be under-recorded in the country.

As previously discussed, records for Italy and Greece were based on county/sub-region presence, but these data types could not be mapped to the finer 10 x 10 km country distribution scale. It is known that such data exists for Italy, but the data is currently unpublished.

A very general assumption can be drawn about the distribution of records throughout Europe based on the extensiveness of biological recording networks in the region. It is not possible for all countries across a large spatial range to have the same standards and detail of biological recording programmes and therefore this can potentially influence the appearance of the distribution maps. It is generally accepted that the most detailed biological recording networks have historically been based in the northern and western countries of Europe (e.g. France, Scandinavia, Germany, UK, etc).

The quality and extent of biological recording and the availability of the results has greatly improved over recent years in Eastern Europe but there still exists a disparity across the region which must be considered when viewing the distribution maps.

4.3 Patterns of Ambrosia artemisiifolia distribution

The distribution patterns of *A. artemisiifolia* throughout Europe as described in Section 2 can be attributed to a range of anthropogenic, biological and geographical factors.

The densest and most significant populations seen in the distribution maps exist in the Rhône valley (France), Netherlands, northern Italy, Serbia, Croatia and Hungary. This supports the findings of the current projects literature report '*A review of information on* Ambrosia artemisiifolia *L. (*Asteraceae*) spreading mechanisms, and the conditions, vectors and drivers that favour its spread*' (NatureBureau, 2011) which identified these same regions as having the most prolific populations.

The French populations of *A. artemisiifolia* are centred along the Rhône valley which flows through eastern France and this population appears to be linked to the Loire river valley which flows in a westerly direction towards the Atlantic Ocean. This type of distribution is typical for *A. artemisiifolia* as the NatureBureau report highlights the importance of rivers in the dispersal of *A. artemisiifolia* seeds (NatureBureau, 2011). *A. artemisiifolia* populations are often found in riparian habitats as the fluctuating water levels maintain the type of open and disturbed ground favoured by the species. Moreover, the high potential for water dispersal of *A. artemisiifolia* seeds suggests that these water bodies can be a significant contributing factor to the geographical spread of the species (Fumanal, 2007; Fumanal, 2007a).

The high number of *A. artemisiifolia* records retrieved from Netherlands is most likely to be attributed to anthropogenic activities. The findings of the NatureBureau report highlight that in all European countries the most likely method of introduction is via imported grain and animal fodder (including bird seed) stocks. Due to this factor, *A. artemisiifolia* is often reported as a casual presence in harbour areas where grain shipments are transferred (Jehlik, 1985; Veerloove, 2006). Crop seeds imported from North America are the most likely causes of this accidental introduction. Therefore, it is unsurprising that the species has spread throughout Netherlands based on its role as an entry point for imported products to the European mainland.

This spread throughout Netherlands is likely to have been assisted by ground disturbance through anthropogenic activities. As discussed in the NatureBureau report, disturbed habitats created by the expansion of road and rail networks have been a key spreading mechanism in the expansion of *A. artemisiifolia* (Protopopov, 1991; Song & Protts, 1998; Chauvel *et al*, 2006; Lavoie *et al*, 2007; Essl *et al*, 2009; Kazinczi *et al*, 2008a, Dullinger *et al*, 2009; Vitalos & Karrer, 2009). It is therefore highly likely that the casual populations accidentally introduced in the Netherlands were able to spread throughout the country as it developed a dense road and rail network in the 20th century.

The invasion of *A. artemisiifolia* in northern Italy can be seen from the distribution maps (Figure 3.18) and the descriptions outlined out by Kazinczi *et al* (2008) to occur predominantly in the Po valley. This river valley intersects northern Italy from the Alps in the west, to the Adriatic Sea in the east. As already discussed, rivers and river valleys can play an important role in the geographical spread of *A. artemisiifolia* which explains the population existence and spread within this region. Moreover, the Po region of Italy is home to some large urban areas and intensive farming practises which may have assisted the species spread in the region. Urban renewal and the construction of transport links, is likely to have further facilitated the species spread. The disturbance of ground (and subsequent transportation of soils contaminated with *A. artemisiifolia*) linked to aggregates required by the building industry (Taramarcaz, 2005) are all also potential contributing factors to the species spread within the region.

Countries which can be seen from the distribution maps to have serious infestation problems with *A. artemisiifolia* are Hungary, Croatia and Serbia. This is supported by the findings of Kazinczi *et al* (1998) who described this region as being one of the most heavily infected with *A. artemisiifolia* in Europe.

The wars experienced in the former Yugoslavian states of Croatia and Serbia during the 1990's are almost certain to have been a contributing factor in the rapid spread of *A. artemisiifolia*. The species preference for disturbed land would have been exploited as waste lands were created as a direct effect of bombing in the region. Furthermore, population displacement and abandonment of fields in areas affected by war have been described as assisting the colonisation and expansion of *A. artemisiifolia* in Croatia (Taramaracaz *et al*, 2005; Bohren, 2006).

Changes in farming practises (the formation of collective farms) in post-Second world war Eastern Europe (Kiss & Beres, 2006) resulted in management changes which allowed *A. artemisiifolia* to colonise these areas. In a similar process, the collapse of communism saw these farms being re-appropriated to private owners which again led to land being neglected for many years (Makra *et al*, 2005). Lack of financial resources and poor farming knowledge contributing to a lack of weed control and poor crop management is also believed to assisted the rapid colonisation of *A. artemisiifolia* in the region during this period (Makra *et al*, 2005; Kiss & Beres, 2006; Novak *et al*, 2009).

The fine resolution maps of *A. artemisiifolia* also show that Switzerland has comparatively dense and significant populations of *A. artemisiifolia* (Figure 3.26).These populations are in close proximity to those found in the Rhône valley, France and the Po valley, Italy but separated from both of these populations by the Alps mountain range which acts as a natural barrier to range expansion. The existence of these populations is likely to be explained by the presence of transport routes (roads and railways) linking the regions. It has been described that the populations in Ticino (Southern Switzerland) are directly related to those in Lombardy, Italy, due to the presence of a major highway linking the two regions (Casarini, 2002; Ciotto & Maspoli, 2005; Riccardo Scalera, pers. Comm.).

The northerly limits of *A. artemisiifolia* distribution in Europe as seen in Figure 3.7 can be assumed to be a naturally enforced barrier as a result of climatic and altitudinal conditions. The NatureBureau report (2011) states that the populations in the United Kingdom and Norway rarely reach flower and seed as the climate is too cool. Therefore a similar conclusion can be drawn as to why the species has a sparser distribution, east towards northern Ukraine, Belarus and the Baltic states. The accidental introduction of the species here through contaminated crop seeds would explain its presence and the lack of a suitable climate would explain why it has failed to colonise these regions. It is also possible that the recording effort for these regions is much less than for Western Europe.

4.4 Patterns of Ambrosia trifida and psilostachya distribution

These species were mapped to detect any notable issues with the taxonomic separation of the three species under investigation. It is clear that both species are much more limited in their distribution than *A. artemisiifolia*, both being recorded from northern Europe. It is also noteworthy that the species are recorded from regions where biological data recording are more established, such as France and the UK. A number of data sets recorded '*Ambrosia*' as a group, not distinguishing between the three species. Such records were grouped into the *A. artemisiifolia* maps.

The distribution of both species corresponds well with the areas where higher abundance levels were recorded for *A. artemisiifolia* (see Figure 3.30). A full ecological review of the two species was not undertaken as part of this project. A greater awareness of the invasive potential of *A. artemisiifolia* in these regions may also be responsible for the taxonomic distinction between the three species in the areas where separate species records were retrieved.

It is likely that further records of these two species are present across Europe, but neither species are such a significant threat as *A. artemisiifolia*. However, knowledge of the distribution of these two species may provide useful future information in relation to the crossing of genetic information between the three species.

5 Future application of the mapping methodology

The mapping methodology was developed to allow the most effective and detailed mapping possible of *A. artemisiifolia* across Europe and so that the methodology could be applied to similar projects in the future. The following is a discussion of the success of the methodology and its results which also describes how a similar project could improve on this method.

5.1 Successes

Overall the methodology and its results have been successful. As previously discussed the results display the pattern which was anticipated based on analysis of existing research, implying that the methodologies developed for retrieving, standardising and mapping data were robust. Previously unmapped populations of *A. artemisiifolia* were also added to published research which further supports the statement that the data retrieval methodology was a success.

The cost of retrieving data was relatively low in terms of financial output as only three data sets required payments to obtain. This suggests that repeating this methodology, either in the future to update the distribution map of *A. artemisiifolia* or to map another similar species in Europe, is a financially viable project which will yield strong results and therefore would be a worthwhile investment of both time and money.

A consideration prior to collecting the data was that it may not be possible to obtain and standardise so many data sets across a wide geographic scale from a number of different data providers. One concern was that data providers may be reluctant to share their data sets (especially unpublished data) with other organisations. This problem was encountered for Italy where a number of authors were reluctant to provide data to the project as they were keen to publish the data within their own research publications. It was also suspected that strong data sets may not exist for countries in the east of the study region as the quantity of biological records has only been advanced in this region in recent decades. While there were concerns about the quality of some data sets (Section 3.2), for the most part records in some form were available for all the countries investigated.

The 50 x 50 km and 10 x 10 km grid resolutions for the two distribution maps proved to be a very effective way of displaying the distribution. The lower resolution 50 x 50 km grid allows general conclusions about the species distribution to be drawn and when viewed in conjunction with the higher resolution 10 x 10 km maps, more detailed conclusions about distribution patterns can be drawn. This method also assists in identifying potential issues with data sets as patterns which may not have been obvious at the 50 x 50 km resolution become more striking at finer resolutions.

The use of two distribution scales also created the opportunity to produce the abundance map (Figure 3.30). This would not have been possible if only one distribution map had been produced. The extra context given by the abundance map and the further support it gives to drawing conclusions about population distribution patterns would make repeating this exercise worthwhile in the future. It should be noted that a small number of the data sets retrieved included their own assessments of abundance, however the approaches to the estimation of abundance varied significantly and in some instances metadata detailing how these estimations were made were unavailable.

5.2 Potential changes to the methodology

Whilst the 10 x 10 km resolution maps were very effective at showing distribution detail on a local level, a drawback of using such a fine resolution is that data sets which are at lower resolution cannot be displayed accurately and therefore the distribution becomes distorted. This was encountered during the mapping of Italian and Greek data sets. As these two data sets were based on anecdotal descriptions of presence in counties/sub-regions, the resolution was much lower than the 10 x 10 km grids required and they were eventually excluded from the 10 x 10 km grid map. County-based distribution can only be used on the courser scale 50 x 50 km maps.

The ‘date of record’ information collected for each record did not yield as interesting results regarding A.artemisiifolia spread on a temporal scale as had previously been hoped. It was a worthwhile exercise but ultimately the number of data sets containing this information was too few to draw any significant conclusions. There is also potential that these dates were not always reliable, especially in relation to the first known record dates. Patterns of recurring dates were noticed for the first known record of a species (e.g. 1863) which leads to the assumption that a generic date may have been used by some data providers when the first date was not actually known. This would require further investigation if similar research is carried out again in the future but it suggests that it is not recommended to infer from these dates.

Additional information was also collected during the data retrieval stage of the methodology regarding population size, density and status (casual/established) for *A. artemisiifolia*. Some interesting and potentially useful conclusions can be drawn from studying this information but not at the scales used to map the distribution during this exercise. All records occurring in a given square on the distribution grid (both at 10 x 10 km resolution and 50 x 50 km resolution) were grouped together in the GIS tables, thus much of this information was lost where multiple aspects of information are recorded from one grid square. If the exercise was repeated in the future and the distribution mapped at a finer scale it may be possible to display this information within the GIS tables and draw more detailed conclusions concerning population abundance, density and status. However, the majority of data sets retrieved during this exercise did not contain this type of information and within those that did there was a lack of standardisation making it difficult to draw comparisons between data sets. If this type of data was retrieved and analysed in future studies then a rigid criteria would need to be set to assign them within the GIS database (e.g. 'casual', 'established' and 'unknown' conditions identified in separate columns in the GIS table). It should also be noted that this would decrease the amount of automation that can be applied to the standardisation process for larger data sets and subsequently data standardisation would take much longer.

6 Conclusion

The methodology and results presented in this report have provided a basis for future control of the invasive species *A. artemisiifolia*. Regions and countries with significant populations have been identified are clearly presented allowing the prioritisation of countries requiring control measures. Country-scale maps also provide valuable information with regard to key localities where control measures are required. The maps provided also detail valuable information that can be utilised to assess the future spread of the species.

The methodology presented is repeatable and it is hoped that the methodology will be used to assess the spread of other invasive species in the near future.

7 Contributions

A wide range of data providers kindly gave permission for NatureBureau to incorporate their data into the maps provided within this report. All data holders that provided data to the project are referenced below.

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France

Conservatoire et Jardins botaniques de Nancy

Fédération des Conservatoires botaniques nationaux (FCBN)

Floraine, Association des Botanistes Lorrains - Villers-lès-Nancy France

GBIF

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Germany

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Slovakia

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Spain

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Sweden

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Switzerland

AWEL, Amt für Abfall, Wasser, Energie und Luft, Abteilung Abfallwirtschaft und Betriebe Sektion Biosicherheit

CRSF/ZDSF - Center of the data network of the Swiss flora

Ukraine

Olga Umanets

UK & Ireland

Botanical Society of British Isles

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Task 4: A general systematic methodology to assess the social, environmental and economic impacts of invasive species and a thorough qualitative assessment of the current and probable future harmful effects of ragweed

1 Introduction and methodology

Although ragweed *Ambrosia artemisiifolia* is generally regarded as a damaging invasive (e.g. Déchamp and Méon, 2005; Bohren, 2006; EFSA, 2010), information on the range and degree of its impacts in Europe has not previously been considered objectively and systematically. Ragweed in Europe is well known to cause allergic reactions in humans (e.g. Taramarcaz *et al.,* 2005) and to be an important crop weed (e.g. Pinke and Karácsony, 2010), but there is a need for collation of the evidence. Little is known about the degree to which suggestions of other impacts in Europe – such as harm to pets and livestock, biodiversity declines, ecosystem disservices, or hampering human activities – are supported by the evidence. The aim of this task was to develop a systematic review methodology to collate and analyse all relevant data concerning the social, environmental and economic impacts of ragweed, which could be applicable to other invasive species. We then applied this methodology to particular questions concerning human and animal health, biodiversity, the wider environment, production systems, and transport and built infrastructure.

1.1 A general methodology for reviewing harmful effects of invasive species

In this section we develop the principles for reviewing the impacts of an invasive species. Systematic review methods were developed for medical studies and have been implemented subsequently in many other areas, including biodiversity research (e.g. Newton *et al.*, 2009; Rey Benayas *et al.,* 2009). The purpose of a systematic review is to provide the best available evidence to answer particular, clearly defined, questions. It is, therefore, a tool to support decision-makers by providing independent, unbiased and objective assessment of evidence. A systematic review involves summarizing and assessing the results and implications of a large quantity of research and other information. It is particularly valuable as it can be used to synthesize results of many separate studies, which may have used different methodologies and resulted in conflicting findings. Due to its systematic nature, the approach is far more robust and powerful than a traditional literature review, which may be purely narrative, subjective or susceptible to publication bias. A systematic review strives to obtain all relevant unpublished literature and research findings as well as journal publications. The process of study inclusion into the systematic review is entirely transparent, and should therefore be repeatable in its conclusions. The results from individual studies may then be summarised; either statistically using meta-analysis (e.g. Rey Benayas *et al.,* 2009), or by formally collating results where statistical analysis is unnecessary.

Recent extensions to the systematic review approach are particularly valuable when applied to the assessment of the harmful effects of invasive species. Many potential impacts may be poorly researched, or assessed in a few, limited studies. In a traditional literature review, such impacts could not be assessed. Alternative qualitative data sources, such as expert opinion, allow one to make the best use of current knowledge. However, expert opinion is subject to greater bias and error than scientific research data, and so must be used carefully. Where qualitative data are used to answer a particular question, one might use Bayesian Network (BN) modelling (Newton *et al.,* 2007). BNs comprise a graphical modelling approach which incorporates probabilistic relationships among variables.

These considerations lead to general systematic review approach as represented in Figure 4.1.

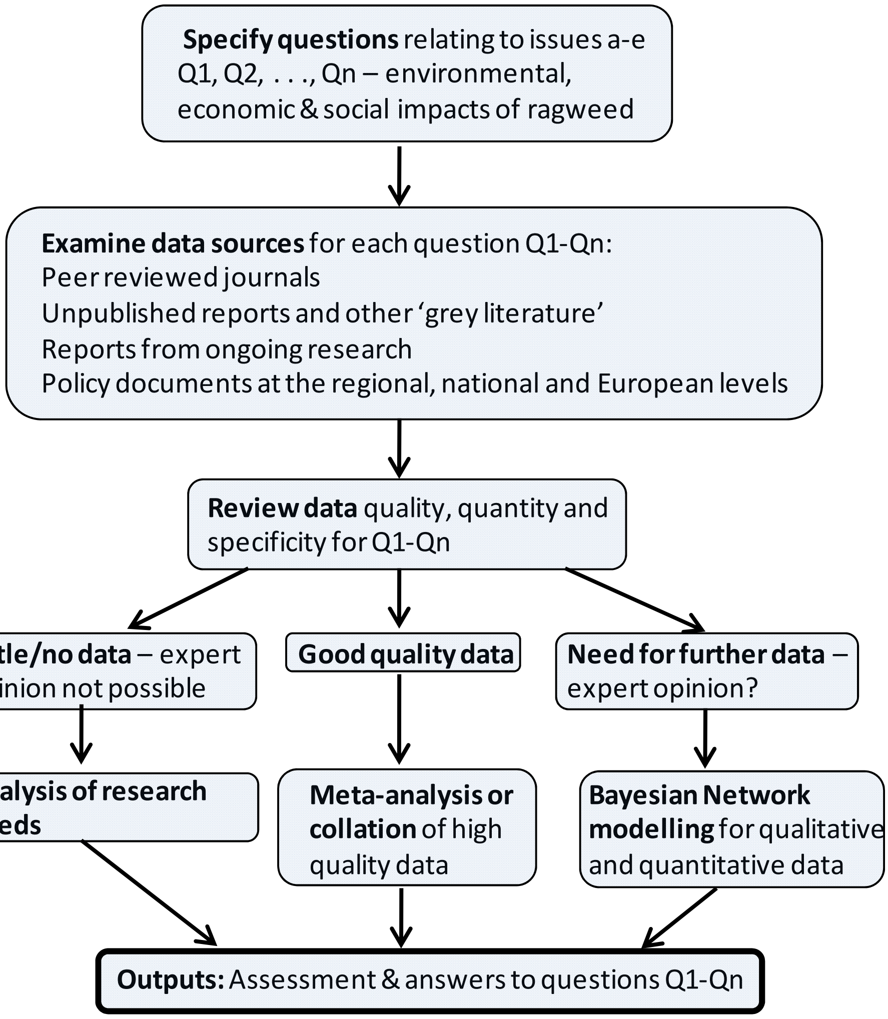

Figure 4.1. A systematic methodology for assessing the impacts of an invasive species.

1.2 Specification of questions

Questions were specified by taking as the starting point the five main areas of interest specified in the Technical Proposal, which reflect the Project Specifications. These areas of interest consider the impact of *Ambrosia artemisiifolia* on: a) Human & animal health, including medical and veterinary effects, medication and work or production losses; b) Biodiversity, such as out-competing other species and adversely affecting natural habitats and ecosystems; c) The wider environment, including effects on soil and water; d) Production systems, such as agriculture, horticulture, construction and other relevant economic sectors; and e) Transport & building infrastructure. Impacts on the wider environment were considered to encompass impacts on ecosystem services. For clarity in describing ecosystem services and for compatibility with the economic analysis in Task 5, we used The Economics of Ecosystems and Biodiversity (TEEB) classification of ecosystem services as described in Task 5.

The questions were specified by discussion within the project team, but also by initial consultation with the national experts, as the questions formed the basis of the Task 4 part of the national expert questionnaires (see General Methodology). The questions relevant to this Task are listed in Table 4.1. The issues a-e were reorganised and sub-divided to allow a more systematic specification of questions.

Table 4.1. The questions specified for Task 4. Each question is general, but to understand geographical and regional variations, specific answers for different countries and regions in Europe were also considered.

	Main question	Subsidiary questions
Human health impacts	1) Have human allergic reactions to ragweed been reported?	a) What types of reaction are reported (e.g. hay-fever, asthma, contact dermatitis) b) What is the incidence of allergic reactions (e.g. number of reports, % of population affected) c) Are there any hospitalisations due to the allergic events? d) Have the reactions affected people's ability to attend work and how many work days are lost?
	2) Has the incidence of allergic reactions increased over the last 10 years?	a) What types of reaction are reported? b) What are the changes in incidence?
	3) Are the allergic reactions reported to be worse, less, or no different from those to other plant allergens (e.g. grass or *Brassica napus* pollen)?	a) What types of reaction are reported? b) What are the differences in reactions, including the plant species against which ragweed was compared?
	4) Over what distances from ragweed infestations are allergic reactions to its pollen manifest?	a) What types of reaction are reported? b) At what distances are allergic reactions manifest?
	5) What concentrations of ragweed pollen cause allergic symptoms: i.e. what is the minimum concentration for which responses are reported?	a) What types of reaction are reported? b) At what minimum concentration are responses reported? c) How does the response change with pollen concentration?
	6) Are certain sectors of the human population more affected by ragweed and its pollen?	a) What are the determinants of sensitivity? b) What groups are more affected and what is the size of the effect on these groups relative to others? c) What percentage of the total population are these groups?
	7) Has sensitisation to ragweed and its pollen led to sensitivity to other allergens?	a) What types of reaction are reported? b) To which other allergens has ragweed increased sensitivity?
	8) What medication is used to relieve	a) What types of reaction are considered?

	Main question	Subsidiary questions
	allergic responses?	b) Which other allergies is this used for?
Animal health impacts	1) Have allergic reactions of animals to ragweed been reported?	a) Which animal species are affected (pets, livestock, etc)? b) What types of reaction are reported? c) What is the incidence of allergic reactions?
	2) Has the incidence of allergic reactions increased over the last 10 years?	a) What types of reaction are reported? b) What are the changes in incidence?
	3) Are the allergic reactions reported to be worse, less, or no different from those to other plant allergens (e.g. grass or *Brassica napus* pollen)?	a) What types of reaction are reported on which animals? b) What are the differences in reactions, including the plant species against which ragweed was compared?
	4) Over what distances from ragweed infestations are allergic reactions to its pollen manifest?	a) What types of reaction are reported on which animals? b) At what distances are allergic reactions manifest?
	5) What concentrations of ragweed pollen cause allergic symptoms?	a) What types of reaction are reported on which animals b) At what minimum concentration are responses reported? c) How does the response change with pollen concentration?
Biodiversity impacts	1) Which ecosystems are most invaded by ragweed, and does this vary geographically?	a) Which ecosystems have been studied? b) For each ecosystem what is the degree of invasion? c) What impacts are reported on the biodiversity of each ecosystem (e.g. decline of native species)? d) Do time since invasion or ragweed density change impacts?
	2) Are protected sites invaded by ragweed – e.g. Natura 2000 sites?	a) For each site what is the degree of invasion? b) What impacts are reported on the biodiversity of each site?
	3) Are species of conservation concern affected by ragweed?	a) Which protected species have been studied? b) What impacts on this species are ascribed to ragweed?
	4) How serious are the effects of ragweed in the context on national conservation goals and strategies?	a) Which national conservation goals or strategies are considered? b) What is the impact of ragweed on achieving the conservation goal?
Impacts on the wider environment	1) What are the impacts of ragweed on the functioning and services of invaded ecosystems?	a) Which ecosystem functions or services which are reported to be affected by ragweed for each ecosystem type? b) What data exist describing these impacts?
	2) What effects do ragweed control measures on have on ecosystem functions and services?	a) Which ecosystems have been studied? b) Which ragweed control or eradication measures were used? c) Which ecosystem functions or services were affected by the control or eradication measures and to what degree?
Impacts on arable agriculture and horticulture	1) Where is ragweed an agricultural weed?	a) Is ragweed a serious, moderate or minor agricultural weed in the regions considered? b) What area of cropped land in each region is affected?
	2) Which crops are affected by ragweed?	a) What area of each crop is affected by ragweed in each region considered? b) What are the yield losses to ragweed of each crop is affected by ragweed in each region considered?
	3) Are certain agricultural systems more likely to suffer ragweed problems: e.g. organic farms; or farms with agri-environment management	a) What is the evidence for differential susceptibility of ragweed invasion?

	Main question	Subsidiary questions
	such as birdseed strips?	
	4) Does ragweed invasion cause other problems in agriculture and horticulture, such as restricting access of humans or livestock, interfering with machinery, or contaminating agricultural products?	
Impacts on other sectors	1) Have construction projects (buildings, roads, etc) been disrupted by ragweed invasions?	a) What construction projects have been affected? b) What type of disruption occurred (e.g. evacuation of the site, ragweed control, the use of safety equipment)?
	2) Have ragweed invasions of transport links (roads, railways, etc) restricted private and/or business travel?	a) What transport links have been affected by ragweed? b) What type of disruption occurred (e.g. road closure)?
	3) Do ragweed infestations affect leisure, recreation or tourism?	a) What activities have been affected by ragweed? b) What type of disruption occurred (e.g. restricting access to amenity - including city parks - or tourism sites, or causing health problems amongst visitors to such sites)?
	4) Is other evidence is available to calculate the economic effects of ragweed impacts on these or other sectors not considered elsewhere?	

1.3 Examination of information sources

The questions specified above were addressed using two approaches.

a) Completion of the questionnaire by national experts. This has given us access to regional reports and documents and papers published in the (non-English) languages.

b) Systematic reviews of information by project members with expertise in: human health, specifically human allergies; horticultural, arable and livestock systems, including animal health; biodiversity and the wider environment, including ecosystem services; and other sectors, including construction, transport and tourism.

The national experts used local contacts, access to regional institutions, records and reports, and published non-English language papers to complete the questionnaires. The project members gathered information by searching for papers and conference proceedings on bibliographic search engines, including Web of Knowledge. Broad searches were carried out using the search term "Ambrosia" (which resulted in 840 hits), and these were refined to focus on studies covering the European region of interest (+ "Europe" or individual country names) and the subject areas of interest (e.g. + "biodiversity" or + "ecosystem" or + "allerg*"). Websites for relevant projects (e.g. DAISIE http://www.europe-aliens.org/), conferences (e.g. "Towards sustainable management of *Ambrosia artemisiifolia* in Europe" http://www.cabi.org/default.aspx?site=170&page=2014) and other activities (e.g. http://www.internationalragweedsociety.org/) were perused. We extended our search to other regions, especially North America to find relevant studies that could inform our analysis; this was especially important in providing data to inform more qualitative assessments of potential impacts in Europe. All useful literature and other sources of information were entered onto a Mendeley bibliographic database which allowed sharing of papers, etc among project members. These information sources were examined by the relevant project member and information relevant to the questions was extracted from relevant sources. Any relevant publication cited by these initial sources were also tracked down, examined, and, if useful, added to the data sources. In addition, once the national expert questionnaires were returned, the relevant project member extracted and assessed the information; this included following up information sources provided by the national expert. These sources (276 in all) provided by the national experts were invaluable as they found many useful papers and other publications which were published in local, native language journals not accessible by statndard searches of bibliographic databases

1.4 Review and analysis of information gathered

Fig 4.1. summarises possible approaches to reviewing and analysing data. The data and results garnered from the expert questionnaires and our examination of the available literature showed that certain subject areas are relatively well studied; impacts on human health in Europe and on European crops. Other areas, such as animal health, impacts on the wider environment, or impacts on construction and tourism industries have sparse data. Biodiversity impacts are moderately well studied. Furthermore, there is large variation in the state of knowledge and research among the different EU countries. Certain questions yielded moderately large quantities of quantitative data; for example measures of the incidence of allergic reactions in Europe (section 2). Other questions were answered more qualitatively; for example the crop weed status of ragweed in different countries (section 6). Other questions yielded virtually no data – for example disruption of building activities by ragweed infestation (section 7) – but the expert responses, our perusal of the literature and expertise of relevant members of the project team allowed us to assess the causes and meaning of this lack. For example, often no data meant the suggested harm from ragweed is not actually experienced in Europe. We adopted the collation approach to summarising the data, which involved tabulating or plotting a set of data about a certain issue and constructing a narrative around these and less structured quantitative and qualitative data. Formal meta-analysis was not considered relevant as quantitative data were generally from such dissimilar studies (countries, time periods, subject group, data type) that such analysis would have either been uninformative or would have necessitated discarding a large proportion of studies (the latter is a common problem in systematic reviews of environmental evidence – Stewart *et al.*, 2005; Newton *et al.,* 2007). For example, a very important aspect of the reviews is the variation in ragweed impacts across Europe; to assess this often required combination of different qualities of data from better and less well studied regions. Thus, our approach was systematic in the sense that we accessed all available information, but we did not go down the route of discarding data that did not conform to narrow rules of systematic evidence. In the following we clarify which data types are being referred to and give precedence to: scientific study > quantified observations > expert opinion; and quantitative > quantitative.

In reporting the results of these data surveys, most economic evidence is presented in Task 5. This is to avoid repetition, but also because there is little direct evidence of economic impacts, so the modelling approach presented in Task 5 gives a more rounded picture of these.

2 Human health impacts

2.1 Summary of human allergic reactions to ragweed reported across Europe

The three main allergic diseases that have been associated with exposure to aeroallergens – allergic rhinitis, hayfever, asthma, and atopic dermatitis (eczema) – individually and collectively impose both substantial health effects and large economic burdens. After being exposed to ragweed pollen, people with allergies will often experience sneezing, a runny nose, and swollen, itchy, watery eyes. Allergic reactions such as rhinitis significantly reduce quality of life, interfere with both attendance and performance at school and work and lead to substantial healthcare costs (Scadding *et al.,* 2008; Pawankar *et al*., 2011).

The returns from the national experts detailing the incidence and types of reported ragweed allergies varied across Europe. For example, the no/minor status for Latvia, Belgium and Denmark reflect the low infestation levels of ragweed in these countries. The results are summarised in Table 4.2 and show that it is difficult to generalise about the incidence of allergic reactions to ragweed across Europe.

During 2006-2007, Burbach *et al.* (2009) carried out a pan-European study of ragweed sensitisation for 16 centres in 13 European countries; this provides the most wide-ranging, comparable information about incidence in Europe. The study population consisted of routine out-patients with allergic symptoms who presented to one of the study centres, and standard skin prick tests were carried out. Ragweed sensitisation was above 2.4% in all European countries, with a rough average across countries of about 10% (Fig. 4.2). Hungary showed very high sensitisation of >50%, as might be expected as ragweed infestation in this country is one of the highest in Europe. However, Denmark, which has a minor ragweed presence, also had a high sensitisation rate of 19.8%. Burbach *et al*. (2009) contrast these figures against the rather low sensitisation rates in a similar study carried out across 32 centres in 13 countries (including Europe, but also the USA and Australia) in the late 1990s (Bousquet *et al.*, 2007). That study reported an average sensitisation among allergic individuals of 0.8%, with a range of 0-8.7%.

These studies suggest that the incidence of ragweed allergies varies greatly. This can be the case within countries. For example, in Austria the percentage of allergic patients with sensitivity to ragweed appears to be related to geographical location (Hemmer *et al.*, 2009). While an incidence of 1.7% was found for Austria as a whole, this breaks down by area as: Burgenland 16,300 allergy patients (6.01%); Carinthia 1,600 (0.29%); Lower Austria 33,200 (2.25%); Upper Austria: 4,000 patients (0.30%); Styria 13,300 patients (1.12%); and Vienna 72,500 patients (4.49%). Furthermore, in Tyrolia and Vorarlberg almost no people are affected (Jäger *et al.,* 2010). In another Austrian study an average of 11.1% (2450 patients) of the 14,000 allergy patients examined showed positive reactions to ragweed pollen based upon prevalence of sensitisation. However, there was east-west gradient and an altitudinal gradient: from 20.8% in the Seewinkel (northern Burgenland near the Hungarian border) to 6% (northern Lower Austria) and 4.71% (inner Alps of Lower Austria) (Hemmer *et al.,* 2009).

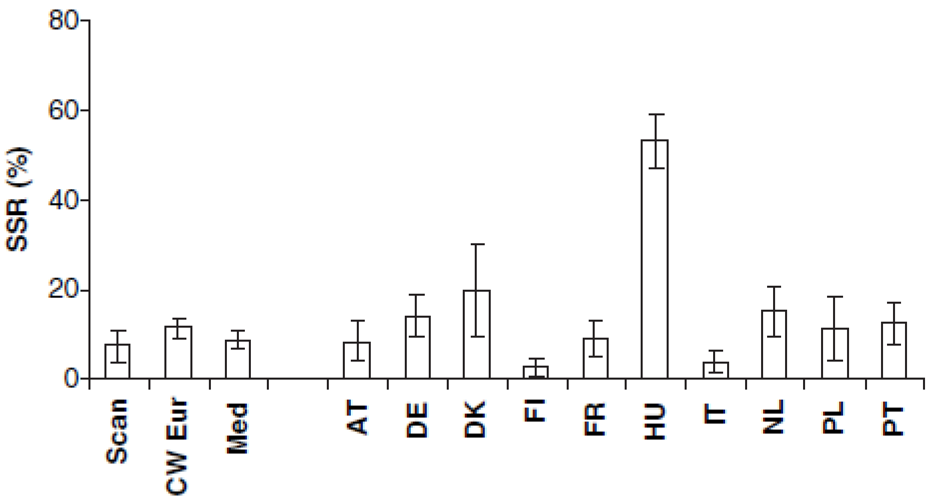

Fig. 4.2. Results from the Burbach *et al.* (2009) pan-European study of ragweed sensitisation, showing standardized sensitisation rates for *Ambrosia artemisiifolia* (SSR, n = 2026) by region – Scandinavia (Scan), Central/Western Europe (CW Eur), Mediterranean (Med) – and country – Denmark (DK), Finland (FI), Austria (AT), Belgium, Germany (DE), Netherlands (NL), France (FR), Greece (GR), Italy (IT), and Portugal (PT). 95% confidence intervals are shown. (Copied from Burbach *et al.*, 2009)

These figures give incidence of ragweed allergies amongst the atopic population, i.e. individuals with a tendency to be allergic. Considering the population as a whole, the global incidence of allergic rhinitis is believed to be between 10-30% adults and up to 40% of children (Pawankar *et al*., 2011). Some studies have estimated the proportion of the European population that exhibits allergies. Bauchau and Durham (2004) surveyed adults in Belgium, France, Germany, Italy, Spain and the UK, and found an average of 23% (range 17-29%) exhibited allergic rhinitis (about half had not had a previous diagnosis by a physician). The first European Community Respiratory Health Survey examined rates of allergic rhinitis amongst adfult population samples in a number of countries including, in Europe: Belgium (26% showed allergic rhinitis), France (36%), Germany (20%), Iceland (24%), Italy (19%), Ireland (24%), Norway (17%), Spain (18%), Sweden (29%), Switzerland (26%), The Netherlands (19%), and the UK (29%) (Bousquet *et al.*, 2008). These figures indicate that roughly a quarter of the adult population in Europe exhibits allergic rhinitis. However, allergy rates tend to be lower in Eastern Europe than in the west (Beasley *et al.*, 1997; Kramer *et al.*, 2009), so this figure may be an over-estimate.

Table 4.2 A summary of the assessments by the national experts of ragweed allergies. The demographics presented include assessment of country, region, date of occurrence, classification of symptoms and measurement type. Further comments have been added where appropriate to detail the incidence. SPT = Skin Prick Testing.

Country	Region	Date of occurrence	Rhinitis	Hayfever	Asthma	Dermatitis	Measurement	Incidence	Reference
Austria	All	2010	x	x	x		SPT	The sensitisation rate of allergic individuals increased from 8.5% (1997) to 17.5% (2007). There is an east-west gradient: from 20.8% in the Seewinkel (nothern Burgenland near Hungarian Border) to 6% (northern Lower Austria) and 4.71% (inner Alps of Lower Austria). Links to gastrointestinal discomfort.	Jäger *et al.* (2010); Hemmer *et al.* (2009)
Belgium		N/A						Ambrosia is not considered an important allergen Some testing has been performed with patients, very few showed sensitisation.	No reference
Bulgaria	North	1991-1997	x		x		SPT	The incidence of ragweed sensitisation among allergic individuals increased 6.9 times in a seven year period.	Yankova *et al.* (2000)
Croatia	Central Croatia	2009	x	x	x	x	Epidemiology / clinical	2.8% of allergic subjects were allergic to ragweed pollen.	Gajnik and Peternel (2009)
	Eastern Croatia	2003	x		x		Not documented	400 000 inhabitants of Croatia, or every 10th person is allergic to ragweed.	Strategic Health Plan of the Osijek-Baranja County (2003)
Czech Republic Slovakia	All	1999		x		x	Clinical	20-25% of atopic patients are sensitive to ragweed.	Rybníček (1999)
	All	2000					SPT	19-25% adult and 22% child atopic patients sensitive to ragweed.	Rybníček (2000)
Denmark								No data	

France	Lyon	1982-2005	x		x		Epidemiology	6 to 20% of the population was affected by ragweed pollinosis. French National Hygiene Council estimates the prevalence of allergic reaction to ragweed to 1.6% to 12% depending on weak or high infestation of concerned regions. There has been an increase in ragweed pollinosis of 17% in this area between 1999 and 2004.	Déchamp and Méon (2005); Hedreville and Rouviere (2005)
	SE Lyon and NW Lyon	1998 and 2002-2003	x	x	x		Not documented	Average prevalence of allergic reaction to ragweed is 8.5% (7.7%-9.9%) while other species have an average prevalence of 12.6%. Allergenicity fluctuates between 6.3% for moderately infested areas to 12.1% for highly infested areas. It is estimated that 2 to 5 % of the inhabitants of the Rhônes-Alpes are allergic to ragweed.	Thibaudon, *et al.* (2004)
Germany	Bavaria	2006-2008	x				SPT	20.3 % of 1131 atopic subjects reacted positively to ragweed. 210 demonstrated ragweed specific IgE antibodies yielding a total of 312 patients (27.2%), with ragweed sensitisation.	Ruëff (2009a)
	Munich	2009	x					A study by the TU München Klinikum of 133 patients with allergic rhinoconjunctivitis identified 33% as being sensitised towards *Ambrosia.*	Jaeger *et al.* (2009)
	Baden-Württemberg	2005-2008					Clinical	Among 2213 atopic 10 year-old children, 41.6% showed sensitisation to ragweed. 20% of these had specific ragweed IgE antibodies.	Behrendt *et al.* (2010)
	Baden-Württemberg	1992 - present						Sentinel public health offices carried out allergy screening on 9-10 year-old school children. 15% were sensitised against the native -ragweed allergen, about 3% were sensitised against the major allergen of *Ambrosia* (Amb a 1) and approximately 5% were sensitised against the native major allergen of mugwort (Art v 1).	Gabrio *et al.* (2010)
	Bavarria	2011		x		x	Clinical	Of 1,022 atopic subjects, 289 (28.3%) exhibited ragweed sensitisation.	Bayerisches Staats-ministerium für Umwelt und Gesundheit (2011)

Hungary	Kecskemét, Eger, Nyíregyháza	2006		x				In vitro specific IgE determinations (inhalative and food allergen panels, 49 items) resulted in 52-56% of the examined subjects showing allergic reactions.	Páldy *et al.* (2010); Nekam *et al.* (2011)
Italy	Piedmont	2009					SPT	Two sets of tests: out of 9,757 subjects 14.97% showed allergic reactions; out of 1,055 subjects, 19.7% reacted.	Anonymous (2009)
	Piedmont	2007	x		x		SPT/ clinical	6,917 of 82,965 (8.3%) subjects were positive to SPT for ragweed. Of these 6,917 individuals 3,801 (55%) presented with rhino-conjunctivitis and/or asthma .	Calamari and Galimberti (2007)
	Magenta	1996-2004	x		x			The prevalence of ragweed allergies in the adult population was 9.2% in 1996 and 13.65% in 2004.	Bonini *et al.* (2004)
	North	1990s					SPT	In the late 1990s, positive results of skin prick tests or positive radioallgergosorbent test (RAST) reactions to ragweed allergens in pollen-allergic patients in Northern Italy reached nearly 70%.	Gadermaier *et al.* (2004)
	Whole country	1988-2004					SPT	26,551 allergic patients, revisited with questionnaire and SPT. Ragweed sensitisation increased from 0.74% to 7.25% during this time. 56.3% of subjects were sensitive to pollen.	Della Torre *et al.* (2006)
	Magenta	1994-1996	x		x		Clinical	Of a sample of 1,166 children 5 to 12 years old, 132 (11.3%) were sensitive to ragweed pollen, and 45 (3.9%) of these had a diagnosis of rhino-conjunctivitis, with or without asthma.	Pastori *et al.*(1997)
	Brianza, Milan	1988-1990	x	x	x		SPT	SPTs were positive in 27 patients of 1,526 (1.76%) in 1988, in 25 patients of 1,517 (1.64%) in 1989, and in 56 patients of 1614 (3.41%) in 1990.	Piazza *et al.* (1992)
	Legnano	1989-2008	x		x		SPT, clinical	Among patients with pollinosis, sensitisation rate to ragweed increased from 24% to over 70%.	Tosi *et al.* (2011)
	Bologna	2006					SPT	1,048 outpatients (406 males and 642 females) of a Bologna allergy clinic had SPT. 188 (37%) came up with positive reactions to ragweed; the 2 sexes were similarly represented (90 males and 98 females).	Zauli *et al.* (2006)
	Chieti-Pescara	1998			x		Clinical	A cohort of 507 children aged between 1 to 17 years was examined. Prevalence of allergic reactions to ragweed pollen was 5.9% among atopic children.	Verini *et al.* (2001)

	Lombardy	1995-2002	x	x	x			In the Lombardia and Friuli areas ragweed constitutes a cause of significant morbidity for asthma and rhinoconjunctivitis: 12% of the general population may suffer from allergic symptoms due to ragweed. This percentage is higher in areas where the plant has been established for a long time and is present in large quantities.	Zanon *et al.* (2005)
Latvia								No data	
Poland	Warsaw	1998-2003					SPT	Positive response in 0.3% of tests in 1998 and 1.5% in 2003.	http://www.klimatazdrowie.pl/index.php?strona=zagrozenia&artykul=32
Romania Moldova	All	2008-2009	x		x			Reported symptoms in the atopic population In 2008: 21% asthma, 61% allergic rhinitis, 18% asthma and allergic rhinitis In 2009: 18% asthma, 47% allergic rhinitis, 35% asthma and allergic rhinitis	Faur *et al.* (2003); Ianovici *et al.* (2009a,b, 2012)
Switzerland	All	1995	x		x			Rhinitis and asthma at respectively 11.1% and 6.8% in adults and 17% and 9% in children (6345 patients). The results document low ragweed sensitisation rates in 1991 and in 2002, even in areas with a significant ragweed pollen load, strongly suggesting that the feared rise in sensitisation to ragweed has not yet taken place.	Taramarcaz and Lambelet (2005); Bohren (2006)
Ukraine Belarus								No data	
Serbia								No data	

2.2 Recent changes in the incidence of allergy to ragweed

There is some direct evidence that the incidence of ragweed allergy is increasing in Europe. In Serbia it is reported that the number of patients in the last ten years has risen, especially in highly industrialized regions (http://polj.uns.ac.rs/~korovi/medicinski_ zizvestaj.html). In France, the first cases of ragweed pollinosis were reported in Paris in 1955 and then in 1964 in the Nièvre department and in Lyon region. Its radius of action has increased, with a very sharp expansion since the 1990s. The pollen counts and the number of days *p.a.* with an allergic risk increased between 1990 and 2005. In 1987 the number of days with an allergic risk higher than 3 was 10; in 1999, it was

40 (Thibaudon *et al.*, 2004). In Northern Italy, Calamari and Galimberti (2007) reported that in the Novara Province of Piedmont, the cases linked to ragweed allergy have increased from 55 in 2004 to 634 in 2007.

Two linked factors suggest further that the proportion of the European population suffering from allergic reactions to ragweed has increased over recent years. One factor is the geographic spread of ragweed reported in Task 3, which exposes a greater proportion of the European population to the allergen. The second factor is evidence of an increasing proportion of the exposed population showing allergic reactions to ragweed. Burbach *et al.* (2007) suggest that higher levels of sensitisation in their study (2006-2007) compared to Bousquets *et al.* (2007) carried out in the late 1990s (see above) suggests an increase in sensitisation over that period. More specific examples are reported for individual countries:

- in Austria it is reported that the sensitisation rate increased from 8.5% in 1997 to 17.5% in 2007 (Hemmer *et al.*, 2009);
- in Sofia a study of hayfever sufferers showed a 6.9-fold increase in sensitisation to ragweed from 1991-1997 (Yankova *et al.,* 2000);
- in Legnano near Milan, the sensitisation rate to ragweed of patients with pollinosis (i.e. hayfever reaction to pollen) increased from 24% in 1989 to over 70% in 2008. In 1989, about 45% of the ragweed-sensitised patients suffered from respiratory symptoms (rhinitis, asthma). After five years, this percentage increased to 70% and finally reached 90% (Tosi *et al.*, 2011);
- in the Lombardy region of Italy the proportion of people allergic to ragweed changed from 3-12% in 1997 to 5-15% in 2005 (http://www.comune.milano.it/portale/wps/portal/CDM?WCM_GLOBAL_CONTEXT=/wps/wcm/connect/ContentLibrary/Ho%20bisogno%20di/Ho%20bisogno%20di/benesseresalute_iniziativediprevenzioneinformazione_ambrosia; accessed 29/6/2011);
- in Milan, a regular increase in the proportion of patients aged <20 years becoming allergic to ragweed was observed 1997–2006; this subset of patients was 0% 1990–96 and grew to 18% (Asero, 2007);
- in the French Rhône-Alpes, there was an increase by 17% in the population showing allergies to ragweed between 1999 and 2004 (Thibaudon *et al.*, 2004);
- In Switzerland sensitisation to ragweed increased from 29.3% in 1991 to 30.2% in 2002 (Ackermann-Liebrich *et al.,* 2009);
- In Warsaw, positive responses to ragweed increased from 0.3% of tests in 1998 to 1.5% in 2003 (http://www.klimatazdrowie.pl/index.php?strona=zagrozenia&artykul=32).

- In Zagreb, the proportion of the atopic population sensitised to ragweed increased from 21.8% in 1991 to 34.2% in 2004 (Mehulić *et al.,* 2011)

These increases in ragweed sensitisation must be seen in the context of the ongoing increase in allergy rates and the phenomenon of polysensitisation (sensitivity to multiple allergens) (e.g. Holgate, 1999; Asher *et al.,* 2006); i.e. this phenomenon is not confined to ragweed allergies.

2.3 Distance and concentration thresholds in allergic reactions to ragweed pollen

Distances travelled by ragweed pollen

Ragweed tends to grow in large populations, and a single plant can release about 1 billion pollen grains in a season (Thompson and Thompson, 2003). These pollen grains are able to travel long distances depending on weather conditions, with reports of 60 km to over 200 km (Cecchi *et al.,* 2007; Alleva *et al.,* 2009), or even 1000 km under unusual conditions (Belmonte *et al.,* 2000). Starfinger (2009) reports that ragweed pollen remains allergenic even after it has been transported over long distances.

Such long range dispersal suggests that infestations in one region can cause allergic reactions over large distances. For example, in Switzerland the long-distance transport of pollen from neighbouring countries (e.g. Italy) is considered to play an important role in pollen loadings across the country (Köhler, 2006). A study by Cecchi *et al.* (2007) over a two year period compared pollen and meteorological data for the two northern Italian cities, Parma and Mantova, with data from Pistoia and Florence in central Italy. In 2002 and 2004 peaks in ragweed pollen levels above clinical thresholds were detected in these four cities on the same days. In Florence and Pistoia *Ambrosia* pollen grains were found around the peak days only. This observation suggests that in the central Italian cities the presence of ragweed pollen is exclusively caused by long-distance transport. Weather-map analysis and computation of back-trajectories showed that air masses from Eastern Europe might carry ragweed pollen to a wide area of central and northern Italy. These findings supported the hypothesis that ragweed pollen reaches the Italian peninsula in air masses from the Balkans and/or central-eastern Europe. Similarly, Saar *et al.* (2000) showed that incursions of large quantities of ragweed pollen into Estonia and Lithuania were caused by air fluxes originating from the Ukraine as well as from the southeastern and southern regions of the European part of Russia. Kasprzyk *et al.* (2011) calculated that ragweed pollen was reaching western Poland from the Ukraine, while Šikoparija *et al.* (2009) suggested that ragweed growing on the Pannonian Plain around Novi Sad in Serbia is a source for pollen arriving over 500km away in Skopje, Macedonia. Trajectory analyses by Smith *et al.* (2008) suggested that air masses from Slovakia and Hungary were carrying ragweed pollen to Polish sites.

Threshold concentrations of ragweed pollen for allergic symptoms

In the USA, it has been estimated that allergic reactions to ragweed pollen are found with concentrations as low as 5-20 pollen grains m^{-3}, and in the Midwest the typical pollen count during the ragweed season is about 200 grains m^{-3} (Oswalt and Marshall, 2008). The information for Europe suggests that very sensitive people can be affected by as few as 1-2 pollen grains m^{-3} (Calamari and Galimberti, 2007; Bayerisches Staatsministerium für Umwelt und Gesundheit, 2011), but most reports match the range reported for the USA; the likely range taken from Table 4.3 is 5-20 grains m^{-3} d^{-1}. There is little information to link increased pollen concentration with increased reaction effect, but the Bayerisches Staatsministerium für Umwelt und Gesundheit (2011) states that at 10 pollen grains m^{-3} most ragweed sensitised persons show symptoms and a concentration of 50 or more grains m^{-3} is considered a strong stress. In Montreal, Quebec, <20 ragweed grains m^{-3} is considered a low dose, 21-80 grains m^{-3} intermediate, and >80 grains m^{-3} high, and the number of medical consultations for allergic rhinitis in the city increase in relation to these classes of ragweed pollen levels (Breton *et al.*, 2006).

Table 4.3 Information from across Europe on the minimum concentrations at which *Ambrosia artemisiifolia* pollen causes allergic reaction, and the associated allergic responses.

Minimum concentration (grains m^{-3} d^{-1})	**Country**	**Associated symptoms**	**Reference**
10-20	Austria	Not reported	Jäger *et al.* (2010)
5-6	France	Rhinitis, hayfever, asthma	Thibaudon *et al.* (2004)
20-30	Croatia	Not reported	Allergies Guide. Zagreb City Office for Health, Work and Social Care
10	Germany	Not reported	Bayerisches Staatsministerium für Umwelt und Gesundheit (2011)
10-100	Hungary	Hayfever	Harsányi (2009); Apatini *et al.* (2009)
5	Italy	Not reported	Brighetti *et al.* (2010)
30	Romania/Moldova	Not reported	Juhász *et al.* (2007)
8-10	Serbia	Hayfever	Mitrovic-Josipovic *et al*. (2006)
6-10	Switzerland	Hayfever, asthma	Bohren (2006)
11	Switzerland	Not reported	Taramarcaz *et al.* (2005)

2.4 Variation in allergic responses to ragweed

Generally, children are most affected by allergic rhinitis, asthma, etc., particularly those exposed to smoke and pets (Beasley *et al.*, 1998). There is a strong suggestion that sensitised individuals subject to atopic disease will become sensitised to whichever allergen is present. Thus the presence of ragweed will only impact those patients with a tendency to atopic disease, and these will most likely already be sensitised to other allergens. Other data suggests higher rates of allergies in certain countries; the highest prevalence rates of asthma are in the UK, Austria, New Zealand, Ireland and USA and this is hypothesised to be linked to genetic diversity in the human population (Warner *et al,.* 1999).

Urban populations may be more susceptible to allergies in general. Evidence links increased airway reactivity induced by air pollution to increased bronchial responsiveness to inhaled pollen allergens (Shea *et al.,* 2008). Therefore, people exposed to air pollutants such as nitrogen dioxide in high traffic areas are more likely to be affected by pollen leading to asthma. This has been further supported D'Amato *et al.* (2008); whereby high levels of vehicle emissions and westernized lifestyle are correlated with increased frequency of pollen-induced respiratory allergy in people within urban areas compared to rural areas. Urban areas may also have higher ragweed pollen levels, not only because of the abundance of the disturbed habitats colonised by ragweed, but also because the pollen season may start earlier and more pollen be produced due to the higher temperatures and CO_2 levels (Ziska *et al.,* 2003, 2007, 2008). However, in France, Thibaudon *et al.* (2004) found no difference in incidence of ragweed allergies between rural and urban dwellers.

2.5 Climate change and ragweed allergies

Climate change is likely to allow ragweed to increase its range in Europe by broadening the geographical region in which the plant finds suitable climatic conditions allowing the completion of its life cycle, as well as by changing land use (Task 6). A more direct impact is likely through anthropogenic increases in CO_2 concentrations. In controlled conditions, a doubling of CO_2 concentrations over ambient benefited ragweed growth and biomass, leading to an increase in pollen production by 61% (Wayne *et al.*, 2002). More generally, a changed climate may extend the ragweed pollen season. Ziska *et al.* (2011) recently showed that the duration of the pollen season of *Ambrosia* species in North America has been increasing in recent decades as a function of latitude; in particular, the ragweed pollen season has increased by as much as 13-27 days at latitudes above 44°N since 1995. These effects may be exacerbated by ongoing declines in air quality through climate change, increasing urbanisation, etc. (Ziska *et al.*, 2003). In relation to this, Ziska (2002) found that increased ozone levels had no negative effect on ragweed growth or pollen production, suggesting it would not be affected by decreased air quality.

2.6 Allergic reactions to ragweed compared to other plants

People allergic to ragweed appear generally to show allergies to other pollen. For example, Yankova *et al.* (2000) showed that all patients with positive skin prick tests for ragweed were highly allergic to other pollen types - mostly to Poaceae and Asteraceae. However, both the quantity of pollen released and its high allergenic potential mean that ragweed is one of the most important allergenic plants in infested regions; for example the Croatian national expert reports that ragweed is considered as the most allergenic pollen in Croatia. By 2006, only 15 years after its first appearance in the area north of Milan, ragweed pollen had become the second most common cause of respiratory allergies after grass pollen (Asero *et al.*, 2006; Bottero *et al.*, 2006).

The allergenic potential of pollen is related to the quantity of allergens it contains; the index varies from 0 (null) to 5 (very high). Ragweed pollen has an allergenic potential index of 5 (Anzivino-Viricel *et al.,* 2011). Skin prick tests in another study showed stronger allergenic responses to ragweed than to tree pollen (2-5 times more allergenic) or to grass pollen (twice as allergenic) (Steinert, 1999). In France, only cypress, birch and grasses are considered as allergenic as ragweed (http://www.pollens.fr/le-reseau/les-pollens.php). Serious allergy to ragweed pollen can result in allergic asthma (Taramarcaz *et al*., 2005; Ruëff, 2009a,b). A multi-centre epidemiological survey of emerging pollinosis in Italy concluded that ragweed pollen caused asthma much more frequently than other emerging pollens (birch, hazelnut, alder, hornbeam, cypress) (Corsico *et al*., 2006).

2.7 Links between sensitisation to ragweed and sensitivity to other allergens

The cross-reactivity of IgE antibodies to species of the *Ambrosia* genus prevalent in the United States was studied using a serum pool from patients sensitive to *A. artemisiifolia*. Common (*A. artemisiifolia*), giant (*A. trifida*), and western (*A. psilostachya*) ragweed displayed comparable reactivity in both inhibition and absorption experiments. Slender (*A. confertiflora*) and southern (*A. bidentata*) ragweed were considerably less active, indicating that they lacked allergenic groupings possessed by the other species (Leiferman *et al.*, 1976).

Cross-reactivity among the various ragweed species is to be expected from the high cross-reactivity among other members of the genus *Ambrosia* and the family *Asteraceae*. For example, cross-reactivity has been demonstrated for Chamomile tea extract, pollen of *Matricaria chamomilla*, *Artemisia vulgaris* (mugwort) and *Ambrosia trifida* (giant ragweed) (Subiza *et al.*, 1989). Furthermore, similar antigenic determinants were found among common and giant ragweed, cocklebur (*Xanthium strumarium*), lamb's quarters (*Chenopodium album*), rough pigweed (*Amaranthus retroflexus*), marshelder (*Iva annua*), and goldenrod (*Solidago canadensis*) (Perrick et al., 1991). However and surprisingly, common and giant ragweed are not allergenically equivalent because of allergenic differences involving both the major allergens Amb a 1-2 and Amb t 1-2 (all members of the pectate lyase family) and some minor allergens (Asero et al., 2005). Sensitisation to Amb a 1, a pectate lyase, results in cross-reactivity only with other pectate lysase containing plants where a high degree of homology occurs.

Furthermore, mugwort, ragweed, and timothy grass (*Phleum pratense*) pollen share IgE epitopes with Latex glycoprotein allergens; the presence of common epitopes might in part explain clinical symptoms on contact with Latex in patients allergic to pollen (Fuchs et al., 1997). In addition to profilin, mugwort and ragweed pollen contain a number of other cross-reactive allergens, among them the major mugwort allergen Art v 1. These cross-reactive IgE antibodies could result in clinically significant allergic reactions (Roebber and Marsh, 1991). In Europe, Lorenz *et al*, (2009) have suggested a group of homologous weed species including ragweed, mugwort and pellitory

(*Anacyclus pyrethrum*). The principle of homologous groups assumes the data of one allergen extract demonstrating stability, efficacy and safety can, to a limited extent, be extrapolated to other allergen extracts belonging to the same homologous groups. The homologous species are assumed to have similar biochemical composition and homology/cross-reactivity of allergens or allergen sources. Indeed, many national experts identified that ragweed is cross reactive with mugwort: in Austria (Hemmer *et al.*, 2009); Germany (Gabrio *et al.*, 2010); Hungary (Harsányi, 2009); Italy (Bottero *et al.*, 1990; Asero *et al.*, 2006); Switzerland (Ackermann-Liebrich *et al.*, 2009). Thus if mugwort is present in a region it is likely that patients will have sensitivity to ragweed when it invades the area.

An association between ragweed pollinosis and hypersensitivity to vegetables such as watermelon, cantaloupe, honeydew melon, zucchini and cucumber, and banana has been reported (e.g Harsányi 2009). Three allergens have been identified as candidates for causing this cross-reactivity: profilin, Bet v 1, and a 60-69 kDa allergen (Caballero and Martin-Esteban, 1998; de la Torre Morin *et al.*, 2001).

Allergy to celery is also associated with a pollinosis; the allergy is strictly one-way, celery-pollen. Other Apiaceae such as parsley and carrots produce the same effects. The causative pollen is usually the most common of the region, for example in the surroundings of Lyon ragweed and mugwort are particularly important (Déchamp and Deviller, 1987).

Table 4.4. Some medications used against ragweed allergies in individual European countries.

Country	**Medication**	**Reference**
Austria	Lectranal®	www.pollenwarndienst.at
Croatia	Claritin (Loratadine), Rinolan (Loratadine), Flonidan (Loratadine), as well as nasal drops and sprays, and bronchodilators – Ventolin (Albuterol) spray	Gajnik and Peternel (2009)
France	Generic anti-allergic eye lotion, nasal spray and antihistamines, as well as triamcinolone (injectable corticoïd)	Anonymous (2003)
Czech Republic	Aerius® syrup and generic antihistamines and corticosteroids	Rybníček *et al.* (2005); Humlová (2010)
Hungary	Generic antihistamines, corticosteroids, nasal drops and bronchodilators	www.hazipatika.com; Dr László, Rédei pers. comm.
Italy	Immunotherapy	Albasser (1992); Mirone *et al.* (2004); Calamari and Galimberti (2007)
Serbia	Immunotherapy	Plavsic *et al.* (2008)
Switzerland	Antihistamines: Claritin, Allegra, Zyrtec. Decongestants: Néo-Synéphrine, Nasal cortisone sprays: Flonase, Nasacort, Nasonex, Eye and Aerosol sprays, Cromolyn, Opticrom, Nasalcrom	Drachenberg *et al.* (2003)

2.8 Medication used to relieve allergic responses to ragweed

Reported treatments against ragweed allergies are listed in Table 4.4. Generally antihistamines are used as the first line of treatment for rhinitis closely followed by corticosteroids for asthma-related responses. Not until the patient is diagnosed for specific allergies and suffering severe effects is specific immunotherapy used, which can be administered parenterally or sublingually. The same treatment programme is followed for all types of pollen, mite, mould and epithelial allergies. The most common medication used is detailed (DuBuske *et al.*, 2008) for Europe and the USA and consists of: Desloratidine, Loratadine, Cetirizine, Monteleukast, Fluticasone, sublingual vaccines, and subcutaneous vaccines.

3 Animal health impacts

There is certainly a perception that ragweed may affect animal health (and associated livestock production) in Europe (e.g. EFSA, 2010). For example, Otto *et al.* (2008) report a survey of 424 lower nature protection agencies in Germany which found out that officials view ragweed as a problem that could affect animal health. However, there is little evidence in Europe, and only five of our national experts reported any information on this subject. In the following we review European information, but add that from other parts of the world, especially North America, to illustrate the potential problems for Europe.

This evidence we review below concerning ragweed as an allergen simply suggests it may affect horses, dogs and cats (it is unclear whether there are effects on livestock) and the types of reactions seen. There is no evidence as to the minimum concentration of pollen to elicit an allergic response, or the distances from ragweed populations at which effects are manifest.

3.1 Impacts on livestock

The nutritional value of ragweed

While it is generally recognised that weeds will effectively compete with forage for moisture fertility and light, the contribution of weed species to overall productivity and quality is not well known. Not all weed species are detrimental to pastures or hayfields. In fact, some weedy plants provide nutritional value to grazing animals (Payne, 2009). Analysis of common ragweed has suggested that it has some nutritional value to livestock. Marten and Anderson (1975) found that pure samples of common ragweed harvested at early stages of growth were comparable to fresh alfalfa (lucerne, *Medicago sativa*) forage in terms of *in vitro* digestible dry matter (DM) (>65), acid detergent fibre (30%), acid detergent lignin (61g/kg DM), and crude protein content (270g/kg DM). Based on field trials conducted in Missouri, USA to investigate the effects of increasing densities of common ragweed in tall fescue pastures, Rosenbaum *et al.,* (2011) concluded that plant biomass yield and nutritive values of the total harvested biomass are only marginally influenced by increasing common ragweed densities.

However, the value of a given forage is influenced by palatability, intake, digestibility and nutrient content. Maturity, crop species, environment, soil fertility and cultivars play key roles in determining forage quality. As the plant reaches full maturity the stems will become more fibrous and digestibility or intake will decrease (Payne, 2009). As is true of grass and legume forage species, the quality of weeds is better during their vegetative stages and will decrease in quality as the plant flowers and matures (Curran and Lingenfelter, 2001).

In the USA it has been shown that cattle tend to avoid consuming common ragweed when possible (Payne, 2009), but it may be eaten when other desirable forages become scarce due to overgrazing or drought. However, in feeding experiments in the USA, the majority of grazing sheep refused to consume mature common ragweed plants (Marten and Anderson, 1975). In Australia (where ragweed is non-native) it is reported that cattle eat the young plants, but may get sore mouths (Simmonds *et al.*, 2000). Palatability is based on a plant and animal function – the grazer's preference to utilize a specific fodder species is determined by the expression of innate and learned behaviour of the animal interacting with the vegetation (Walker *et al*., 1992). A preference to avoid browsing ragweed is attributed to its bitter taste (e.g. Mitich, 1996).

Health impacts

There is little evidence for allergenic reactions of livestock to ragweed. In fact, there are generally few reports of naturally occurring allergies in livestock such as cattle (Gershwin, 2009). The European Food Safety Authority's Panel on the Contaminants in the Food Chain (EFSA, 2010) suggested that cattle (and horses) are believed to be allergic to pollen antigens, but admit that information is lacking.

Common ragweed is widely cited in the North American literature as a potential animal health hazard due to its capacity to accumulate nitrate (e.g. Knight and Walter, 2002; Parish and Rhinehart, 2009; Witt, 2011; Vough *et al*., 2011). Ragweed fruits can cause illness in livestock that ingest it (USGS-NPWRC, 2006). Knight and Walter (2002) report that nitrates are readily accumulated in young ragweed plants, especially in rich fertile soils. Nitrates accumulate in plants only when there is a large amount of nitrate in the soil, or some factor interferes with normal plant growth. High rates of nitrogen fertilization and drought conditions are the most important factors contributing to nitrate build up in plants (Vough *et al.*, 2011).

Nitrates are converted to nitrite in the gastrointestinal tract. Nitrite causes the production of methaemoglobin, a type of haemoglobin that cannot carry oxygen. Thus, the effects of nitrate poisoning result largely from oxygen starvation or, in effect, suffocation. The amount of plant material required to poison an animal depends on the amount of nitrate in the plant and, to a lesser degree, on the rate at which the plant is eaten. Many factors affect toxicity, but in general about 0.05% of an animal's weight of nitrate is near a minimum lethal dose. Poisoning occurs primarily in ruminants (USDA, 2011).

Ruminants have different capacities to convert nitrate into nitrite and finally to ammonia. Sheep have the highest tolerance to nitrates, because they have the greatest capability of all ruminants to convert methaemoglobin back to haemoglobin. Cattle have the lowest capability and therefore are at greatest risk (Yaremico, 2009).

In order to reduce losses the USDA (2011) recommends that high nitrate forage should be diluted with low nitrate forage to decrease nitrate intake, or if there are indications of nitrate toxicity, the feeding of nitrate-accumulating forage should be discontinued. Signs of vitamin A deficiency have been associated with the feeding of low levels of nitrate suggesting vitamin supplements may be useful (USDA, 2011).

The magnitude of animal losses to ingestion of poisonous plants in the United States varies considerably between geographic regions (Poppenga, 2011). However, nitrate poisoning is reported to be a leading cause of livestock poisoning (Forero *et al.,* 2011) and its principal cause is the consumption of nitrate-accumulating plants (USDA, 2011). However, in the UK, the National Disease Information Service describes nitrate poisoning as a 'rare but important cause of poisoning in cattle' that 'can occur as the result of eating crops such as Brassicas, green cereals or sweet clover that contain high levels of nitrate. However, the most common source is inorganic nitrate fertiliser, either directly (straight from an open bag), via grazing an over-fertilised field, or via water run-off from heavily fertilised fields' (NADIS, 2011).

The European Food Safety Authority's Panel on the Contaminants in the Food Chain concluded that there is no evidence that *Ambrosia* species form secondary plant metabolites that are of clinical significance for livestock (EFSA, 2010).

Impacts on livestock yield

In North America, ragweed has also been suggested to reduce milk production and make milk unpalatable and unsuitable for human consumption (Ontario Ministry of Agriculture Food and Rural Affairs, 2011). Mitich (1996) reports that ragweed consumption causes cattle to yield bitter milk with a bad odour.

3.2 Impacts on horses

As for livestock, common ragweed is described as a potential health risk to horses in the USA due to its ability to accumulate nitrates (Witt, 2011).

The European Food Safety Authority's Panel on the Contaminants in the Food Chain (EFSA, 2010) suggested that horses show allergic reactions to ragweed pollen antigens – through allergenic airway obstruction and dermatitis – but no evidence is provided.

There is some, albeit limited, evidence for horse allergic reactions to ragweed in the USA. Pascoe (2007) describes ragweed pollen as a common allergen linked to atopic dermatitis in horses.

Similarly, ragweed was identified as an antigen in a study of the response to immunotherapy in six related horses with urticaria secondary to atopy (Rees, 2001). In Europe, Axiom Allergy Vet (UK) includes ragweed in its 'Weed Panel' when measuring immunoglobulin E (IgE) in horses (as well as dogs and cats) by utilising specific species anti IgE antibodies. This panel is described as containing the 'important grass and weeds allergens of northern and central Europe' and, within the UK, they suggest that ragweed "may be important in southern counties in certain years" (http://www.axiomvetlab.com/Allergy%20brochure.pdf).

3.3 Impacts on pets

As for horses, ragweed is described as an important allergen for dogs and cats by UK-based Axiom Allergy Vet (http://www.axiomvetlab.com/Allergy%20brochure.pdf).

In a personal communication to the Italian expert, Dr Chiara Noli – a veterinarian – reports that the only known reaction of ragweed in cats and dogs is atopic dermatitis, sometimes associated with rhino-conjunctivitis. Allergic reactions to ragweed alone are very rare – no cases were recorded in 15 years of work. Reaction to ragweed is associated with sensitivity to other pollens, moulds and mites. As a consequence, the suggested therapy is the same as for any other atopic dermatitis.

Allergies in dogs are better studied than in cats, partly because the techniques are better developed for the former (Lowenstein and Mueller, 2009). Déchamp and Méon (2005) state that in Lyon about 44% of dogs with pollinosis are affected by ragweed: they develop an atopic dermatitis but no rhino-conjunctivitis or asthma. In Northern Italy, ragweed was the most common pollen allergen – with a 22% prevalence – in 486 intradermal tests performed on atopic (i.e. with a history of allergic dermatitis) dogs (Furiani *et al.,* 2009). A similar study based on 800 tests in 12 Italian regions also suggested the importance of ragweed pollen as an allergen; 43% of treated atopic dogs in Lombardy were affected (Ghibaudo *et al.*, 2009). In the Belgrade region Milčić-Matić *et al.* (2009) found that ragweed extract was second only to house dust mites in causing positive intradermal test reactions in dogs. A positive reaction was observed in 66% of atopic dogs and in 10% of clinically healthy dogs. The Croatian expert reports that dogs show allergic reactions to ragweed, especially in the eastern part of Croatia where the occurrence of ragweed is very high, and reactions include dermatitis, rhinitis and occasionally asthma. However, a study of dogs in Hungary found allergies against grass pollen and dust mites rather than ragweed (Király and Tarpataki, 2001). Veterinarians contacted by the Polish expert stated that no allergic reactions of animals to ragweed have been reported, although this is probably related to the low incidence of ragweed in Poland.

In the USA, ragweed can be a serious cause of allergies in dogs (Knight and Walter, 2002) and ragweed pollen has been determined as a causative factor in seasonal dermatitis (Patterson, 1968). In dogs sensitised experimentally to ragweed, the intradermal injection of allergen results in reactions which are similar to those observed in people with atopic dermatitis (Becker *et al.*, 1988). Beagle dogs sensitised systemically by repeated injection of ragweed antigen develop clinical signs of respiratory disease when challenged by the same allergen via the airways (Day, 2009).

4 Biodiversity impacts

4.1 Ecosystems invaded by ragweed

To ensure accurate and precise information, in summarising the types of areas invaded we consider standard ecosystem types (e.g. ruderal grassland), but also types of human land use (e.g. construction sites).

As might be expected by the fact that it is a fast-growing annual, ragweed tends to be found in ruderal and highly disturbed ecosystems (see also Tasks 1, 2). This is true in the native range of ragweed, where it is found in roadsides and waste land (MacKay and Kotanen, 2008), crop land (e.g. Webster and Nichols, 2012) and urban areas (e.g. Ziska *et al.*, 2003), as well as abandoned fields. In such 'old-fields' ragweed disappears rapidly over time in the absence of disturbance (e.g. Kosola and Gross, 1999; Crowder *et al.*, 2007). Armesto and Pickett (1985) showed that ragweed dominated (90% cover) a 2nd-year fallow field in New Jersey, but was virtually absent (<1% cover) in a 7th-year field, although vegetation removal in the latter allowed ragweed to build up again to 10% cover. In Illinois, ragweed was shown to dominate 1st-year old-fields, but to be suppressed by summer annuals by the second year of abandonment (Raynal and Bazzaz, 1975). These findings suggest that ragweed has an extreme requirement for disturbance. Indeed, although ragweed is occasionally found in more natural habitats in its native range, such as prairies, this is usually only following disturbance (http://www.illinoiswildflowers.info/weeds/plants/cm_ragweed.htm).

In Europe, the ruderal and disturbed ecosystems invaded by ragweed include urban areas and the transport infrastructure, but also agricultural land, including arable fields and their borders, and overgrazed or degraded pastures (Table 4.5). Other disturbed land invaded by ragweed includes cleared forest and dry river beds, France reports the occurrence along riverbanks; this highly disturbed (through flooding and erosion) ecosystem is often the focus of invasions by a variety of non-native plant species (Maskell *et al.*, 2006). The arrival of large quantities of seed in particular locations – for example, through contaminated bird seed – can give rise to transient populations in other ecosystems, although these tend to be anthropogenic: for example, parks and gardens. There is general consensus among the experts and publications about the restriction of ragweed to these disturbed ecosystems.

A few national experts report ragweed in other habitats, and these occur in countries at the core of the current distribution of ragweed in Europe. It is suggested in Hungary that 10-20% of protected annual amphibious communities (i.e. river flood zones), lowland tall herb communities and open sand grasslands are also invaded (Szigetvári and Benkő, 2004; Csecserits *et al.*, 2009). The annual amphibious communities are, by definition, frequently disturbed, and it is likely that the other ecosystems are invaded as the result of disturbances; Szigetvári (2002) studied Hungarian open sand grasslands and reported that ragweed occurrence was strongly related to recent disturbances, and it does not threaten undisturbed vegetation. Anikó Csecserits (pers. comm.) reports an experiment in the Kiskunság region in central Hungary, in which ragweed was only able to invade natural grasslands, natural poplar forests, secondary grasslands, and black locust and pine plantations following soil disturbance (usually ragweed sowing was also necessary); the only invasion without experimental disturbance was in newly-planted forest, which is intrinsically highly disturbed. Invasions of floodplain grasslands are also reported in Moldova (Marza, 2010), while steppic and dry grasslands are invaded in the Ukraine (Protopopova *et al.*, 2006) and Serbia (Boža *et al.*, 2002; Rat *et al.*, 2009). Again, these invasions seem to be related to over-grazing or other disturbances (Protopopova *et al.*, 2006).

Table 4.5. The ecosystems and land use types invaded by ragweed in the countries included in the review, and the UK. The assessments combine the judgement of the national expert – often using information from other local experts – and available literature reviewed by the expert or the project team. Reference publications are given, while unreferenced information represents the expert opinion of the national expert and/or colleagues. The invaded ecosystem types are underlined.

Country	Ecosystems invaded
Austria	Ragweed is mainly distributed in the eastern and south eastern lowlands of Austria (Karrer, 2010), where it is predominantly found on arable land and in the *Atriplicion nitentis* vegetation type (a species-poor community on bare soils exposed due to construction, in settlements, around farms and on road embankments) and ruderal grassland that borders rural and urban roads (Essl *et al.*, 2009; Freundorfer, 2009). Ragweed also occurs in forest clearings, on landfills, gravel pits, and construction sites (Freundorfer, 2009). Transient populations, originating from infested bird feed, establish in urban parks, avenues and gardens.
Belarus	No information
Belgium	In urban, ruderal habitats (Martin & Lambinon, 2008). Transient populations have been recorded along road verges, in port areas (most often near mills and granaries), in gardens, and on waste land (http://alienplantsbelgium.be/content/ambrosia-artemisiifolia-0).
Bulgaria	On road and railway verges, strips between arable fields, and overgrazed pastures (Vladimirov, 2005).
Croatia	Throughout inland and in some coastal areas of Croatia, ragweed is very frequent along transport infrastructure: roads, railways, and canals (Rašić, 2011). In the continental part of the country, ragweed is also very common in ruderal habitats, on arable land, and abandoned land in both urban and rural areas (Milović, 2001; Pandža *et al.,* 2001; Galzina *et al.*, 2010a, b). Over the past 40 years ragweed has become one of the most dominant members of the row crop weed flora (Ministry of Culture, 2008; Galzina *et al.*, 2010a, b).
Czech Republic	Ragweed occurs sporadically and in small populations of a few individual plants in ruderal habitats and the arable weed flora (Týr & Veres, 2008), as well as along roads, around railway junctions, harbours, and seed processing factories (Jehlík, 1998; Mlíkovský & Stýblo, 2006; Láníková *et al*., 2009; Mikulka, 2010). (NB same sources as for Slovakia.)
Denmark	Ragweed occurs only in gardens and ruderal habitats caused by construction work.
France	From its northern periphery in Burgundy and to the Languedoc Roussillon region in

Country	**Ecosystems invaded**
	the south, ragweed is found in arable fields, waste land, roadsides, and riverbanks (Fumanal *et al*., 2006; Faton & Montchalin, 2007; Fumanal *et al*., 2008).
Germany	Small and isolated ragweed stands occur in ruderal and urban habitats throughout Germany. More substantial ragweed populations of more than >1000 plants prevail in three federal states in the north-east, south-west and south-east of the country (Brandes & Nitzsche, 2006; Augustin & Mücke, 2010). In these parts, ragweed is found mainly in ruderal habitats, along roads, around inland ports and in urban areas, although it rarely invades arable land (Alberternst *et al*., 2006; Brandes & Nitzsche, 2006, 2007; Starfinger, 2009; Augustin & Mücke, 2010).
Hungary	Throughout Hungary, ragweed is very commonly found along roads and on construction and building sites. Two reports give estimates of the proportions of different habitats in Hungary invaded by ragweed (Szigetvári & Benkő, 2004; Csecserits *et al.*, 2009). It is suggested that high proportions of ruderal habitats, abandoned fields, and arable land (90%, 90%, and 50% respectively) are invaded, as are 20-40% of forest plantations and clearings. It is reported that ragweed occurs in 10-20% of protected annual amphibious communities, lowland tall herb communities and open sand grasslands, although probably only following disturbance (Szigetvári, 2002).
Italy	Ragweed is associated with arable ecosystems (Mandrioli *et al.*, 1998), but is also found in natural and anthropogenic ruderal habitats, such as dry river beds, reforestation areas, road and railway sides, airports, irrigation channels, as well as construction sites (Pizzulin Sauli *et al.*, 1992; Banfi, 1998; Mandrioli *et al.*, 1998; Alleva, 2009; Berti & Ropolo, 2009; Bonini, 2010; Patracchini *et al.*, 2011).
Latvia	Ragweed is occasionally found in ruderal sites.
Moldova	Ragweed has been recorded in vineyards, orchards, forest ecosystems, on floodplain grasslands and degraded grasslands (Marza, 2010).
Poland	Ragweed is mainly found in ruderal habitats and has been recorded on waste land, along road and railway tracks, and on land surrounding factories that processes commodities imported from the USA (fodder, mill and grain processing factories). It also occurs on arable land. (Karnkowski, 2010)
Romania	Ragweed grows on disturbed grassland, along roads and railways, around quarries, construction sites, urban recreation areas, waste land and arable land (Topa & Boscaiu, 1963; Hodişan *et al.*, 2008; Hodişan & Morar, 2008; Sarbu *et al.*, 2010; Sărățeanu *et al.*, 2010).
Serbia	Ragweed is common in many ruderal habitats of Serbia, especially in arable, vineyards and orchards. It is also found in lowland grassland communities (Boža *et al.*, 2002; Rat *et al.*, 2009).
Slovakia	Ragweed occurs sporadically and in small populations in ruderal habitats and the arable weed flora (Týr & Veres 2008), as well as along roads, around railway

Country	Ecosystems invaded
	junctions, harbours, and seed processing factories (Jehlík, 1998; Mlíkovský & Stýblo, 2006; Láníková *et al.*, 2009; Mikulka, 2010). (NB same sources as for Czech Republic.)
Switzerland	Ragweed plants are frequently found in private gardens (1200 verified cases in 2006) (www.ambrosia.ch n.d.), as well as ruderal sites (road sides, recreation areas, parking lots, gravel pits, industrial areas, and construction sites) as well on pasture and some arable land (Bohren, 2006).
Ukraine	Ragweed is known to invade ruderal habitats, overgrazed grassland, meadow and steppe ecosystems (Protopopova *et al.*, 2006).
United Kingdom	Ragweed is a casual (rarely persisting) on rubbish tips, in dockyards, arable fields, on waste ground and in places where bird-seed is scattered (Preston *et al.* 2002).

Ragweed seems to be able to reach high densities in invaded ecosystems – the Bulgarian expert reports densities of up to 400 plants m^{-2}. Brandes and Nitzshe (2006) report densities of 45 m^{-2} over an area of 507 m^2 at abandoned mill site in Magdeburg, Germany. Korczyński and Krasicka-Korczyńska (2011) found densities of *Ambrosia psilostachya* averaging 55-111 m^{-2}, with a maximum of 186 m^{-2}, in invaded roadsides, lawns and disturbed areas in Bydgoszcz. However, most experts report that there is no information on densities or infestation levels. Although there are few quantitative data, the number of sites invaded by ragweed is generally reported as increasing (e.g. in Austria, Croatia, France, Hungary, Moldova, Serbia), while in some countries it remains restricted to few sites (e.g. in Belgium, Denmark, Latvia) (see also Task 3). Populations can be short-lived in the absence of continuing disturbance (e.g. Vladimirov, 2005). In Switzerland, due to concerted eradication campaigns ragweed is being found in a decreasing number of sites (Bohren, 2006), and controls on ragweed contamination of bird food are expected to cause further declines (www.ambrosia.ch).

4.2 Protected areas invaded by ragweed

There are a few reports of ragweed in protected areas. For Austria, Belarus, Belgium, Bulgaria, Czech Republic, Denmark, Latvia, Moldova, Romania, Slovakia, and Switzerland the national experts report that ragweed has not been recorded in protected habitats. In Serbia, ragweed is reported to have invaded the endangered lowland grasslands of the Pannonian Plain (Rat *et al.*, 2009), although no protected sites are specified.

- In continental Croatia, ragweed is reported (in a personal communication to the national expert from Ms Vida Posavec Vukelic, Head of Section for Flora, State Institute for Nature Protection) as present in almost all protected areas, especially so in four candidate Natura 2000 sites: the Nature Parks Kopacki Rit, Lonjsko Polje, Papuk, and Medvednica. Croatian Nature Parks can contain large areas of agricultural land, abandoned plots and pastures, and it is these areas that are often heavily infested with ragweed. However, there are no records of ragweed impacts on ecosystems of conservation status (Ms Vida Posavec Vukelic; Vuković *et al.*, 2010).

- In the Drôme region of south eastern France, ragweed dominates riverbeds in one CORINE biotope, the Ramières Nature Reserve (Faton and Montchalin, 2007; Périat *et al.*, 2011). Here, ragweed can make up to 100% of the ground cover on the parts of the gravel bed of the river Drôme that are subjected to regular flooding. However, ragweed does not grow in the riparian forest or on the flood plains of this reserve.

- In Germany, a survey of 424 local nature protection authorities reported low-level ragweed occurrence in protected habitats of nine counties, but with little recorded impact (Otto *et al*., 2008). In the early 2000s a severe ragweed infestation occurred in a rare inland sand dune habitat in southern Germany, which was caused by the illegal deposition of seed-contaminated top soil (Alberternst *et al.*, 2006; Brandes and Nitzsche, 2006, 2007; Bayerisches Staatsministerium für Umwelt und Gesundheit, 2011). Over 10,000 ragweed plants threatened the rare and protected *Corynephorus canescens* community (*Teesdalia nudicaulis, Veronica verna, V. dillenii*, etc.), but the ragweed was eradicated by hand weeding over several consecutive years.

- The Hungarian expert reports a personal communication from Dr. Tamás Rédei that ragweed prevails in two protected sites: 1) the Kiskunság National Park which lies in the Great Hungarian Plain and comprises sodic meadows and grazing lands, as well as alkali lakes and ponds; and 2) the Pannonhalmi Landscape Protected Area on the Danube which comprises broad-leaved woodland and steppe grasslands. In the former, it is considered that ragweed is a threat to the tall herb communities of the Hungarian plain (Csecserits *et al.,* 2009) as well as to open sand grassland annuals that are exclusively found in the Kiskunság National Park (Szigetvári and Benkö, 2004; Dr. Tamás Rédei).

- In northern Italy, ragweed has been recorded from numerous protected sites: 15 Sites of Community Interest; four Special Protection Areas for birds; one Natura 2000 site; and one Nature Park (Caramori *et al.*, nd; Checklist flora Parco del Taro; Dal Santo *et al*., 2006; Barrillari *et al*., 2008; Fornasari and Brusa, 2008; Galinaro *et al*., 2008; Buvoli *et al*., 2009; Anonymus, 2010; Bogliani *et al*., 2010a,b; Brusa *et al*., 2010; Fasola, 2010; Mariotti, 2010; Rossi and Campia, 2010; Sparla *et al*., 2010a,b; Carlini *et al*., 2011; Gazzola *et al*., 2011; Malavasi, 2011; Rigoni, 2011). However, the impact of ragweed in these sites is not recorded.

- For the Ukraine, the national expert reports that ragweed is found in the Biosphere Reserves of the Black Sea and Danube but is confined to disturbed ground, track sides and road margins and embankments.

4.3 Impacts of ragweed invasion on biodiversity and conservation goals

Impacts on plant species and communities

The general evidence is that ragweed causes limited conservation problems in Europe. As stated by the Botanical Society for the British Isles – "there is no suggestion that it is of value for nature conservation or poses any threat" (sppaccounts.bsbi.org.uk/content/ambrosia-artemisiifolia.). Because it is associated with disturbed ecosystems, the consensus among many national experts and publications is that it is unlikely that ragweed has detrimental effects on the biodiversity of protected plant communities (e.g. Valdimirov, 2005; Martin and Lambinon, 2008). It is explicitly stated by the national experts – using publications, communication with local experts, and their own expert judgement – that ragweed causes no conservation problems in the following countries: Belgium, Bulgaria, Czech Republic, Denmark, Italy, Latvia, Moldova, Poland, Romania, Slovakia, and Switzerland. However, certain characteristically ruderal ecosystems are of conservation concern, and there is concern that these could be negatively affected by ragweed invasion. Such concerns have been raised for the following countries.

- **Austria**. Several endangered plant species, typical of the segetal (i.e. crop weed) and ruderal communities of the Austrian Pannonian region may in the future be negatively affected should ragweed continue its spread (Karrer, 2010; Austrian national expert).

- **Croatia**. Ragweed is reported to be so frequent in the Croatian lowlands that, along with *Galinsoga parviflora*, it is reported to have "displaced all the indigenous weed species" (Pandža *et al.*, 2001). This competition with native crop weeds is widely reported (Ministry of Culture, 2008; Galzina *et al.*, 2010a,b). However, it is unclear whether this is seen as a conservation issue as the Red Data Book of Flora for Croatia does not consider ragweed as a threat to any protected plant community or species (personal communication to the national expert from Ms Vida Posavec Vukelic, Head of Section for Flora, State Institute for Nature Protection).

- **France**. The invasion of ragweed onto gravel beds of the river Drôme in the Ramières Nature Reserve is reported in negative terms (Faton and Montchalin, 2008; Périat *et al*., 2011), although the precise biodiversity impact has not been specified.

- **Germany.** The single example reported above (Section 4.2) of the impacts of a ragweed introduction on the plants of an inland sand dune illustrates the potentially damaging effects on rare species (Alberternst *et al.*, 2006; Brandes and Nitzsche, 2006, 2007; Bayerisches Staatsministerium für Umwelt und Gesundheit, 2011). However, ragweed is more generally not considered a threat to conservation status flora (Brandes and Nitzsche, 2006; Lütt, 2007; Otto *et al.*, 2008; Starfinger, 2009).

- **Hungary.** Ragweed appears to cause more conservation problems in Hungary than in other parts of Europe. It is reported that it drives out native annual plants in forest clearings and on fallow land (Csecserits *et al.*, 2009). More seriously, it is reported to threaten protected plants such as dwarf and annual amphibious annuals (personal communication from Dr. Tamás Rédei to the national expert; Szigetvári and Benkő, 2004), plants of the tall herb communities of the

Hungarian plain (Csecserits *et al.*, 2009), and open sand grassland annuals that are exclusively found in the Kiskunság National Park (Dr. Tamás Rédei; Szigetvári and Benkő, 2004).

- **Serbia**. The conservation impacts of ragweed are generally unrecorded, but Rat *et al.* (2009) report that ragweed has invaded the fragmented and highly endangered lowland grasslands of the Pannonian Plain and that numerous endemic relict species of conservation status are at threat.

- **Ukraine.** Ragweed is reported to have limited impact on any native or rare flora as the Ukraine's protected sites usually have intact, natural vegetation status. But, in overgrazed steppes, ragweed penetrates even into dense stands of *Festuca sulcata* and disturbs the structure of the diverse herbaceous and feathergrass communities of the steppe habitat (Protopopova *et al.*, 2006).

Negative impacts of ragweed control measures on plant species and communities

It is also reported for two countries that measures to control ragweed on arable land may lead to greater threats to the native segetal flora than competition with ragweed itself. In Germany, herbicide treatment and/or mechanical control measures in these habitats may be be detrimental to segetal weeds, ruderal *Stellarietea* communities, and agricultural *Sisymbrion* associations (Starfinger, 2009; Brandes and Nitzsche, 2006, 2007; Alberternst and Nawrath, 2009). In Hungary, the practice of early stubble ploughing and ragweed eradication campaigns are considered to pose the greatest challenge to the conservation of many segetal weeds (Pinke and Pál, 2009; Pinke *et al.*, 2011b), 41 of which are Red List species (2 of which critically endangered; 4 endangered; 7 vulnerable) (Pinke *et al.*, 2008). The *Stachya annua - Setarietum pumilae* segetal weed association which includes 13 endangered species and provides an excellent food source for honeybees is considered to be under particular threat from such actions (Pinke, 2000; Pál, 2004; Pinke and Pál, 2009).

A related issue is suggested for Switzerland. Here, is found on set asides and field margins managed to enhance biodiversity. About 5-10% of wildflower strips that have been promoted under agri-environment schemes have been invaded by various noxious weeds (Delabays *et al.*, 2005, 2007; Fumanal *et al.*, 2008; Bohren, 2009).

Impacts on other trophic levels: wild animal species and fungi

The concerns described above apply to the plant component of biodiversity. In its native range ragweed is associated with certain animal species. In the USA ragweed provides pollen for honeybees (*Apis mellifera*), the foliage is eaten by certain moth larvae (e.g. Ragweed Flower Moth *Schinia rivulosa*) and grasshoppers, while many birds, squirrels and voles are attracted to the oil-rich seeds (Robel and Slade, 1965; MacKay and Kotanen, 2008; http://www.illinoiswildflowers.info/ weeds /plants/cm_ragweed.htm).

There is little information on the use of ragweed by wild animals in Europe, nor do we know of any reported negative impacts of ragweed invasion on native fauna. Surveys of herbivorous arthropods found the following species to be most common on ragweed in Hungary: sucking insects (bugs) *Eupteryx atropunctata*, *Emelyanoviana mollicula*, *Philaenus spumarius* (Auchenorrhyncha), *Brachycaudus helichrysi*, *Aphis fabae* (Aphidoidea), *Lygus rugulipennis, Adelphocoris lineolatus* (Heteroptera); the chewing beetle *Longitarsus pellucidus* (Chrysomelidae, Alticinae); and the stem boring beetle *Agapanthia dahlia* (Cerambycidae) (Kiss *et al*., 2008; Kiss, 2009). In glasshouse and field studies in Hungary, Basky and Magyar (2008) showed that the native aphid species *Aphis fabae, Brachycaudus helichrysi* and *Myzus persicae* could all form colonies on ragweed. There are also reports of fungal pathogens on ragweed in Hungary (Bohár and Kiss, 1999; Farr and Castlebury, 2001), and two species have caused epidemics on ragweed: *Phyllachora ambrosiae* (Vajna *et al.,* 2000) and *Plasmopara halstedii* (Vajna, 2002). Genton *et al.* (2005) showed that invasive populations of ragweed in France were attacked by herbivores (mostly generalist aphids and grasshoppers) and white rust fungi (possibly *Albugo tragopogonis*). In accord with the Enemy Release Hypothesis that non-native plants benefit by escaping their native, co-evolved herbivores and pathogens, the French populations showed less herbivore damage, and had a much smaller range of herbivorous species compared to ragweed populations in Ontario.

Is ragweed a passenger rather than a driver of change?

MacDougall and Turkington (2005) suggested that there are two primary pathways to dominance by invasive non-natives: 1) superior access to limiting resources by competition or 2) limited susceptibility to processes that constrain resident species. Thus, the 'Driver Model' states that changes in biodiversity or other changes are caused by the invasive species itself. The 'Passenger Model' suggests that an invasion is caused by anthropogenic environmental change – such as disturbance or eutrophication – and thus invasive species can be mere passengers increasing in abundance in response the altered environment. There is evidence for both models from different case studies, and subtle variations on these models have been proposed (Chabrerie *et al.*, 2008; Bauer, 2012).

The evidence for ragweed impacts on biodiversity suggest that it may be a passenger, riding on habitat degradation or disturbance, rather than being a true driver of community change. Thus, ragweed is most often found in highly ruderal ecosystems and, where it invades other ecosystems, this seems mostly in response to anthropogenic disturbance, such as overgrazing of grasslands, or vehicular tracks through important ecosystems. Appropriate management of these latter ecosystems should reduce ragweed invasion and its habitats. The greatest threat, therefore is to ruderal communities of conservation concern; such as rare segetal weed floras, floodplain communities, or open sand grassland. Such ecosystems are characterised by their dependence on disturbance and so are particularly susceptible to ragweed invasion.

5 Impacts on the wider environment

5.1 Ecosystem service impacts of ragweed

A range of possible wider environmental impacts of ragweed were considered in terms of ecosystem services (see section 1.2). Other sections consider specific ecosystem services affected by ragweed in Europe: human health and wellbeing (Sections 2, 3); provisioning through agriculture and horticulture (Sections 3, 6), and human activities (Section 7). The work by the national experts and our review of the literature produced no evidence of impacts on other ecosystem services. This is partly due to a lack of studies on such other possible impacts, but may also relate our suggestion that ragweed follows the 'passenger' model of invasion (section 4.3). Thus, its invasion of ecosystems is a response to environmental change (i.e. disturbance) rather than a cause of such changes. Indeed, a recent meta-analysis of the ecological impacts of invasive alien plants (Vilá *et al.*, 2011) reported no studies on ragweed.

Related to the potential biodiversity impacts of responses to ragweed infestation (section 4.3), chemical ragweed control in the agro-ecosystems of eastern Croatia (Baranja) is considered likely to affect water provision and soil fertility (Rašić, 2011).

6 Impacts on agriculture and horticulture

In the following review we analyse the detailed returns from the national experts and publications on ragweed as a crop weed in Europe. We use studies from other parts of the world where these give relevant extra information.

6.1 The status of ragweed as an agricultural weed in Europe

Ragweed is a serious crop weed problem in its native range (e.g. Webster and Nichols, 2012), and there is increasing evidence of its impacts as a weed in European agricultural and horticultural crops. This effect is generally attributed to high growth rates and competitive ability in open conditions, although it may be attributed to other traits such as allelopathy (Task 2). The returns from the national experts detailing the impacts of ragweed as a crop weed (Table 4.6) generally matched the known distribution of ragweed in Europe (Task 3). For example, the no/minor status for Latvia, Belgium and Denmark reflect their low infestations. A nil return from Bulgaria is more surprising although ragweed is poorly recorded in this country. The Bulgarian expert explained that the "distribution of *Ambrosia artemisiifolia* in Bulgaria show[s] its presence mainly in disturbed plots along roads, railroads, cultivated fields (but very rarely inside the fields)."

Table 4.6. A summary of the assessments by the national experts as to whether common ragweed causes serious, moderate, minor or no problems as an agricultural weed in their region.

Country	**Assessment of weed status**
Austria	Serious
Belarus	No-Minor
Belgium	Minor
Bulgaria	No
Croatia	Moderate–Serious
Czech Republic	Minor
Denmark	No
France	Serious
Germany	Minor
Hungary	Serious
Italy	Serious (locally)
Latvia	No
Moldova	Minor
Poland	Minor
Romania	Moderate–Serious
Serbia	Serious
Switzerland	Minor (locally severe)
Ukraine	Serious

The most seriously affected countries include the following, and some statements from the national experts (based on review of publications and personal communications from relevant experts) provide further information on the extent of the problems.

Austria. An agricultural weed in eastern Austria (parts of Upper and Lower Austria, of Vienna, of Carinthia, major parts of Styria and almost the entire Burgenland), but its distribution is patchy. In Styria ragweed is widely spread, but only in the warm and humid south is it very common. Here it builds huge populations.

Croatia. Ragweed is among the ten most frequent weed species in inland Croatia, rising from the tenth most frequent in 1979, to second place in 2009. Within annual broadleaf weeds, common ragweed rose from fifth to first place over the same period, and was present in 75% of the investigated area (Galzina *et al*., 2010b).

France. A serious problem in Rhônes-Alpes, Poitou-Charente, and Bourgogne.

Italy. Reported as a serious problem in the Lombardy and Emilia Romagna regions, and the Milano Province where 13,000 ha of crops were reported as affected in 2005 (Bonini and Colombo, 2005).

Hungary. A serious weed over the whole country, particularly in Somogy, Baranya and Szabolcs-Szatmár-Bereg counties (Dancza *et al.*, 2006). In 2003 ragweed occurred on 5.4 million ha of crops, of which 700,000 ha were heavily infested (Tóth *et al.*, 2004). It is described as the most important arable (Novák *et al*., 2009) and noxious (Pinke *et al.*, 2011a) weed in Hungary.

Serbia. Ragweed is a serious weed over the whole of Serbia and has most impact in the territories of Vojvodina, Mačva, Drina, Šumadija and valleys of major rivers (Vrbničanin and Malidza, 2008).

Romania. A serious problem in north-western Romania, but more moderate impacts in eastern Romania.

Ukraine. A serious weed over the whole of the Ukraine. In 2011, the area of arable land where ragweed occurs amounted to some 3,726,000 ha.

6.2 The crops most susceptible to ragweed invasion

Row crops would appear to be the most susceptible to ragweed invasion in Europe, with sunflowers and maize as the main crops affected, being mentioned in 11 returns from the national experts. Soya beans and potatoes were a close joint third, being mentioned in seven returns. These assessments are supported by published accounts. For example, Pinke and Karácsony (2010) found ragweed to be the most common weed in a survey of sunflower crops across Hungary, with an average cover of 10%. Furthermore, an analysis of ragweed distribution among 243 arable fields in Hungary showed the most important determinants were crop type and cover, with highest abundance in sunflower fields and with low crop cover (Pinke *et al*., 2011a). Týr and Veres (2008) report the main crops infested in Slovakia are maize, sunflower, and soya, and Galzina *et al.* (2010b) report that sunflower crops are infested. All these crops are characterised by being precision or conventionally drilled/planted using wide (30 cm) row spacing, which provides regular spacing of crop seeds, but also allows room for weeds to grow in between where there is bare ground before the crop begins to fill in the gaps. Sunflowers are in the same family as ragweed (*Asteraceae*), which means that there are few agrochemicals which can differentiate between crop and weed, rendering control difficult (Kukorelli *et al.*, 2011). Ragweed infestation in sunflower grown for bird feed exacerbates the weed's spread through distribution of the seed in birdseed mixtures (Task 1).

Other crops cited include peas, sugar beet, small grain crops (wheat or barley), tobacco, pumpkins, beetle beans (*Phaseolus coccinius*), Sudan grass grown as fodder, sorghum, oilseed rape, vineyards, orchards and field vegetables. It was also recorded on land in set-aside or left fallow, as well as in cereal stubble (see also Týr and Veres, 2008; Galzina *et al.,* 2010b). Pinke *et al.* (2011a) report ragweed as a minor weed of poppy (*Papaver somniferum*) crops in Hungary.

These results are similar to those found in the USA, where ragweed is most serious as a weed in maize, soya and cotton (Byrd and Coble, 1991; Kruger *et al.*, 2009). Genetically modified Roundup-Ready (glyphosate tolerant) versions of these three crops are widely grown, although it is widely reported that ragweed is building resistance to glyphosate in nearly all US states (Brewer and Oliver, 2009).

6.3 Which cropping systems and other conditions enhance ragweed problems?

As discussed above, the crop type and cover seem most important in determining the impact of ragweed as a crop weed. Other factors are poorly studied. Pinke *et al.* (2011a) showed higher ragweed abundance in Hungarian arable fields with sandy or acid, and nutrient rich soils. Also in Hungary, a comparison of an organic *vs* a conventional farm showed higher ragweed abundance in the former (Zalai and Dorner, 2010); a finding which is to be expected as herbicides are the main control against ragweed (see section 6.5).

6.4 Crop yield (and other) losses resulting from ragweed infestations

Returns from the national experts and other literature showed substantial effects of ragweed on crop yield. Other effects were minor and were mentioned infrequently. These potential (i.e. unsubstantiated) other effects included honey contamination (Hungary), grain export problems into Russia and the Ukraine because of ragweed seed infestation (France), and transfer of ragweed seed by contractor machinery between France and Switzerland (Switzerland).

Where it occurs, ragweed can be a dominant part of the weed flora – as reported in Hungary (Pinke and Karácsony, 2010) and Croatia (Galzina *et al.,* 2010a). There is less information on yield losses, and for many crops the national experts report no quantitative data. The most comprehensive information comes from the Ukraine where a national programme to locate and eliminate ragweed by 2017 was set up in 2011 (Table 4.7).

Table 4.7. Reported yield losses in 2010 within the 3.7M ha of the Ukraine (from the national expert report) infested by ragweed

Crop	**The area of this crop affected by ragweed (ha)**	**% yield loss in infested fields**
Cereals and legumes	1,733,600	60
Maize	161,700	65
Sunflower	1,071,800	61
Soya	37,500	41
Rape	54,800	70
Sugar beet	4,050	82

A number of trials were reported from western Hungary and these are tabulated (Table 4.8). Another trial reported a maize yield loss of 0.235 t ha^{-1} for a ragweed population of only 1 plant m^{-2} (Varga, 2002). Our literature search found other studies. Another small-plot experiment (Dávid and Kovács, 2008) showed no effect of ragweed on maize yield, which was explained by the late emergence of ragweed (compared to large yield losses caused by other major weeds jimsonweed

Datura stramonium and cocklebur *Xanthium italicum*, which emerge earlier). In a sugar beet field, plots infested naturally with ragweed at 2-5 plants m^{-2} had 40-50% lower yield by weight with 13-15% lower sugar content than plots with no ragweed; resulting in an average 50% loss of sugar yield (Bosak and Mod, 2000). These losses to ragweed were greater than to fat hen (*Chenopodium album*) or velvetleaf (*Abutilon theophrasti*), which caused about 30% losses at similar infestation densities.

Table 4.8. Yield losses caused by ragweed in a variety of experiments in western Hungary

		% Yield loss			
		Sunflower[1]	Sunflower[2]	Maize[2]	Maize[3]
Ragweed density Plants m^{-2}	1	7	4	24	
	2	11	6	33	
	5	25	21	30	
	10	37	33	30	
	9				42
	18				52
	26				62

[1] Varga *et al.,* (2006)
[2] Kazinczi *et al.,* (2007)
[3] Varga *et al.,* (2000)

In an experimental study in maize fields in Germany, ragweed densities of 2 and 8 plants m^{-2} led to yield reductions of 9% and 32% respectively (Zwerger and Eggers, 2008). The website www.halt-ambrosia.de reports that the presence of ragweed in German fields can lead to a severe reduction in yield; losses of up to 73% in maize, 50% in sugar beet and 70% in beans have been reported, but these figures are not based on trials.

France reports that infestations can be as high as 1,000 plants m^{-2} in the Drôme department and this can lead to losses of between 20-80% for sunflower, 9% for sorghum, 4.5% for rapeseed, 1.5% for maize, and 50% of wheat stubbles (Bruzeau, 2007).

Austria reports “very important”, but unquantified, yield losses in pumpkin, soya and beetle bean because ragweed is difficult to control in these crops. Impacts on sunflower crops are reported to vary; they can be severe as ragweed is difficult to control in sunflower crops, but it is also suggested that sunflower competes well against ragweed. Maize and cereals (both winter and summer) are important by area, but ragweed can be controlled comparatively easily by herbicides. Ragweed is considered to be less important in sugar beet because of the crop rotation.

Data from other experimental trials across the world are limited for ragweed, and should be taken only as illustrative of relevant issues given the differing climatic conditions and cropping practices. An experiment in Ontario using a range of ragweed densities (0, 0.5-32 plants m^{-2}), showed strong impacts despite the fact that ragweed emerged after the crops (Weaver, 2001). Yield losses were high, but varied among years depending on the summer weather (smaller effects in very hot summers); at high ragweed densities, maize yield was decreased by 20-60%, and soya by 65-70%. Work in Ontario on white beans (*Phaseolus vulgaris;* note that white beans are not widely grown in Europe) illustrates the importance of the timing of ragweed emergence for its effect on yield (Chikoye *et al.*, 1996). Losses were 10-22% when 1.5 ragweed seedlings per metre row emerged with the crop, and 4-9% losses when the same weed population emerged at the 2 trifoliate leaf stage of the bean crop.

Also in Ontario, Cowbrough *et al.* (2003) attempted to measure economic thresholds for infestations of ragweed in soya crops. Trials were carried out over two years in 1999 and 2000 and the results showed big differences between the two years. In 1999 the economic threshold was 0.17 ragweed plants m^{-2}, in 2000 it was 0.49. It is, at present, impossible to provide a definitive model of economic thresholds of infestation, according to crop type, yield and price, as there are insufficient data. The data summarised above show a strong effect of ragweed on yield of various crops across Europe. More replicated, randomised trial work is needed on specific row crops (sunflowers, maize and soya in particular) before these models can be reliably produced. These should be multi-factorial encompassing not just infestation levels, but also time of emergence of weed compared with crop.

6.5 Ragweed control measures in crops

As demonstrated in the previous section, a large part of the impact of ragweed on particular crops is determined by the ease of control. For some crops like sunflower, there seem to be few, if any, effective herbicides against ragweed (e.g. Kukorelli *et al.*, 2011). Therefore, we consider the ease of ragweed control in crops here, although broader aspects of control are covered in Task 7.

There are a number of options for weed control in crops. The most obvious is the use of chemical herbicides, and these are widely used on ragweed in Europe (e.g. Bohren *et al*., 2008; Knežević *et al.*, 2008). Chemical control strategies are described in the Euphresco project AMBROSIA (Buttenschøn *et al.*, 2009). The best spray strategy was a one spray application at the 4-leaf stage of the weed, with no difference between the active ingredients: mesotrione (Callisto, Syngenta), clopyralid (Lontrel, Dow), MCPP (mecoprop, various) and florasulam (Boxer, Dow). However, it was suggested that a two spray sequential programme may give better results in less than ideal seasons. Resistance to several herbicides is reported in North America (e.g. Saint-Louis *et al.*, 2005; Chandi *et al.,* 2012), and atrazine resistance has been reported in Europe (Cseh *et al.*, 2005). Glyphosate seems the most effective herbicide in Europe (e.g. Delabays *et al.,* 2008), and outside the EU the most obvious chemical control is the use of glyphosate on Roundup-Ready varieties of the main arable crops. This is widely used in the USA and South America. However, ragweed resistance to glyphosate is increasing and there is doubt as to how long the technique will be effective for *Ambrosia* spp. (Hurley *et al.*, 2009; Kruger *et al*.*,* 2009). The additional use of Best Management Practices (BMPs) for weed control to overcome weed resistance is increasing costs in the USA in cotton, corn and soya crops. BMPs involve more frequent crop scouting (walking), cultivations, cleaning of equipment between fields, use of full rate glyphosate and early control when the weeds are at their most susceptible (Hurley *et al.*, 2009).

A more diverse and integrated armoury is possible for controlling ragweed in crops, which includes cultivations, cultural control and biological control. In Europe, using no or minimum tillage seems to encourage ragweed compared to conventional cultivation (Zimmer *et al.*, 2001; Lehoczky *et al.*, 2009). Cultivations could include the use of inter-row and inter-plant hoeing which, with modern precision farming technology, can be done quickly and accurately within crops. It could also include the use of false and stale seed beds, cultivations on bare or fallow ground, and weed combing in non-row crops.

Cultural control includes the use of rotations or crop sequences to provide a varied competition habitat for the weed. For example, the use of high biomass crops such as oilseed rape can shade out weeds to such an extent that they do not survive the season. It could also include the use of green cover crops during periods of potential bare ground e.g. between the harvest of one crop and the sowing of a following spring crop. This gives more competition for the weed during winter. It may also mean a careful choice of crop varieties to ensure growth characteristics which give maximum shading of weeds e.g. wide leaves, non-erect leaves in maize. The cost of establishing green cover crops will be the seed costs plus any cultivation required. Variety choice may have a cost implication depending on seed availability and age of variety.

Biological control of ragweed has been implemented successfully in Australia (Gerber *et al*., 2011) and China (Zhou *et al.*, 2011), but is in its infancy as a technique in Europe (Kiss, 2007; Bohren *et al.*, 2010; Gajnik and Peternel, 2009). Gerber *et al.* (2011) identified possible biocontrol agents for use in Europe; six insects and one fungal pathogen species as potential agents in non-farmed areas, and for arable fields identified a defoliator leaf beetle, *Ophraella slobodkini*, and a fungus, *Septoria epambrosiae*. In Croatia, it is stated that the ragweed leaf beetle *Zygogramma suturalis* has been introduced (Igrč *et al.,* 1995; Maceljski, 2003), but it has failed as a biocontrol agent for ragweed in Russia (Reznik *et al.,* 2008).

7 Impacts on other sectors

7.1 Impacts on transport, construction and tourism industries

We considered possible impacts of ragweed on relevant industries other than agriculture (see Section 6). The transport and construction industries are relevant because transport infrastructure and land cleared for construction activities are susceptible to ragweed invasion, which might affect activities directly (e.g. by restricting access by the workforce or the public to protect them from allergens) or indirectly (e.g. by control measures causing a constraint on activities). Tourism was considered another relevant sector as visits by tourists might decline if a popular site or region becomes infested.

The national experts and our literature review produced no evidence of ragweed impacts on the construction or the transport sector. This is generally reported as a lack of information, but the general perception is that there are no effects. In Switzerland, the discovery of ragweed stands must be reported and authorities provide detailed guidance for the eradication of the plant. At building and construction sites in Switzerland, substantial ragweed stands are to be treated with herbicide at the end of August, and any excavated soil must be reused on the same site or has to be disposed of in refilling a gravel pit (Canton of Zurich plant protection services http://www.strickhof.ch/ fileadmin/strickhof_files/Fachwissen/pflanzenschutz/ambrosia/Ambrosia-Verantwortliche_Gde_2010.pdf). However, the Swiss national expert reports that no data exists on how these ragweed eradication measures impact on the construction industry.
The Austrian expert suggests that allergic rhinitis or contact dermatitis caused by ragweed could in future have a detrimental impact on tourism. Several municipalities in eastern Croatia (Osijek, Poreč, Istria) where ragweed infestation levels are high are aware that tourism may be affected (Strategic Plan for Health in Osijek-Baranja County www.zdravi-grad-porec.hr/program_ekolosko zdravstveni. php, accessed Sept 2011).

8 Conclusions: Evidence for current and future impacts

The review methodology provided a comprehensive assessment of the impacts of ragweed in Europe. We concentrated on current impacts, but use of studies from outside Europe and expert opinion allowed us to consider how impacts might develop in the near future; Tasks 5 and 6 do the latter more formally.

As expected, the evidence is that the most important impact of ragweed in Europe is on human health, with allergic responses comprising rhinitis, hayfever and, less commonly, dermatitis and asthma. There is good quantitative evidence for ragweed health impacts. Amongst the European population showing allergies in general, the incidence of ragweed allergies varies strongly among regions and among studies. The most comprehensive study suggests that the incidence of ragweed allergy ranges widely from 2-50% of the allergic population. However incidence varies among different cohorts, with children and urban populations most affected by pollen allergies. The evidence is that roughly 25% of the European adult population shows general allergic rhinitis. However it would be too speculative to combine these figures to suggest the proportion of the European population with ragweed allergies, especially as exposure varies greatly. Ragweed does seem to be a particular problem as its pollen: is highly allergenic; causes allergic reactions at relatively low concentrations – about 5-20 pollen grains m^{-3} of air; and can be transported by air masses 100s of km. However, allergic reactions to ragweed are treatable by the same medications as used for other pollen allergies in Europe.

Evidence for animal health impacts of ragweed is much poorer and this is probably due to a lack of studies, as the available evidence suggests there could be widespread allergic reactions for pets, and to a lesser extent horses. Studies in the USA report widespread allergies amongst animals. Dermatitis caused by ragweed is reported for dogs and cats in Europe and the USA, and there is some limited evidence in the USA for dermatitis in horses. It is unclear whether there are effects on livestock, which may suffer more by grazing ragweed, which is known in North America as a potential animal health hazard due to its capacity to accumulate nitrate.

The second aspect for which there is strong evidence of ragweed impacts is as an arable weed, although the quality of evidence varies among countries. In most of the countries in which it is widespread and in large numbers, ragweed ranks amongst the most serious agricultural weeds. It infests arable crops at high densities, with row crops appearing to be the most susceptible. Sunflower is the most affected, especially as its close relationship to ragweed limits the herbicides that can be used. Other susceptible crops include maize, potatoes and soya bean, as well as peas, sugar beet, small grain crops, tobacco, pumpkins, various legume crops, sorghum, oilseed rape, vineyards, orchards and field vegetables. Yield losses can be very high; figures depend on infestation levels and success of control, but losses of >>50% are reported. Ragweed is much less important as a pasture weed, where it generally indicates overgrazing.

In contrast, the evidence suggests that ragweed causes limited problems for biodiversity in Europe. There is a lot of evidence from surveys and observations that report ragweed is mostly confined to ruderal and highly disturbed ecosystems, especially those created by humans, such as urban areas and the transport infrastructure, cleared forest, arable land, and degraded pasture. Semi-natural habitats invaded by ragweed in Europe also tend to be disturbed, either naturally – e.g. dry river beds or flood plains – or through human activity – with examples of tall herb communities, sand and steppe grasslands reported. A few protected areas have been invaded, but this is again linked to human activities. Species of conservation concern are generally not suggested to be at risk from ragweed, although it is assumed that ragweed may threaten certain scarce or rare plants associated with ruderal communities, such as rare crop weed associations, or annually flooded communities. This assessment is based on good evidence and counters fears expressed in some papers and by some of the national experts that ragweed could damage biodiversity. Our assessment supports the EFSA conclusions that there is no direct evidence that ragweed causes species extinctions (EFSA, 2010). This fear may be explained by a general antipathy of conservationists toward non-native species even when there is no objective evidence for harm (Manchester and Bullock, 2002). Indeed, we speculate that ragweed may be classified as a passenger, riding on habitat degradation or disturbance, rather than being a true driver of community change.

While we found good evidence for harm to human well-being and agricultural production, we found no indication of ragweed affecting other ecosystem services or the wider environment. There have been no studies of such impacts either in Europe or in its native range, so we may simply lack evidence. However, many national experts suggested there are no such impacts. Indeed, as ragweed invades disturbed systems, we might hypothesise that direct effects on the wider environment are unlikely; this relates to our suggestion that ragweed follows the 'passenger' model of invasion in that it responds to environmental change (i.e. disturbance) rather than causing changes.

Similarly, no evidence was found for ragweed impacts on the construction or the transport sector in Europe and no such effects have been reported elsewhere either. Again, this reflects a lack of information, but the general perception from the experts is that there are no effects. However, since the travel infrastructure and building sites are highly suitable for ragweed invasion, and ragweed is regularly reported from such disturbed sites, one might expect there to be detrimental impacts by the invasive.. It would certainly be worth maintaining vigilance in these sectors to detect any future effects. It also speculated – although there is no evidence – that human allergic reactions to ragweed could in future have a detrimental impact on tourism by dissuading tourists from visiting infested regions, and it would also be advisable to remain alert to this potential problem.

In the future, as ragweed increases its range in Europe (Task 3) and moves into new regions under future environments (Task 6), its impacts are likely to increase. Adverse effects on human well-being and economic activities (e.g. agriculture) will grow simply as a larger area of Europe becomes invaded by ragweed (see also Task 5). However, other more subtle processes may also come into play. As reported in Section 2, evidence suggests that the incidence of allergy to ragweed is increasing in Europe – in line with higher ragweed abundances, poorer air quality, and the general rise in the incidence of allergies. Climate change may also exacerbate ragweed allergies by increasing pollen production and extending the pollen season. We also recommend that vigilance is maintained concerning biodiversity impacts. As ragweed invades new biogeographical regions with different habitats, communities and plant species, these may show greater susceptibility to ragweed impacts. Admittedly, this is a low risk due to the dependence of ragweed on disturbance.

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Task 5: A quantitative and costs analysis of the impacts of ragweed, based on the countries most affected within and beyond the EU

1 Introduction and approach

1.1 Background

This chapter presents economic evidence compiled to build on the findings from Task 4 and construct an economic model of the current and predicted future impacts of *Ambrosia artemisiifolia* in the study area (which covers the EU27 and adjacent countries: Albania, Belarus, Bosnia and Herzegovina, Croatia, Kosovo, Macedonia, Moldova, Montenegro, Norway, Russia, Switzerland, Turkey, Ukraine). In combination with spatial modelling (see Task 6), this economic modelling is then used to estimate these economic impacts. The results are presented in aggregate, and by main impact area (human health, agriculture and monitoring and control) for current impacts and expected impacts in 2032. We selected 2032 as a target date (20 years hence) in the near future by which time we estimate that control strategies against ragweed might have had an effect and climate and land use change might have begun to affect ragweed.

1.2 Approach

The rest of this section summarises the approach taken to this analysis. This chapter then reports on a literature review on the economics of invasive species and the limited sources on economic impacts of *A. artemisiifolia* in the study area. It then looks at the costs and assumptions related to monitoring and control (Section 3.1). Different control strategies are a variable in the analysis of the different impacts of *A. artemisiifolia* in Sections 3.2-3.7, including the key areas of human health impacts in Section 3.2, and agricultural impacts (Section 3.5). Section 4 discusses gaps in the evidence available.

Despite these gaps, economic modelling of the impacts of *A. artemisiifolia* has been possible as described in Section 5. The results of this modelling are presented in Section 6. In Section 7 sensitivity analysis of key assumptions is reported and Section 8 gives conclusions of the work.

To provide economic data to support policy-making in relation to *A. artemisiifolia*, we carried out a detailed analysis of the different costs arising from the effects of *A. artemisiifolia* identified under Task 4, in relation to the distribution of *A. artemisiifolia* established in Task 3 and modelled in Task 6.

The aim of this work was to be able to estimate (possibly in broad ranges):

A. The current costs of ragweed impacts in the study area.
B. Future costs of ragweed impacts in the study area in 2032 with no controls.
C. Costs of a possible control strategy.
D. Future costs of ragweed impacts in the study area in 2032, with a control strategy implemented.

These estimations allow comparisons of potential actions (e.g. are the costs of a control strategy less than the benefits of impacts it could mitigate?), which can support conclusions on appropriate strategies for managing *A. artemisiifolia* and its economic impacts.

In this context costs are defined as both the value of financial costs and losses of value to humans, with 'value' understood from an economic perspective to include all welfare changing impacts, expressed in monetary terms where possible. Therefore, the purpose of Task 5 is to provide an analysis that translates the impacts of *A. artemisiifolia* identified in this project into economic terms. Expressing impacts in standardised monetary units enables comparisons of the different effects of *A. artemisiifolia*, both with each other and with other concerns in society. In combination with predictions of the future distribution of *A. artemisiifolia* and human activities, it also allows anticipation of the potential economic impacts of *A. artemisiifolia*. Together these inform planning of cost-effective responses to preventing and controlling the spread and/or impacts of *A. artemisiifolia*.

The overall approach adopted by the work to assess economics impacts has involved iterations of information between this Task and other Tasks. Economic analysis of *A. artemisiifolia* will only be as accurate as the impact information it is based on.

Task 5 has been undertaken through the following actions:

- Identify search mechanisms and potential sources of information (including costs from common ragweed research, and cost data in relevant impact areas; a-e in Task 4)
- Conduct review of scientific and grey literature and other sources of information (English language)
- National experts identify costs data in scientific and grey literature and other sources of information relating to/available in their countries
- Collate economic evidence on costs of effects of ragweed
- Assess gaps in costs evidence
- Use an analysis framework to calculate costs of effects of ragweed

The different impacts of *A. artemisiifolia* identified for Task 4 and therefore considered for economic analysis were:

- Human health;
- Animal health;
- Biodiversity and effects on the wider environment;
- Agriculture and horticulture production systems;
- Other relevant economic sectors (such as tourism);
- Transport and building infrastructure, which has been further subdivided as;
    - Control activities, and

- Administrative costs of national and local planning and management of *A. artemisiifolia* monitoring and control activities.

Some of these areas (e.g. administration costs) were not identified in the original project plan, but were highlighted in information inputs made to the project from infested countries. They include the costs of commissioning the collection and collation of data on the presence of *A. artemisiifolia*, and the development of eradication and/or control strategies. The direct research for economic data has been targeted to support the delivery of the analysis framework. This requires a wide range of different types of valuation and cost information. This necessitated looking for information from a large list of potential sources to cover all information needs.

2 Economic impacts of invasive species

This section presents the result of the review of literature and analysis is aimed to identify cost data that is relevant to the impacts identified in Task 4. It brings together supporting information and data that give useful context and information to construct an analysis of the effects of *A. artemisiifolia*.

An extensive literature exists on the economic impacts of invasive species. The economic impacts of invasive species have been felt on all continents, and in the majority of ecosystems; the most easily identified costs associated with invasive species are the costs of eradication efforts, which have been documented in marine (e.g. Holt and Cordingley, 2011), island (e.g. Stoneman and Zonfrillo, 2005), freshwater (Ciruna *et al*. 2004), forest, montane and open-habitat ecosystems (Stutzman *et al* 2004).

Various studies on the economic costs of invasive species have been produced. They estimate very significant costs, often of the order of €10s millions to €billions at national or regional (sub-continental) levels. For example, in the UK, the current annual cost of all (marine, aquatic and terrestrial) invasive non-indigenous species is approximately £1.7 billion (approximately €1.9 billion) in total (Williams *et al*, 2010); although these costs refer almost exclusively to controlling invasives. Invasive agricultural weeds can generate a substantial part of these costs. For example, the impacts of invasive weeds on agriculture in Australia are estimated at approximately €2.61 billion to €3.36 billion annually (Cacho *et al.,* 2008).

The impacts from invasive species extend to human health, production standards, access to overseas markets, a population's sense of security, cultural identity, and native biodiversity (Emerton and Howard, 2008). Economic analysis of these effects has lagged behind the environmental effort put into analysis of invasive species management (Perrings, 2001). However, recent literature demonstrates greater economic engagement in the problem. Kettunen *et al.* (in Shine *et al.*, 2011) report documented monetary impacts of invasive alien species (IAS) in Europe amounting to a total of €12.5 billion/year. The majority of these costs, (€9.6 billion) result from the damage caused by invasive alien species, whereas the rest are related to their control. They state that: "*available data on IAS monetary costs remains scarce and unevenly distributed between different geographic areas* *and IAS taxa. Consequently, in reality the costs of IAS are probably significantly higher than the estimated 12 billion EUR/year*".

In recognition of the need for including economic considerations in invasive species management the IUCN produced a Toolkit for the Economic Analysis of Invasive Species (Emerton and Howard, 2008).

The IUCN toolkit provides a number of useful pointers for the economic analysis in this study:

- It describes a wide array of impacts that invasive species can give rise to, ranging from effects on production systems (such as forestry, fisheries and agriculture), through development systems (such as water supply and quality, infrastructure and energy), human health and biodiversity, to the physical needs to manage and respond to invasions and mitigating the threat of invasions. This categorisation matches the areas of analysis (a-e; see Task 4, Section 1) identified for this research, with the exception of management and response of invasions (Tasks 7, 9). This has been added to the list of issues covered.
- It defines direct and indirect economic impacts of invasives: direct production impacts arising from the effects of the invasive species on the host ecosystem; and secondary and tertiary effects on other sites and sectors in terms of markets, prices, health, nutrition, trade, the environment and public and private spending. Both direct and secondary effects are covered in this analysis.
- It is also possible to define tertiary economic effects of invasives – such as those occurring due to associated shifts in consumer demand, and changes in the relative price of inputs. These changes affect not just the site or sector where an invasion has taken place, but spread across other parts of the economy, including reductions in land rental prices, profits, tax revenues, foreign exchange earnings, employment, food security, human health and an increase in livelihood vulnerability. These effects will be considered in this study, but they may be difficult to assess and hence may not always be covered.
- It also defines potential benefits of invasives. These perceived benefits (e.g. potential for commercial profit from farming of a species) are reflected in the motivations for deliberate introductions (e.g. Gozlan and Newton, 2009). As the arrival of *A. artemisiifolia* in Europe is believed to have been accidental (e.g. arriving in contaminated grain supplies; see Task 1) and no benefits are reported, these arguments are not considered relevant to this analysis.
- Detailed economic analysis of the effects of invasives relies on the specification of a series of dose-response relationships which link a given level of biophysical or ecosystem change with a particular level of economic change. Such relationships are extremely hard to quantify reliably, and often depend on numerous assumptions. These must be borne in mind in undertaking careful analysis, and sensitivity analysis, and often mean that a range of results are given, but these can nevertheless give useful guidance for policy development.

Overall, Emerton and Howard (2008) describe how the economic impacts of invasive species are wide-ranging and very hard to document, model or predict. An overview by Athan (2005) of approaches to assessment of cumulative economic impact of invasive plants identified the possibility of non-linear and non-additive impacts, undermining the economic method of summarizing results as present values of costs and benefits.

Athan (2005) also identified other sectors that should be considered for the potential impacts of *A. artemisiifolia*. Within production systems potential impacts can arise on non-food agriculture (e.g. cut flowers) and concerning transport and building infrastructure, there could be reductions in capital land values due to the presence of invasive species. Athan (2005) points out that in assessing the additional impact of invasive alien weeds, consideration must be given to interactions with native weeds. If the invasive weed competes with and reduces the abundance of native weeds, then the additional impacts of the alien weed will be lower than its total impacts (as some of its impacts are displaced from native weeds). If there is no displacement, all the impacts of the alien weed are additional.

The costs of monitoring and control of invasive species also factor into the economic impacts of invasive species (see Tasks 7, 8, 9). Shine *et al*. (2010) estimate costs of implementing an EU level information and early warning system (EWS, see Task 8) to be around €445,000/yr/Member State (MS), based on a sub-sample of six nations, and an additional €26,000/yr/MS to develop and maintain a basic national database. Independent national EWSs would require an average budget of around €1.35M/yr/MS, based on a sub-sample of eight nations.

Controlling the trade and human-mediated movement of invasive alien species is crucial to controlling their spread. Establishing a framework to control the trade and movement (i.e. running permit systems supported by appropriate scientific advice and carrying out a number of inspections) is estimated to cost between of €2000 to €1M/yr/MS depending on the level of ambition and €115,000/year at the EU level for coordination and administration. Provision needs to be made to monitor and control unintentionally introduced invasive alien species; this is estimated to cost an additional €115,000/yr/MS at EU level and around €203,000/yr/MS (Shine *et al*. 2010).

'On-the-ground' monitoring actions are seen as additional to EU-level monitoring activities and data collection. Shine *et al*. (2010) estimate the cost of establishing a national programme for regular on-the-ground monitoring to be around €150,000/MS, based on available information from Great Britain and France. Several monitoring schemes already exist (see Tasks 7, 8, 9) to cover other legislation and research needs (Habitats and Birds Directives) and could be adapted to include monitoring of alien invasive species, leading to cost savings through economies of scale. Additionally, Shine *et al*. (2010) estimated the minimum earmarked national financing for 'on-the-ground' management actions to currently range between €30,000 - €360,000/species /yr/MS.

The development of an EU-level action/management plan for controlling and managing an invasive alien species is estimated to be around €42,000/action plan/species. In cases where more detailed national / regional activities are needed costs for drawing up national-level plans are estimated to be €4,000 - €30,000/management plan (Shine *et al*., 2010).

2.1 Economic impacts of ragweed in Europe

Evidence on the economic impacts of *A. artemisiifolia* in Europe is currently sparse. A study by Karnkowski (2001) briefly looks at the potential range of economic impacts in Poland. Impacts considered are:

- Reduction in yield for a variety of crops (citing evidence from the USA of losses of between 15% and 90%).
- Allergic responses in humans, requiring medical treatment.
- Impacts on patterns of trade; through the requirement for imported plant material to be free from *A. artemisiifolia* or to be thoroughly tested (and cleaned if *A. artemisiifolia* is detected), and/or internal quarantine measures.
- Additional costs of control measures to farmers.

These categories of impact are covered by the categories identified for this study, although they highlight the importance of local control measures within agricultural systems. Therefore, this Task builds on the effects identified in Task 4 with the addition of the issue of the administrative costs of national and local planning and management of *A. artemisiifolia* monitoring and control activities (Tasks 7, 8, 9). This includes the costs of commissioning the collection and collation of data on the presence of *A. artemisiifolia*, which in turn inputs to the development of eradication and/or control strategies.

The costs of control measures can arise in several of the activities looked at in areas a-e, and so are a cross-cutting feature of the analysis. To help structure the analysis it is noted that Emerton and Howard (2008) describe four general types of control, which also reflect those assessed specifically for ragweed in Tasks 7, 9:

- Mechanical control which involves the physical removal of the invading species.
- Chemical control which involves pesticides, herbicides, poisons and pharmaceuticals used to kill species of concern or eliminate them from host animals and plants.
- Biocontrol can be employed by introducing or enhancing natural controls of an alien invasive species in the form of specific parasites, predators and pathogens.
- Integrated control involves the use of more than one of the methods above to ensure management of the invasion and prevention of its spread. For example, biocontrol would be used to reduce the population of the invading species to an acceptable level while mechanical and chemical control would enhance this by eliminating ”outlier” subpopulations and advancing fronts or otherwise difficult-to-control areas or groups.

All stages in the prevention and management of invasive species should have a scientific basis. Establishing this has an extra cost to those of addressing invasions identified from Shine *et al* (2010) above.

3 Costs evidence

3.1 Costs of monitoring and control strategies

The costs of national and local planning and management of *A. artemisiifolia* monitoring and control activities, include:

- Monitoring for presence of *A. artemisiifolia*,
- Data collation and analysis,
- Development of control strategies (including preventing its spread),
- Undertaking control activities, and
- Administrative tasks associated with each of these.

Unfortunately, there is limited economics evidence on the monitoring and control of *A. artemisiifolia.* Even in countries where monitoring and control strategies are relatively well developed, there is little published information. For example, literature in Austria and Switzerland describes modelling the spread, action to control the spread and warnings about potential health risks, but does not indicate the costs or resources required to undertake these activities.

The costs of administrative activities to support monitoring and control activities have not been quantified separately and are therefore discussed as part of an overall monitoring and control strategy. In practice these administrative costs, and monitoring costs, for an invasive alien species like ragweed would be shared across a strategy for existing and new future activities to monitor and control all invasive alien species. Such a strategy is beyond the scope of this modelling, but is discussed in Shine et al (2010).

3.1.1 Extent and types of monitoring

Monitoring activity will be required everywhere in *A. artemisiifolia's* potential range. It may be undertaken in greater detail at the spatial boundaries of *A. artemisiifolia's* occurrence. This is where activities to control its spread are most active, and therefore where information on its presence is most valuable.

Different monitoring approaches may be suitable in different parts of the study area. Early warning systems will be particularly appropriate for vulnerable land surfaces in un-invaded areas (Task 8). However, as such surfaces may also have increased susceptibility to colonisation by other invasive species, the costs of monitoring could be shared across several species or be part of a wider monitoring programme.

Monitoring of un-invaded areas should take into account the risks of *A. artemisiifolia* arriving through different vectors which have different spatial extents and costs. Task 1 showed that the main vector for longer distance dispersal is humans using machinery. Local transport occurs on mowing machinery and tractors, while the greatest dispersal distances are through transport in contaminated agricultural products (incl. seed sold for bird food) and of contaminated soil for construction activities, etc. Spread also occurs along the transport infrastructure (mainly road, but also rail) by movement of seed by adhesion to vehicles.

Where *A. artemisiifolia* is already present, monitoring may be more intensive if it is present at low levels and its spread is being monitored, particularly where controls have been undertaken and their effectiveness is being assessed.

There may be variations in the timing of both monitoring and control across different parts of the study area due to environmental conditions. For example, greater seasonality further north in the study area may mean there is a shorter period when monitoring is required. The influence of climate change may alter the future timing of monitoring requirements (Task 6).

Identifying the areas with a higher threat of *A. artemisiifolia* invasion is considered difficult and brings risks that its spread will be missed in areas wrongly categorised as lower-risk. Therefore, following Task 7,9, the monitoring approach modelled is one that focuses on certain habitat types and on awareness raising amongst professionals that operate in those habitats (e.g. farmers, garden owners, construction sector, transport sector etc.). Through the widespread knowledge and awareness of these professionals, such monitoring is expected to be more cost-effective. This is because the costs are kept to a minimum (involving one-off training for professionals and relatively low-cost support activities), while the professionals can provide much wider coverage than through other monitoring options. The costs of raising awareness amongst relevant professionals are estimated as involving a minimum of 1 full time job per country in each of the three main sectors (farmers, infrastructure/construction, and domestic). The countries involved are obviously of very different sizes and so this estimated average covers a wide range of variation.

The modelling of expected impacts suggests that only two countries in the study area (the Faroe Islands and Ireland) will not experience any health impacts from *A. artemisiifolia.* Therefore it is assumed that some kind of monitoring should take place in the 37 other countries in the study area.

For the purposes of economic analysis, simplifying assumptions are necessary to analyse the potential costs of monitoring. It is assumed that most monitoring is undertaken through two approaches:

1. Voluntary networks using public reporting, and/or
2. Compulsory monitoring, whereby landowners are required to report on the presence of *A. artemisiifolia* on their land.

Task 7, 9 identified that the majority of the applied preventative measures are enforced by law (i.e. are compulsory – option 2). These laws usually entail other concrete measures for prevention. These include quarantine regulations to prevent the transportation of contaminated seed and soil. Other regulations include requirements to report sightings, remove the plant and set limits for the allowable quantity in animal feed. However, some of these requirements are difficult to enforce in practice.

3.1.2 Monitoring costs

Assuming monitoring is undertaken through a combination of both awareness raising amongst professionals in relevant sectors and citizen-science data collection, its costs are estimated as follows.

For awareness raising amongst relevant sectors, the costs to the professionals of one-off training are estimated to be very low, as it will take a small amount of time (perhaps 15 minutes) for professionals to become aware of the appearance of *A. artemisiifolia*, how to report its presence and the importance of doing so. This training would need to be repeated at regularly intervals. A financial cost for using professionals' time in this way has not been estimated.

However, there would also be costs associated with needing to communicate with relevant sectors to raise professionals' awareness of *A. artemisiifolia.* As discussed above, it is assumed that one person is employed to communicate with each of the three key sectors (farmers, infrastructure/construction, domestic) in each country. The average wage in these communications jobs is estimated to be higher than the average wage for public administration employment in the EU (of €17,500, source: Eurostat), at €25,000. This cost is doubled to cover pension and employment taxes, and overhead costs of employment and management, and an allowance of €10,000 per year is made for communications materials and travel, giving a total estimated cost of €60,000 per year.

Thus the minimum average total costs for three sectors would be €180,000 per country year. For the 40 countries covered in this study, this would produce a cost of €7.2 million per year.

Citizen-science[1] is already being used to monitor the presence of invasive species in the EU[2]. Based on electronic communications through the internet (and smart phones for providing a geo-reference) it provides a potentially powerful source of data – see also Task 7, 9. Such systems are still in their infancy and as they develop, more understanding of their costs and economies of scale in their deployment will be gained. The estimated costs of developing a citizen science monitoring system include one-off and ongoing costs. One-off costs are estimated at €20,000 for one-off system costs, €10,000 for one-off country costs (e.g. for translation, advertising and motivation of citizens through links to national activities).

[1] Information on citizen science informed by discussion with Dave Kilbey, Manager of Nature Locator Project, University of Bristol (10/5/12).

[2] e.g. http://planttracker.naturelocator.org/; http://leafwatch.naturelocator.org/

Ongoing costs involve the annual costs of quality control and data collation undertaken by professional staff. This is estimated to involve the equivalent of one full-time scientific staff per country per year. The costs of this are valued according to the costs of employing professional scientific staff (around €45,000 wage, plus overhead and other employment costs of the same amount, giving total costs of €90,000 per year).

Estimating these costs for the 40 countries in the study area suggests year one set-up and operation costs of €4.1 million, and then annual costs of €3.7 million.

The costs of citizen science monitoring are assumed to be fixed per country, as the same systems are required whether some proportion, or the whole of a country, are monitored. The exception to this would be to monitor very small areas, but the mobility of *A. artemisiifolia* makes this an unsuitable approach.

It is worth noting that citizen science data can have sample bias which limits its usefulness. For example, is likely to be biased towards areas with public access (Dickinson *et al.*, 2010). Therefore data may give better coverage of attractive locations in the countryside, but poor coverage of some land uses (e.g. derelict land) which may be more suitable for *A. artemisiifolia* colonisation. As a result a combination of compulsory, professional and amateur monitoring approaches may be required.

Whatever types (or combinations) of monitoring are required, there are assumed to be a set of generic costs for:

(a) Information provision and setup costs,
(b) Ongoing costs of managing use of a national platform and processing the data it generates, and
(c) Collation and analysis of data across the EU/study area (e.g. by the European Environment Agency).

The setup-costs and management costs (a) and (b) are assumed to be as per those for a citizen science system. For (c) additional costs are assumed to be equivalent to one full-time scientific employee (€90,000 per year).

Future monitoring systems are expected to rely heavily on modern information and communications technologies, and development of systems appropriate to invasive species monitoring is ongoing and has high costs. A current project (ENVIROFI[3]) aims to establish an Environmental Observation Web in which all environmental data, whether from sensors, citizens, or models, are available anytime

[3] http://www.envirofi.eu/

anywhere through the Internet in a standardised, usable format. It has a cost of approximately €600 million. These costs are assumed to be sunk across society, and are not assumed to be additional in relation to *A. artemisiifolia.*

It should be noted that estimates of monitoring costs are uncertain for several reasons. For example, rates of technological change are rapid over the time-horizon for this study, and secondly because economies of scale could be significant but are not well understood.

For comparison, the costs of specialist contracted monitoring activity were investigated. In the UK an ecological survey of a 1km^2 for the Countryside Survey[4] on foot takes about 2-3 hours. A targeted search in areas more likely to hold *A. artemisiifolia* (e.g. along roads, tilled land and farmsteads, river banks) is estimated to require 2 hours per km^2 (estimates from Centre for Ecology and Hydrology).

The costs of employing a scientist to undertake field work are estimated through a wage of €2,000 per month. To estimate the costs of their time to undertake a survey this is doubled to cover pension and employment taxes, and overhead costs of employment and survey organisation, to €4,000 per month. This is broken down assuming 18 days work per month, at 6 hours per day spent in the field, to give an estimated cost of a trained surveyor of approximately €37 per hour. Therefore each km^2 would cost around €74 to survey. Assuming two survey visits per year gives a cost of €148 per km^2.

The crop areas alone that are vulnerable to *A. artemisiifolia* are measured in millions of km^2 (Task 6). Therefore the costs of specialist contracted monitoring over large areas vulnerable to *A. artemisiifolia* would clearly be very high (potentially €100s millions per year) and prohibitive to using extensive professional monitoring as part of a *A. artemisiifolia* monitoring and control strategy. It is possible that professional monitoring could be used in a targeted manner (e.g. to assess the effectiveness of control efforts) over limited areas.

A further means to undertake monitoring is through the use of volunteers or 'citizen science'. Although volunteers' time is obviously free, this method is not zero cost, as various support and coordination is required to obtain appropriate results. As discussed above, volunteer efforts are likely to be biased towards locations with public access and that are attractive for recreational activities. As such they are seen as a complement to monitoring by relevant professionals (described above), rather than an alternative.

A further monitoring cost would arise by making the reporting of *A. artemisiifolia* compulsory. This would involve regulations that require land owners and managers, and/or particular activities to monitor their land or operations and report whether *A. artemisiifolia* is present. This imposes a cost

[4] http://www.countrysidesurvey.org.uk/

on those activities, and to the government in that there would have to be some system of checks, and penalties, to enforce the reporting requirement. The scale of this cost is dependent on whether the activities involved have the skills to identify *A. artemisiifolia* and report its presence.

3.1.3 Modelling of controls

Detailed mapping is needed to determine the extent of land areas requiring controls. The modelling of the effect of controls is described in detail in Task 6, Section 6. This gives outcomes for different scenarios of *A. artemisiifolia* control, which we use to model different potential costs of its impacts in 2032 in the following parts of this chapter.

The predicted extent of control requirements can be distinguished for the areas modelled in Task 6:

- The current extent,
- The 2032 extent with controls undertaken 2012-2032, and
- The 2032 extent with controls not undertaken 2012-2032.

We considered the most effective control strategy in Task 6 that restricted the spread of ragweed by undertaking control activities in the 5% of the study area predicted to become suitable for invasion over the next 20 years. Three aspects of control are modelled separately in this study, relating to the two main locations that ragweed is expected to colonise. Firstly, controls within agricultural production systems have been costed based on additional applications of herbicides to vulnerable crops. These could take place in response to detection of ragweed, or as a precaution in more high-risk areas.

Secondly, costs of controlling ragweed within urban areas are estimated. Ragweed can occur in a variety of different locations in urban areas (e.g. ruderal habitats, derelict or brownfield land, broken soil in parks and gardens; Tasks 1,2, 4). It is not possible to model detailed control strategies for each of these locations: firstly the control approaches are uncertain (see Task 7,9) and secondly the amount of ragweed in each of these locations requiring control is not possible to predict.

Instead a more general estimation of urban control requirements and costs is made. This is based on, and is very sensitive to, assumptions about the area of urban land control measures would be applied to. Task 6 modelled the parts of the study area susceptible to ragweed, and the areas of vulnerable habitat in those places (i.e. agricultural and urban land) in significant detail. However, the pattern of occurrence of growth of ragweed in these urban locations is less well understood.

To model ragweed control costs in urban areas requires an estimate of typical control costs, and of the area of land in urban areas requiring extra controls. For example, road verges are vulnerable to ragweed colonisation, but the typical frequency of ragweed on road verges in the most vulnerable parts of the study area is not known. Would ragweed plants be present along their entire length, or in clusters every 10 metres or 100 metres, or 500 metres? Any of these patterns could produce significant levels of pollen and therefore result in the health impacts modelled in other parts of this analysis (see Section 3.2). However, they could have different control strategies and therefore costs.

Thirdly, the costs of controlling seed imports in order to restrict this route for ragweed to enter the study area are analysed. This cost is not fully understood, due to uncertainty over the measures that might be taken, and how seed markets might react to any restrictions (e.g. what alternative sources of supply might act as substitutes). Therefore, the scale of the trade is analysed in order to give an indication of the possible effects of control measures on seed movements.

3.1.4 Extent of agricultural controls

The areas of crops impacted by *A. artemisiifolia* in the study area has been estimated taking into account the probability of *A. artemisiifolia* presence in an area, land cover, and the cropping patterns in different countries, within a GIS on a $5km^2$ grid (see Task 6). The spatial data layers describe the area of arable land within each 5 km^2 cell (they do not just assume that the whole 5 km^2 is arable). As with the health analysis in Section 3.2, the modelling of the extent of *A. artemisiifolia* describes a probability of its presence with 5 km^2 grid cells. The area of arable land estimated to have *A. artemisiifolia* from the modelling is probability-adjusted (using probabilities from Task 6 modelling); i.e. if cell has 10 ha cropland and 50% probability, it is estimated that 5 ha is affected. This gives the total arable area estimated to be affected by *A. artemisiifolia.* The percentages from the Task 6 modelling used in this analysis are shown in Table 5.1.

To estimate the types of crops on the arable area affected by *A. artemisiifolia,* it is assumed that the area of arable land potentially affected is divided equally amongst the percentages of different crops in each country as a whole[5]. Note that this assumption may obscure the prevalence of different crops in areas more or less suitable for colonisation by *A. artemisiifolia.* The crops for which yield loss was calculated were chosen from a list of all crops for which FAOSTAT offered data (162 crops). These were narrowed down to 69 crops by removing crops which were not harvested in the countries of study, and crops which did not need annual replanting.

[5] 2010 data from FAOSTAT-Agriculture (agriculture section of the Food and Agriculture Organization of the United Nations' statistical database). It is important to note that crop areas are counted by the area of each harvest – so some areas might be counted twice due to being harvested twice in a year. This does not affect our analysis as we are concerned with crop production from crop area rather than crop area itself.

Table 5.1. Percentage of agricultural land in each country invaded by ragweed, from the spatial modelling in Task 6.

Country	% agricultural land invaded
Albania	5%
Austria	17%
Belarus	0%
Belgium	0%
Bosnia and Herzegovina	30%
Bulgaria	33%
Croatia	48%
Czech Republic	1%
Denmark	0%
Estonia	0%
Faroe Islands	0%
Finland	0%
France	4%
Germany	1%
Greece	1%
Hungary	61%
Ireland	0%
Italy	5%
Kosovo	33%
Latvia	0%
Lithuania	0%
Luxembourg	0%
Macedonia	6%
Moldova	71%
Montenegro	3%
Netherlands	0%
Norway	0%
Poland	1%
Portugal	0%
Romania	36%
Russia	4%
Serbia	38%
Slovakia	38%
Slovenia	29%
Spain	0%
Sweden	0%
Switzerland	1%
Turkey	1%
Ukraine	27%
United Kingdom	0%

The current and expected future (2032) percentage of the crop land affected by *A. artemisiifolia* in each country was obtained from the spatial modelling (see Task 6). For all crops in the FAOSTAT-Agriculture database with crop area in the European Union, those susceptible to *A. artemisiifolia* invasion were identified by the project team at the Royal Agricultural College (see also Task 4, Section 6). The total area of these crops in each country in the study area was multiplied by the percentages of the total crop area in that country expected to be impacted by *A. artemisiifolia*. This gave the estimated area of each crop in each country expected to be impacted by *A. artemisiifolia*.

For example, in Hungary there were 3.7 million ha of harvested crop in 2010, of which 501.5 thousand ha was sunflower. The spatial analysis estimates that 92.9% of Hungary's cropland will be affected by *A. artemisiifolia* giving an affected area of Hungary's sunflower crop of 465.6 thousand ha (501.5 x 0.929).

The density of *A. artemisiifolia* must be sufficient so that a negative impact arises. Fairly low densities are capable of causing impact, with densities of < 1 plant m^{-2} having been shown to have an impact on crop yields (Task 4, Section 6.4). The assumption that costs arise for all crops exposed to *A. artemisiifolia* is examined through different assumptions in the model.

The agricultural impacts are calculated based on a probability-adjusted measure of the area of cropland where *A. artemisiifolia* is expected to occur and environmental conditions are such that it could persist and flourish. This represents areas where there is more certainty that significant costs will arise for arable farmers.

3.1.5 Costs of agricultural controls – use of agro-chemicals

The costs of control of *A. artemisiifolia* in crops relate to the need for increased applications of herbicides. The cost of extra herbicide application is obtained by firstly identifying the herbicide chemical used on each crop type and the amount of herbicide used per hectare. RAC experts provided guidance on which chemical treatments are effective on *A. artemisiifolia* (see also Task 7,9, Section 4.4). These were identified as:

a) Mestrione – 'Maize' and 'Maize, green'. Where cost of application/ha was not given, country data suggest it is used at 0.2 - 0.8 lha^{-1}.
b) Mecoprop – Cereals (barley, cereals, millet, mixed grain, oats, rice, and wheat). Where cost of application ha^{-1} was not given, country data suggest it is used at 2 lha^{-1}.
c) Glyphosate – General (all other crops). Where cost of application ha^{-1} was not given, country data suggest it is used at 1.6 lha^{-1}.

Other chemicals that can be used on *A. artemisiifolia* were identified; however these were more expensive options. The cheapest option was used as it is assumed that this is what the farmer would do. This does not take into account the potential differences in effectiveness of the chemicals.

The financial cost of treatment varies according to the type of crop and the country where it is applied. Different chemical treatments are used for different crops and herbicide supply and application (costs of labour, machinery and fuel) prices vary from country to country. The costs of chemicals were obtained from experts in Austria, Serbia, Hungary, Netherlands, Croatia and Ukraine, and Nix (2011) for the UK, were used for those countries. Nix (2011) was used as the default value for other countries.

All costs of chemicals and their application were converted to Euros (2011) through using World Bank conversion rates and deflating/inflating prices to 2011 using the HICP inflator values if needed. The total extra cost of herbicide application was calculated from the area of crop affected (calculated above) multiplied by the sum of the cost of chemical and the cost of application per ha.

Table 5.2**.** Agricultural wages in countries of study (€)

Country	**Employer**	**Worker**
Austria	8.08	6.85
Belgium	11.45	9.93
Bulgaria	0.93	0.69
Switzerland	10.00	8.00
Czech	3.93	3.49
Germany	10.80	8.95
Denmark	15.30	14.27
France	10.83	8.27
Croatia	3.37	2.82
Hungary	2.54	2.17
Italy	7.46	6.87
Latvia	1.09	1.00
Poland	1.71	1.34
Romania	2.76	2.17
Serbia*	2.40	1.96
Ukraine**	2.37	1.89
Moldova***	2.76	2.17
Data based on average of bordering countries: * from Bulgaria, Hungary, Croatia, Romania ** from Romania, Hungary, Poland *** from Romania		

Source: Agri-info.eu, The ITAG Project[6]. Prices in €, 2007

[6] http://www.agri-info.eu/english/tt_wages.php

The opportunity costs of undertaking actions to tackle *A. artemisiifolia* with agro-chemical systems include the need to use more farm labour. Many farms are micro-enterprises, meaning that much farm labour is carried out on a self-employed basis. This may have a low or zero financial market cost, but has an opportunity cost equivalent to the relevant wage rate. The costs of farm workers can be measured in a more straightforward way through their wages.

Farm wages for employers (i.e. self-employed) and workers for European countries affected by *A. artemisiifolia* are shown in Table 5.2. Data exist for EU member states and candidate countries, but for other countries estimates of wage rates are made on a similar basis to those in Table 5.9.

Using chemicals to control *A. artemisiifolia* will reduce the loss of crop yields. In this case the impacts of *A. artemisiifolia* are the additional chemical control measures required. It is assumed that the short-term response to the presence of *A. artemisiifolia* in crops is likely to be to make additional applications of herbicides.

It is noted that use of herbicides is not an option in organic agricultural systems, and therefore the % area of organic arable land in each country would not in practice receive additional chemical treatments. For this area of organic land, other control options in response to the presence of *A. artemisiifolia* would need to be undertaken. Information allowing these responses to be modelled in detail is not available.

Therefore for organic areas it is firstly assumed that they face an additional cost of controlling ragweed that is similar to that for conventional crop systems (even though they will involve different actions). The potential costs of different control activities for organic land, such as the use of mechanical weeders (see Task 7,9), are explored in sensitivity analysis (see Section 7).

Some responses to control measures can be different in organic crops. For example, organic cereals will respond more than conventional crops to effective weed control in terms of percentage increase of yield. However, as with conventional crops, these responses cannot currently be quantified (see Task 4). For organic areas, loss of yield is still assumed to occur, and is modelled in Section 3.5.

The costs of additional herbicide treatments are assumed to be the financial cost of treatment ha^{-1}, multiplied by the frequency of treatment per year. Treatment costs are calculated ha^{-1}, and multiplied by the area of land that needs to be treated. It is assumed that herbicide treatments that are effective against *A. artemisiifolia* are already being used, and that one additional treatment per year will be needed to tackle the *A. artemisiifolia* problem.

As well as the financial costs of herbicide treatments to farmers, they can also give rise to external costs such as:

- Impacts on the environment and biodiversity. Herbicides can reduce plant diversity, and the diversity of species reliant on those plants (see Task 4, Section 4),

- Increased treatment of water resources for domestic and commercial supplies in order to remove agro-chemical (see Task 4, Section 5), which has both financial implications, and brings further environmental costs (e.g. through increased energy consumption), and
- Where water treatment systems are not effective, increased consumption of chemicals through water supplies can have significant effects on human health (European Commission, 2007).

These external costs can in some cases be quantified (e.g. in the UK[7]), and they can be assumed to increase with the increased use of agri-chemicals. However, the marginal effect of the extra chemical applications required as a result of the presence of *A. artemisiifolia* is not understood well enough to estimate the cost of the impacts of increased chemical use on the wider environment.

A complication in estimating the costs of herbicide treatments of *A. artemisiifolia*, is that it is the same family as sunflower. As a result there is a particular problem with herbicides, as those that are effective against *A. artemisiifolia* would also be likely to kill the sunflower crop (see Task 4, section 6.5). There is one herbicide currently available that can be used with sunflowers and is moderately effective against *A. artemisiifolia*. In this case the impacts are likely to involve both loss of yield of sunflowers and additional costs of herbicide treatments.

Sunflowers are an important crop in many parts of the study area. In the absence of effective herbicides, farmers are likely to adopt longer-term responses, such as switching crops (see below). The costs of switching crops are hard to predict, as it is dependent on the economics of individual farms. Alternative crops may not necessarily be less profitable, but may involve higher risks (including the risks of a less diversified crop mix) or require initial capital investments.

In the absence of more detailed data, the short-term costs of additional herbicide treatments are felt to be a reasonable proxy for the minimum costs of switching to other crops. This is because, if herbicides were significantly more expensive than switching crops, we would expect crop switching to occur across many crop types (including those where herbicides can be effective) and to already be happening in areas invaded by *A. artemisiifolia*, which is not currently the case (although it remains a possibility, particularly for sunflowers).

A further factor is that if changes to crop types occurred on a large scale, this could affect crop prices. This could reduce the revenue to farmers from crops they have switched to, or raise the value

[7]The Total External Environmental Costs and Benefits of Agriculture: www.environment-agency.gov.uk/.../costs_benefitapr07_1749472.pdf

of more susceptible crops making it possible to grow them profitably using more frequent herbicide applications.

This issue of the effects of herbicides on *A. artemisiifolia* and on commercial crops may become more significant, as there is evidence of *A. artemisiifolia* becoming tolerant to some herbicides such as glyphosate (Task 4, Section 6.5). Increased use of specific chemicals for one weed, such as *A. artemisiifolia*, potentially creates this problem more generally, as it may increase resistance of other weed species to these herbicides.

The default figures used where crop-specific data were not available are of chemical costs of €6.4 and labour and machinery costs of €7.3 per ha, giving a total of €13.7 per ha.

3.1.6 Extent of controls in urban areas

The extent of urban areas in the 5% of the study area most vulnerable to future invasion by ragweed has been determined from the spatial modelling used in Chapter 6. For this area, an assumption is needed about the proportion of it that ragweed would actually grow on and therefore where it would require additional controls. This requires consideration of the makeup of land cover of urban areas:

- Within the 'urban' areas identified in the model, only a minority is usually covered by built development. It is assumed that this land is 'sealed' and therefore cannot be colonised by ragweed. The exception to this is brown field or derelict land, and construction sites. There is no consistent definition of brown field land in the study area, but it is estimated to occupy between 1 and 10% of urban areas (Oliver et al., 2005), with 3-4% being typical. If contaminated agricultural land is included in the definition of brown field land then the areas of land involved are much larger. However, these areas will have been included in the agricultural land impacts based on the modelling from Task 6, and so are assumed to be controlled through agricultural management practices. It is estimated that approximately 2-8% of urban areas are brown field land that can be colonised by ragweed.
- The majority of urban areas are typically green space (i.e. parks and private gardens), for example in the UK this makes up around 70% of urban areas (UKNEA, 2011). The majority of this space is assumed to be maintained in ways that prevent ragweed colonisation – e.g. permanent tree or bush cover is maintained; playing fields, parks and lawns are mowed; and flower beds weeded. Therefore if a ragweed plant were to grow in these areas its control would not entail an additional cost. However, such management of urban green space cannot be assumed to be comprehensive. There are likely to be small areas within this type of land where broken soil is present and that are missed by such management, and therefore which ragweed can colonise. It is estimated that approximately 2% of urban areas are green space that can be colonised by ragweed.
- Other land cover in urban areas includes roads, canals and rivers, the margins of which are known locations for ragweed colonisation. Road verges make up around 2.5% of urban areas

in the UK (Source: UKNEA) and therefore road verges are likely to be less than half that (i.e. around 1% of land cover). Many road verges in urban areas are pavements, and these may be maintained such that ragweed control does not entail additional costs. It is estimated that approximately 2% of urban areas are linear features that can be colonised by ragweed.

This consideration of urban land cover suggests that the area of land in urban areas that could be colonised by ragweed will usually be low, at around 6% - 12% of the total area. The proportion of these areas that will actually be colonised by ragweed, and therefore require additional control measures, depends on the frequency of occurrence of ragweed plants (again, will it occur in clusters every 10 metres or 100 metres, or 500 metres?). The size and frequency of clusters of ragweed are not well understood, with some of the evidence reported probably describing extremes. For example, Brandes & Nitzshe (2006) report 25,000 plants in the German city of Magdeburg in 2005, with 22,600 of these at a single site (a former seed oil mill) over an area of 506 m^2.

As discussed above, evidence at this level of detail in not available for ragweed. Some studies report the size and density of individual ragweed infestations in urban areas, but the incidence and size of colonies in urban (or other) habitats is not well quantified. More generally, Maskell et al. (2006) surveyed along urban rivers in central England and found 60% of 560 4m^2 quadrats contained non-native species, and in these the cover of non-natives averaged 20%; the commonest individual non-native *Impatiens glandulifera* was in 9% of quadrats, with a cover of 6%. Polce et al (2011) surveyed a range of habitats in 13 countries across Europe and found that the cover of all non-native species combined averaged 10%.

For the purposes of estimating control costs it is assumed that for the 6-12% of the land could be colonised, between 0.5% and 10% of this is actually colonised. This is equivalent to there being a 1m^2 area of ragweed growth every 500 m – 10 m along a linear feature. Therefore, the overall portion of urban land colonised by ragweed is estimated at between 0.03% and 1.2%. The large range in this data reflects the uncertainty of the area requiring controls.

3.1.8 Costs of controls in urban areas

The information that has emerged from the national experts about the cost-effectiveness of different control measures is summarised in Table 5.3 (see also Task 7, 9). It shows that only a few measures (manual pulling/weeding; herbicides; and various mowing approaches) have been tried in more than one country.

The most cost-effective approach to control depends on the stage of *A. artemisiifolia* infestation. At early stages, pulling/weeding may be cost-effective, whereas with more severe infestation herbicide treatments become necessary. The effectiveness of using herbicides in arable crops can be improved by combining it with crop rotation practices. However, herbicides cannot be applied in all urban locations due to concerns over public exposure to the chemicals. Therefore other approaches, such as mowing or burning, may be required in public spaces.

Table 5.3. Potential cost-effectiveness of control measures; taken from the national expert surveys.

Measure	**Country**	**Observations**	**Cost-effectiveness?**
Manual pulling/ weeding	Austria	May be more cost-effective than herbicides in less densely affected fields, but is labour-intensive. Little research into long-term effectiveness.	Yes if sustained and thorough effort before ragweed infestation is severe.
	Germany	Requires long-term effort and thoroughness, but apparently has been effective in combating ragweed.	
	Switzerland	Has worked well. Relies on local population (householders or commune workforce) taking action at early stages of infestation.	
Herbicides in arable crops	Austria	Correct use of herbicide – as part of standard farmer training. Chemicals are costly, and more effective for more severe infestations. Combine with crop rotation.	This measure has potentially high costs due to need for repeated applications of chemicals, but is cost-effective when infestations are severe. Limitations due to need to avoid public exposure to agro-chemicals, and risk of herbicide resistant strains of *A. artemisiifolia* developing.
	Germany	Effectiveness depends on the specific compound and active agent used and on the development stage of the plant. Effective compounds available to eradicate ragweed in corn and grain fields. Long germination period means a combination of leaf and soil active compounds might have to be utilized to achieve a lasting abatement during the vegetation period. Herbicides eradication success in 2008 was good overall. Limits to use due to laws controlling public exposure to chemicals.	
	Hungary	Herbicide use known to be effective in sunflower crops, but expensive and lack of knowledge on best practice	
	Serbia	Has been effective but requires repeated applications of chemicals. Limitations on herbicide use close to concentrations of people.	Reported cost in Belgrade: €0.3 – 0.5 m^{-2}.
Crop rotation	Austria	Takes time, and requires cereal cultivation within rotation. In combination with herbicides probably most important measure.	Part of cost-effective approach to using herbicides
Mowing roadsides	Austria	Correct mowing can reduce, but not eradicate infestations, and prevent further spread.	Low-cost supporting measure of existing activity
Mechanical removal	Croatia	Considered to be cost-effective if done with correct timing.	Possibly, where infestation severe.
Mowing and mulching	Germany	Mulching of plants just before seed ripening can control plant, but this is not effective at mitigating health impacts in that year.	Uncertain
Mowing and transportation	Serbia	Measures need repeating to ensure eradication	Reported cost €2-3 m^{-2}
Milling and plowing	Germany	Does not eradicate seeds, and can leave bare ground suitable for re-colonization. Needs follow-up checks.	Less effective
Burning	Germany	Tried on one highway site and said to be effective in combination with weeding and mowing	Potentially yes.

Depending on the control strategies recommended, further research may be undertaken into the cost-effectiveness of action plans that use these measures:

- Public awareness campaigns to encourage private individuals to undertake control of *A. artemisiifolia* (see below).
- Local government programmes to remove localised/low-level *A. artemisiifolia* infestations.
- Herbicide treatments for the relevant crop/agro-chemical combinations across Europe.
- Implementing mowing in public spaces such that it contributes to controlling *A. artemisiifolia*.
- Burning of areas of vegetation.
- In Serbia, separate annual contracts are let simultaneously for control and monitoring of *A. artemisiifolia* populations.

Table 5.4**.** Data on costs of potential ragweed control measures.

Control/Eradication Action	Source	Units	Value (€)
Mowing (Grass cutting)			
Pedestrian mower 450mm wide (once a year)	Spon's (2012)	€/100 m^2	4.5
Canals, edge of roads, mechanical	Rasic (2011)	€/100 m	1.2
Canals, edge of roads, manual		€/100 m	2.7
Mowing and transportation	Table 5.3	€/100 m^2	30 - 300
Hand weeding			
Established area	Spon's (2012)	€/100 m^2	12.10
Chemical applications			
Labour and chemicals for different vegetation	Spon's (2012)	€/100 m^2	3.55 – 4.36
Labour and chemicals on canal or road	Rasic (2011)	€/100 m	1.57 – 3.15
Combinations of costs above			
Grass cutting and hand weeding (once a year)		€/100 m^2	8.3
Grass cutting (mechanical) and weeding along canals/roads		€/100 m	6.65
Hand weeding and chemical applications		€/100 m^2	Approx 8
Chemical applications along roads/canals and hand weeding		€/100 m	Approx 6.5
Chemical application and grass cutting		€/100 m^2	4.02
Chemical application and grass cutting along canals/roads		€/100 m	0.85 – 2.25
Mowing, chemical application and weeding (low)		€/100 m^2	6.7 – 8.9
Mowing, chemical application and weeding along roads/canals		€/100 m	4.5 – 5.5

Only two costs of control activities were identified – Spon's (2012) and Rasic (2011) – and these are used to produce a range of costs from €0.3 m^{-2} for herbicides in agricultural systems, to €3 m^{-2} for mowing. This equates to a cost of €3,000 - €30,000 per ha, or €300,000 - €3million per km^2. These data are presented alongside other sources of data on control costs in the Table 5.4 below.

The data from Table 5.4 are treated with caution for a number of reasons. Firstly, the reported agricultural cost is substantially higher than the costs of treatment in agricultural systems (of around €10 - €30 ha^{-1}, see Section 3.5). Secondly, the costs from Rasic (2011) are from Croatia, and are more in line with expectations based on Spon's (2012).

The costs from Table 5.4 may be represent *ad hoc* or small scale actions, but are not considered representative of the costs of a systematic approach to controls. However, it is noted that higher costs may also be due to the activities taking place in public areas and on very small areas of land, where greater health and safety constraints apply, and economies of scale (e.g. in agricultural activities using farm machinery) are not realised.

The data in Table 5.4 have been selected to represent the costs of additional actions that might be undertaken to control ragweed. For example, one extra chemical application or mowing is shown, as it is assumed that these activities will be undertaken anyway, but may be needed more frequently to control ragweed. Based on this data, estimated average costs of €3 - €8 per $100m^2$ are used to model the costs of control activities.

3.1.9 Restrictions on seed imports

Part of the ragweed control strategy modelled in Task 6 involves prevention of spread through the regulation of seed imports (i.e. 'increased biosecurity' which refers to ending the unintentional import of ragweed seed through other contaminated seed. This is believed to have been the main means of introduction of seed into the study area (Task 1,2). The modelling reflects regulations that end the introduction of ragweed into the study area through seed imports. However, it does not determine how this might be achieved, which is necessary to understand its economic impacts.

Seed imports into the study area occur for different reasons. They are used for cultivation in agriculture; for livestock feed; for bird feed (including feeding of garden birds); and as food for humans (Task 1,2). Regulations on seed imports would affect these different uses in different ways.

A number of ways of preventing ragweed spread through seed imports are possible:

- A ban on trade in seed could be implemented. While this would be most simple and effective, it would have huge economic impacts on agriculture and activities using the seed.
- Requirements for traded seed to be free of ragweed seed contamination could be put in place. In practice, rather than being completely clean, requirements specify that contamination by ragweed seed must be below a certain percentage (as per the new EC regulation 574/2011 concerning ragweed contamination in animal feed imports – see Task 7,9). This requires either carefully monitoring of the growing conditions and origins of the seed (to be sure it is from an area free from ragweed), or cleaning of the seed prior to trade.

Each of these preventative measures could be applied in different ways:

- To all movements of seed, irrespective of the risk of ragweed seed contamination.
- To seeds deemed most at risk of introducing ragweed into the study area. This risk is a function of the type of seed involved and the geographical area of origin.

A further factor is the country to which the seed is being imported. If this country is one where ragweed cannot persist due to climatic conditions (e.g. as in the UK and Ireland), then a measures to regulate seed trade would seem unnecessary. However, once seed is imported into these countries, there may not be regulation of its subsequent trade through the EU, and therefore a risk arises that it is eventually used in areas vulnerable to ragweed invasion.

The value of seed imports and exports for selected countries in the study area are shown in Table 5.5. Unfortunately data are not available for all countries in the study area, but the data covers the countries with the highest value trade, so can be assumed to cover the majority of impacts of regulations on seed trade.

The data show that of a commercial world seed market worth approximately $45billion[8], at least $8.9billion (*ca* 20%) occurs in the study area. Although certain seed types are more susceptible to ragweed contamination, less data on trade in individual seed types is available, and therefore the breakdown of the market is in broad seed types: flower, vegetable and field crops. Of these, vegetable and field crops are more likely to be susceptible to ragweed contamination (see Task 1, 2).

The data illustrate the significance of the seed markets in some of the countries in the study area most invaded by ragweed (e.g. Germany, France, Hungary). Any regulation of seed trade might therefore have significant economic implications. The potential loss of trade due to restrictions is clearly significant, and any reduction in seed imports would have implications for agricultural activities. The exact impacts would depend on the way the market adjusted (e.g. the availability of substitutes of domestic or alternative seed types) and this is not something that can be modelled with certainty. It should also be noted that restrictions on trade could have implications in terms of World Trade Organisation rules, and in terms of political relations with trading partners.

More restrictive (i.e. risk-based) requirements on seed imports would have lower direct impacts on the market, but would have higher administration costs in order to apply the selective trade rules involved. Requirements for cleaning seed and monitoring it for ragweed seed content also have cost implications. No evidence on the costs of these activities could be located for this analysis.

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[8] Source: International Seed Federation http://www.worldseed.org/isf/seed_statistics.html

Table 5.5. Value of seed trade for selected countries, US$, 2010. Source: International Seed Federation http://www.worldseed.org/isf/seed_statistics.html

Countries	Import Value Flower Seeds	Import Value Vegetable Crops	Import Value Field Crops	Total Value IMPORTS	Export Value Flower Seeds	Export Value Veg Crops	Export Value Field Crops	Total Value EXPORTS	Total Trade Value
Netherlands	44	298	235	577	57	1,004	245	1,306	1,883
Germany	24	80	463	567	45	55	504	604	1,171
UK	17	150	150	317	12	18	65	95	412
France	12	116	488	616	17	298	925	1,240	1,856
Belgium	3	26	155	184	2	5	176	183	367
Italy	8	154	196	358	2	106	140	248	606
Russian Federation	6	56	225	287			245	10	297
Sweden	3		45	48	2		34	36	84
Poland	3	43	79	125	2		40	42	167
Romania	2		113	115			80	80	195
Ireland	2			2				0	2
Spain	2	161	149	312		48	81	129	441
Switzerland	2	42		44			21	21	65
Austria	1		89	90			176	176	266
Finland	1			1				0	1
Norway	1			1				0	1
Ukraine	1	25	180	206		6		6	212
Hungary		21	85	106	1	17	235	253	369
Czech Republic			53	53			42	42	95
Slovakia			48	48			36	36	84
Portugal		31	40	71		8		8	79
Belarus			29	29				0	29
Serbia				0			12	12	12
Bolivia				0			42	42	42
Greece		22	59	81			10	10	91
Bulgaria			60	60		8	20	28	88
TOTAL	132	1,225	2,941	4,298	140	1,573	3,129	4,607	8,915

3.1.10 Stakeholder and public involvement in control strategies

Public awareness campaigns are identified above as a way of encouraging individual action as part of the control strategies for *A. artemisiifolia*. However, communications can play a much wider role in the control and management of *A. artemisiifolia* (see also Task 7,9). These communications require:

- Ensuring public understanding of *A. artemisiifolia's* impacts and need for its management. This can increase acceptance of the need to spend public money on its control, and of inconvenience caused by control methods (e.g. limiting public access where herbicides are being used). It can also create a culture where contributing to *A. artemisiifolia's* control is regarded as a responsible course of action and a positive thing to do for society.
- Informing farmers about the potential commercial impacts on crop yields and need for different control techniques. Networks for communicating with farmers generally already exist (e.g. connected to public subsidy payment systems), so the additional costs of communications may be low.
- Informing different decision-makers about ragweed impacts and the need for its management. This can be important as political willingness to take decisions to implement control activities (despite the relevant evidence being available) was noted as a barrier to the effective use of control measures by national experts in several of the countries (e.g. Italy, Serbia). Control measures may be required within several different public bodies (e.g. bodies responsible for agriculture, public spaces, highways) and lack of coordination may mean effective action in some sectors is undermined if others do not take action.

Each of these requirements has a cost, including:

- Staff time to design, undertake and manage communications; and
- Communications materials (e.g. printed material) and facilities (e.g. web pages).

The costs of stimulating public involvement in control measures would be expected to overlap with the costs of citizen-science reporting measures estimated above. The additional costs of managing public involvement in control measures have not been estimated, as it is unclear if this is a suitable strategy for control of *A. artemisiifolia* in the study area.

3.1.11 Additionality of control measures

As with other elements of the analysis, the focus must be on where *A. artemisiifolia* results in additional costs to society. The information analysed has been presented on this basis, but there are uncertainties over levels of future additionality. For example, climate change may result in increased requirements for control measures for other plant species that also work against *A. artemisiifolia.* This would effectively reduce the additional control costs resulting form *A. artemisiifolia.*

There could also be co-benefits to some of the control measures that could be taken. For example, measures to control *A. artemisiifolia* spread on agricultural equipment would increase biosecurity generally. They would therefore have the beneficial side-effect of reducing the risks associated with other pathogens that affect agricultural production systems.

3.2 Evidence for impacts on human health, including medical effects, medication and work or production losses.

Evidence of the impacts of *A. artemisiifolia* on human health within the countries studied is extensive. The main health impacts relate to allergic reactions to pollen exposure (Task 4, Section 2). The economic impacts resulting from these health impacts involve the costs of:

Treatment

These costs generally refer to the costs of prescribed medication. However, this is only part of the overall costs of treatment, which also include the costs of non-prescribed medication, and that of medical staff time and facilities in which diagnosis of the problem is made and the treatment provided. The costs of medical staff and facilities are not always straightforward to estimate, because they may (at least in the short-term) be fixed costs. In other words, staff and facilities in public health services are already provided, and treatment relating to *A. artemisiifolia* makes use of these existing facilities. However, in the long run, resources can be adjusted more easily and therefore costs are more variable (i.e. can be reduced if the need for treatment is lower). As *A. artemisiifolia* represents a long-term health risk to European populations, these fixed costs should be included in the costs of its health impacts.

Reduced individual health

The costs of human health impacts include the costs of quality of life or life years lost.

Lost working productivity

Reduced workforce health can reduce economic productivity. Some limited evidence exists on this issue which allows an estimation of the loss of work time as a result of ragweed allergies. This lost time can be valued by the Gross Value Added (GVA; a measure of the value of goods and services produced) per worker or by wage rates.

The evidence available does not readily support systematic modelling of economic impacts. For example, the costs of treatment for the allergic reactions to *A. artemisiifolia* vary between countries. Furthermore different levels of state support for the costs of treatment obscures the true cost of different treatment regimes in different countries.

The key assumptions necessary to undertake this modelling are identified below and will be subsequently investigated in sensitivity analysis (see section 7). They have been constructed drawing on relevant literature where possible, but also relying on expert advice from within the project team.

3.2.1 Population exposed to ragweed

The current and predicted future populations that will be exposed to pollen and therefore that can experience allergic reactions have been estimated through the distribution modelling (see Task 6). This gives estimates of the population living in parts of the study area where pollen is or will be present. This presence is recorded as a percentage (reflecting the probability of *A. artemisiifolia* occurrence; see Task 6). The estimated population exposed to pollen is adjusted to take into account this probability. For example, if a 5 km^2 cell in the mapping has a population of 10,000, and a 100% probability, then the exposed population is 10,000. If the probability is 50% then the exposed population is 5,000.

The modelling is based on mapping data that reflect the probabilities of pollen being present that originates from plants in surrounding cells. This is important because in the modelling, larger urban areas may be recorded as unsuitable habitat for *A. artemisiifolia*. However, populations in these urban areas could still be exposed to *A. artemisiifolia* pollen dispersed through wind from neighbouring rural or urban-edge areas. Therefore a buffer is applied to locations where ragweed plants are present, in order to model the area over which its pollen spreads (see Task 6, Section 6.2).

The modelling assumes that people do not adjust where they live in response to the potential effects of ragweed pollen. There is little evidence of this happening currently, but it is potentially something that will not be recorded in population monitoring.

For the modelling of impacts in 2032, population growth is accounted for. Population estimates for 2032 were made using Eurostat population projections where available[1]. These give data for every five years (2030, 2035) so data for 2032 was estimated by interpolating between these years.

Where Eurostat data were not available[2], estimates were made by projecting forward World Bank annual population growth data for the last 10 years (2000 – 2010) to estimate population in 2032. It should be noted that for two countries (Bosnia and Herzegovina, and Montenegro) population growth rates have been both positive and negative during the last 10 years, which may make the future projections less reliable, but the same method was used and is not thought to have influenced results significantly.

[1]Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germamny, Greece, Hungary, Ireland, Italy, ILatvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom

[2] For Belarus, Bosnia and Herzegovina, Croatia, Faroe Islands, Kosovo, Macedonia, Moldova, Montenegro, Russia, Serbia, Turkey, Ukraine

Finally, the predictions using the method based on World Bank data were also made for countries for which Eurostat Data were available, and the two sets of results were compared. The variation in the predictions based on the two data sources where generally very similar, with no differences that would influence the results produced significantly.

3.2.2 Exposure levels triggering health impacts

Calculating the costs of health impacts must take into account the population's exposure levels to *A. artemisiifolia* pollen. This is a function of the presence of ragweed in areas with climatic conditions in which it can produce enough pollen to trigger allergic reactions (see Task 6). It is important to note that it can be present in areas where climatic conditions do not allow it to produce pollen (e.g. where it has arrived on northern European countries in seed imports), so in these areas *A. artemisiifolia* is present, but there is no health impact.

Where conditions allow plants to produce pollen, human exposure to just a few pollen grains (e.g. 10 m^{-3} of air) can be sufficient to trigger an allergic response (Task 4, Section 2). As a single plant can produce over 1 million pollen grains (Thompson and Thompson, 2003), a few plants can produce a density of 10 grains m^{-3} over a wide area.

The relationship between pollen exposure and the extent of allergic reactions (in terms of the number of people affected and the severity of the impacts) may be a positive one (that is, greater exposure causes greater reactions). However, this relationship is not well known – Task 4, Section 2 shows that there are few data – and is hard to model. What is important for economic modelling is the relationship between pollen exposure and responses to the impacts that have costs.

The medical treatment for an individual's allergic responses to ragweed that is required at the lowest levels of exposure that require treatment, is similar to the treatment required when individuals experience higher levels of exposure. Therefore, while the allergic reaction may vary with the level of exposure, the costs of treating individuals does not vary significantly. For the purposes of this analysis it is assumed that any exposure to ragweed will require the same level of treatment.

With more information the model could develop assumptions about different treatment costs at different levels of exposure. However, health and economic data do not support such analysis at present.

3.2.3 Population experiencing health impacts

Only a proportion of the population exposed to *A. artemisiifolia* pollen experience allergic reactions (Task 4, Section 2). Therefore, for the population in areas exposed to pollen, only a percentage will require treatment and therefore give rise to medical costs. Estimating this percentage is difficult, because for economic analysis, the relevant figure is the percentage of the population who require treatment for allergic symptoms as a result of exposure to *A. artemisiifolia*. This does not include those already with allergies for which *A. artemisiifolia* does not necessitate extra treatment, but includes those who might not need treatment for their response to *A. artemisiifolia* but do need treatment because *A. artemisiifolia* increases their sensitisation to other pollen allergens (see Task 4, Section 2.7).

Based on review of the available data on sensitisation rates in Task 4, Section 2.1, the percentage to use is uncertain. That review showed that incidence of ragweed allergy ranges widely from 2-50% of the allergic population and roughly 25% of the European population shows general allergic rhinitis. Therefore the modelling uses a range of figures of 2%, 5% and 10% of the exposed European population needing additional treatment.

Multiplying these percentages by the population the modelling predicts to be exposed to pollen gives the estimated number of individuals experiencing allergic reactions. This is then the basis for calculating current and future health treatment costs, based on an average cost of treatment per patient. The costs of treatment for an allergic reaction to *A. artemisiifolia* pollen per patient involve the costs of medication and of the medical process for administering medication (diagnosing, supplying and giving that medicine).

The analysis undertaken using these assumptions estimates that between 6.5 and 50 million people in the study area will suffer allergic reactions to *A. artemisiifolia*.

3.2.4 Cost of medication

The diagnosis, treatment and medication costs of *A. artemisiifolia* are known to be very significant. In the US, according to a study by Ziska *et al* (2011), the cost of *A. artemisiifolia* induced asthma and hay fever is estimated at $21 billion (approximately €15.7 billion) a year. The method used in making this estimate refers to costs calculations by Center for Disease Control and Prevention. Unfortunately the link provided to this specific work does not function, and the organisation's website does not have other cost information. Another study puts the costs of *A. artemisiifolia* allergy in the US at around €3billion per year (Goetzel, 2004). The unit costs of treatment are given in Biomedical Insights (2010) at €810 per diagnosis, and €3,700 per year over the first three years[3].

The cost of medication can be calculated per dose for a typical number of doses, or for a programme of treatment considered as a block. The two main treatment regimes available for allergic reactions to *A. artemisiifolia* are either:

- Intake of antihistamines or corticosteroids, or
- Immunotherapy treatment.

[3] Converted from $ to € at a rate of $1 to €0.81.

Of the two options, antihistamines or corticosteroids are cheaper per dose, but are required each day. Immunotherapy treatment is more expensive, but is not required daily. This therapy involves three years of treatment with injections (with an estimated cost in the UK of £2,600 [approximately €3,030] Source: Frew A, Brighton, Sussex, UK, PEI Seminar Washington Sep 2011), and is cost effective if its effects last ten years.

Table 5.6. Summary of treatment costs evidence.

Country	**Cost per patient**	**Total cost per year**
Austria	€630	€88 million
Czech Republic - anti histamines etc immunotherapy	 €8.3 (210 CZK) € 43.5 (1,100CZK)	N/A N/A
Germany	€650	€17-47 million
Hungary		€100 million
Switzerland - rhinitis asthma immunotherapy antihistamines	 €806 (1,000 CHF) €8,060 (10,000 CHF) € 484 – 645 (600-800 CHF) €24 (30.2 CHF)	 €80.6 million (100 million CHF) €8.06 – 24.19 million (10-30 million CHF) €210 million (260 million CHF) €262 million (325 million CHF)
Italy - hospital visits, immunotherapy, hospitalisation	-	€ 1.74 million
Serbia - antihistamines	€ 547-2,555 per year	-
France	€26 – 386 reimbursement	-
UK - Immunotherapy	€3,030 one-off	-

A summary of the information provided by the national experts and project team on relevant treatment costs is given in Table 5.6. The UK cost (€3,030 over 10 years) is particularly useful for our purposes because it is the medication cost of a whole treatment course (a series of immunotherapy injections). The cost of a course of injections should in theory be the maximum cost per patient, because where symptoms will persist, this would be the cost-effective choice of treatment. However, there are several potential complicating factors, such as:

- The most efficient treatment cannot always be known at the outset of treatment, and so in practice costs may be higher than this (as some costs may be sunk before efficient long term treatment decisions are made);
- Some patients may wish to avoid discomfort caused by injections;
- The length of the season over which allergic reactions arise will influence the cost-effectiveness of different treatments. Longer pollen seasons mean that drug treatments would have to be taken for longer, therefore making injections (which require a fixed period of treatment) more attractive in terms of both a) length of time of treatment, and b) cost (injections cost being fixed, drugs costs being proportionate to the length of treatment);

- Some patients may experience side-effects which deter them from taking certain medicines;
- The medications available may also help treat the effects of other allergens to different extents, so the efficient choice of medication may be different for different individuals.

It is not possible to assess these factors with the available data.

The UK cost of €3,030 is assumed to be the total cost for medication per patient over 10 years of treating allergic reactions to *A. artemisiifolia* pollen exposure. For annual costs this is divided by 10 to give €303 per patient per year. This value sits towards the centre of the range of other costs per patient identified in Table 5.6. If anything it may be relatively low when the costs of other treatments are multiplied across the numbers of doses and the timescales they are required. For the purposes of this economic modelling, €303 per patient per year is the estimated cost of medication.

In reality medication costs will vary across countries in the study area. However, medicines are traded on a global market, and therefore the influence of national currency/purchasing power rates may be relatively low. It is difficult to gather comparable data on medication costs because prices often controlled by national regulatory bodies, with different processes and rules. For this modelling it is assumed that extrapolating from UK costs of medication is a reasonable approach.

This approach captures the costs of treatment through the formal health care system. It does not consider the cost of over-the-counter medications. Storms *et al*. (1997) estimated that the cost in the USA of over-the counter medications for allergic rhinitis was €73 per patient per year. Thus, excluding the cost of over-the-counter medications will result in an underestimate of the direct medical costs of *A. artemisiifolia*. However, it is very difficult to estimate the proportion of these over the counter costs which could be additional costs resulting from the presence of *A. artemisiifolia* (see additionality discussion below).

It is possible that medication costs might change in the future. They might become cheaper, if patents run out and generic drugs are used instead. The emergence of new drugs could increase medication costs, or reduce them if treatments become more effective. Such effects are based on rates of innovation and so cannot be predicted, and therefore it is assumed that future medication costs are the same as current costs.

3.2.5 Cost of administering treatment

The administration costs of the medical processes for diagnosing, supplying and giving medications are also hard to assess. They will vary for different types of medicines. While injections are given at a clinic, and therefore face repeated staff costs, drugs can be self-administered, so there may be only one 'administration' cost per year.

The average cost of the medical process for diagnosing and supplying medication can be estimated from the value of medical staff time required, plus overhead costs for facilities. We expect that medical staff time for diagnosis is likely to involve at least two consultations; one to diagnose the problem and another to administer treatment. These consultations could be with a medical professional, which could be a doctor, pharmacist or nurse. A typical treatment is assumed to require 1 hour of additional consultation time. It is assumed that these consultations are additional (i.e. are not required in response to other allergens). This may be an unrealistic assumption, but the additionality of *A. artemisiifolia* impacts to those of other allergens is poorly understood.

The value of this time is taken as the wage rates of the relevant professionals. For the purposes of this modelling the hourly staff costs are calculated as the mean of nurses and doctors pay rates. This effectively assumes that half the treatment is from doctors, and half from nurses.

These costs of administering treatment are calculated based on the hourly rate of medical staff. This was taken from OECD (2012). It is defined as average gross annual income, including social security contributions and income taxes payable by the employee. Figures used are the average costs for 'salaried' general practitioner doctors (GP) and nurses. Figures were converted to 2011€ prices using World Bank exchange rates and Eurostat HiCP inflation rates for European Union.

Some interpolation was necessary. For countries without information available on nurses or GPs, the average of all countries with information (Denmark, Estonia, Finland, Germany, Greece, Hungary, Luxembourg, Netherlands, Slovakia, Slovenia, Spain, Sweden, Turkey, United Kingdom) was used. Some countries without data on GPs' salaries have data on nurses' salaries. Where their nurses' salaries are higher than the average GP salary of all countries, their nurses' salary figure was used as an estimate of their GP salary (Belgium, Ireland, Norway).

Annual salaries were divided by 1680 (5 days x 42 weeks x 8 hrs) to get salary costs in $€hr^{-1}$. Staff wage rates do not reflect the full costs of consultations, as they do not include pension contribution, buildings and equipment costs. Therefore, the wage costs are doubled to estimate the total costs.

3.2.6 Reduced individual health

The health impacts of *A. artemisiifolia* also include its impacts on individuals' quality of life (morbidity). Even with treatment, some people experience continued allergic reactions (Pawankar *et al*., 2011). These impacts can be measured in theory through quality of life years (QALY) lost[4], and their costs calculated by applying an average willingness to pay per QALY.

However, QALYs are a complex system of measurement, and while allergy symptoms can have significant effects on quality of life, the evidence on this is mainly anecdotal. It includes both impacts

[4]http://www.nice.org.uk/newsroom/features/measuringeffectivenessandcosteffectivenesstheqaly.jsp Accessed 29/07/2012

from avoidance actions (e.g. reduced ability to undertake outdoor activities), and physiological effects. For example, a US study suggests 80% of patients experience reduced quality of life (e.g. reduced sleep (AAAAI, 1996−2005).

Tripathi and Patterson (2001) and Meltzer (2001) discuss the impact of allergic rhinitis on the quality of life. They point out that poorly controlled symptoms of allergic rhinitis may contribute to loss of sleep, secondary daytime fatigue, learning impairment, decreased cognitive functioning, and decreased long-term productivity. Pharmacological therapies in some cases have considerable adverse side effects, affecting attention, working memory, vigilance, and speed (*via* sedation). However, to date no studies have attempted to assign monetary value to the deterioration of quality of life resulting from allergic rhinitis.

A further consequences of reduced individual health due to contact with *A. artemisiifolia* pollen is that people adjust their lifestyles and behaviour to avoid areas where they will be exposed to it. This could lead to reduced levels of outdoor activity within daily lives, and to different choices made about where to undertake commercial or recreational activities. These choices could have significant economic consequences for leisure, recreation and other outdoor industries. These are discussed further in Section 3.6.

It is important to note that reduced participation in outdoor activities could have knock-on effects on general health and fitness. Reductions in physical activity rates are a major cause of 'lifestyle diseases' such as heart disease and type II diabetes (Bird, 2005).

As *A. artemisiifolia* pollen exposure is unlikely to cause death, the focus of the analysis is on morbidity, and no attempt has been made to assess mortality impacts.

3.2.7 Lost working productivity

Another cost associated with reduced individual health is loss of working productivity. Even with appropriate medical treatment a proportion of those individuals sensitised to *A. artemisiifolia* will experience symptoms severe enough reduce their work capacity. Some anecdotal evidence exists of impacts on workers (e.g. the Italian national expert reported a policewoman moving her job to another city to avoid exposure to ragweed pollen), but information on the rates of sensitisation severe enough to affect the workforce is not available. The symptoms of allergic rhinitis and the sedating side effects of some allergic rhinitis medications are typically not severe enough to cause work absence. However, the symptoms may significantly lower on-the-job productivity.

The costs of workforce impacts will vary in different sectors, and in the timing and predictability of the impacts. Unforeseen impacts are expected to reduce output, but predictable ones can be managed, resulting in increased workforce costs, but possibly no loss of output. If known, loss of workforce capacity can be valued using the average wage rate to reflect the cost of additional labour, or through GVA per worker to reflect work capacity that is lost and not replaced. It should be noted that even if medical treatment is applied in all cases, there would still be expected to be reductions in workforce productivity due to the side effects of medications on some patients.

Sectors with outdoor workforces (e.g. agriculture, construction) may face particularly high risks of impacts on their outputs, although there is no evidence for such an impact of ragweed in Europe (Task 4, Section 7). These sectors are given specific consideration in subsequent Sections.

The basis for estimating the workforce productivity impacts of ragweed is the number of people exposed to ragweed pollen, i.e. the same data as used to estimate health treatment costs: the number of people exposed to ragweed pollen is estimated from the total population (World Bank) of each country in the study area, multiplied by the percentage of people exposed to ragweed pollen from the modelling data.

The number of people in the working population exposed to ragweed pollen is estimated by multiplying this exposed population by the percentage of population who are working. This percentage is taken from the World Bank's Total Labour Force[5] data. No data was available for two countries in the study area (Kosovo and Montenegro), so for these countries the percentage was estimated as the average of the percentages for two neighbouring countries (Serbia and Albania).

The working population exposed to ragweed pollen was multiplied by 2%, 5% and 10% to give low, medium and high estimates, respectively, of the number of people in the workforce with additional allergic symptoms as a result of the presence of ragweed in the study area. The results are shown in Table 5.7.

In general the labour force in the study area estimated to be affected by additional allergic symptoms due exposure to ragweed is between 0.4 and 2 million. As a proportion of the labour force this is small, at between 0.1 and 0.5% (i.e. a maximum of 1 in 200 workers).

However, in some countries larger proportions of the workforce are estimated to be impacted. For example, under the medium scenario 2.4% of workers are affected in Hungary and 1.4% in Romania (i.e. between 1 in 40 to 1 in 70 workers), with even higher impacts estimated for Moldova.

For the workers impacted by ragweed (the number of people in the workforce with additional allergic symptoms as a result of the presence of ragweed), the effect on their work are difficult to estimate. Some data on average days of lost work to allergies are available but these are hard to

[5]Total labour force comprises people ages 15 and older who meet the International Labour Organization definition of the economically active population: all people who supply labour for the production of goods and services during a specified period. It includes both the employed and the unemployed. http://data.worldbank.org/indicator/SL.TLF.TOTL.IN

relate to the estimates of the population suffering additional symptoms as a result of exposure to ragweed in the study area.

Table 5.7. Estimated workforce incidence of ragweed allergies

	Population exposed to ragweed pollen	Total allergic working population			Percentage of labour force		
		Low	Medium	High	Low	Medium	High
Albania	55,423	515	1,288	2,576	0.0%	0.1%	0.2%
Austria	1,019,265	10,485	26,212	52,424	0.2%	0.6%	1.2%
Belarus	13,262	126	315	629	0.0%	0.0%	0.0%
Belgium	1,033	9	23	46	0.0%	0.0%	0.0%
Bosnia and Herzegovina	794,974	6,252	15,630	31,261	0.4%	1.1%	2.1%
Bulgaria	1,477,069	13,861	34,651	69,303	0.4%	1.0%	2.0%
Croatia	1,743,438	15,574	38,934	77,868	0.8%	2.0%	3.9%
Czech Republic	63,544	637	1,593	3,187	0.0%	0.0%	0.1%
Denmark	2,529	27	67	133	0.0%	0.0%	0.0%
Estonia	2,168	23	57	113	0.0%	0.0%	0.0%
Faroe Islands	-	-	-	-	0.0%	0.0%	0.0%
Finland	9,058	91	227	453	0.0%	0.0%	0.0%
France	3,105,456	28,491	71,227	142,454	0.1%	0.2%	0.5%
Germany	1,183,064	12,211	30,528	61,056	0.0%	0.1%	0.1%
Greece	36,823	342	854	1,708	0.0%	0.0%	0.0%
Hungary	4,817,607	41,670	104,174	208,348	1.0%	2.4%	4.8%
Ireland	0	0	0	0	0.0%	0.0%	0.0%
Italy	1,434,634	11,832	29,579	59,158	0.0%	0.1%	0.2%
Kosovo	469,871	6,202	15,504	31,008	0.5%	1.3%	2.6%
Latvia	2,412	25	63	125	0.0%	0.0%	0.0%
Lithuania	1,310	13	33	65	0.0%	0.0%	0.0%
Luxembourg	170	2	4	8	0.0%	0.0%	0.0%
Macedonia	153,946	1,410	3,525	7,049	0.1%	0.4%	0.7%
Moldova	2,483,348	17,005	42,512	85,023	1.4%	3.5%	7.0%
Montenegro	14,341	193	482	963	0.0%	0.1%	0.2%
Netherlands	244	3	6	13	0.0%	0.0%	0.0%
Norway	5,587	59	148	296	0.0%	0.0%	0.0%
Poland	266,826	2,543	6,356	12,713	0.0%	0.0%	0.1%
Portugal	1,110	12	29	58	0.0%	0.0%	0.0%
Romania	5,951,607	56,730	141,825	283,650	0.6%	1.4%	2.8%
Russia	3,266,642	34,957	87,391	174,783	0.0%	0.1%	0.2%
Serbia	2,055,944	20,042	50,105	100,21	0.6%	1.4%	2.8%
Slovakia	1,235,174	12,378	30,945	61,891	0.5%	1.1%	2.3%
Slovenia	276,857	2,803	7,008	14,016	0.3%	0.7%	1.3%
Spain	20,395	203	507	1,015	0.0%	0.0%	0.0%
Sweden	38,571	408	1,019	2,039	0.0%	0.0%	0.0%
Switzerland	64,397	734	1,834	3,668	0.0%	0.0%	0.1%
Turkey	35,657	257	641	1,283	0.0%	0.0%	0.0%
Ukraine	9,655,126	98,403	246,008	492,017	0.4%	1.1%	2.1%
United Kingdom	29	0	1	1	0.0%	0.0%	0.0%
TOTAL		396,522	991,306	1,982,612	0.1%	0.3%	0.5%

A US study (Lamb *et al.*, 2006) identifies the number of days of absence per year from work for people reporting allergic rhinitis/hay fever as 3.57 per person. Both the area from which this data is sourced (the US) and our study area has the full range of climatic conditions (i.e. the north-south gradient of temperature ranges) in which ragweed can grow. Therefore the data are considered applicable to our study area. This data can be applied to the estimated population experiencing additional allergic symptoms as a result of exposure to ragweed in the study area.

However, this calculation may result in an overestimate of the impacts. Some of the workforce experiencing additional symptoms that require treatment (estimated at 2%, 5% and 10% as above) may already be having absences from work due to allergic symptoms, with ragweed resulting in worsening of those symptoms, but no change in the number of days they are experienced. In other words they feel more ill, but are not ill for longer. These people are likely to require increased medical treatment, but may not have any greater loss of work productivity, as a result of ragweed. For this reason, and because there are uncertainties in basing this calculation on limited data, the lower estimates of workforce impacts (the 2% and 5% levels) are used for this calculation.

It is assumed that the employees do not undertake any work on the days of absence, so all their productivity is lost. Assuming a working year of roughly 225 days (allowing for weekends and around 30 days holiday), 3.57 days is equivalent to 1.6% of the working year. This estimates the costs to productivity of lost workforce time as a result of allergic reactions to ragweed. It covers absences from work, but it does not cover time spent in work where individuals are symptomatic and therefore less productive. Two US sources give data that suggests this could be an important impact:

- Lamb *et al.* (2006) suggest that affected individual are symptomatic for 52.5 days per year, and during that period lose 2.3 hours from normal productivity from a typical 8 hr work day. This would suggest that, allowing for weekends (giving 37.5 symptomatic working days), gives a productivity loss equivalent to 86.25 hours lost per symptomatic employee. This is roughly 10.5 days work, which is a significant impact (nearly 5% of the working year).
- Szeinbach *et al*. (2007) give an average of 1 hr/week not working during a year-long study. This is 2.5% of working time.

However, it is unclear for what populations of symptomatic individuals in the study area such rates of impact might occur. Therefore it is less easy to extrapolate from these data to estimate a cost of the lost productivity for symptomatic effects experienced in work.

A further source of impact on the workforce is when absences are taken to care for sick children. Lamb *et al*. (2006) identify that employees who are absent to care for a child with allergies are on average absent for 3.68 days/year. However, a symptomatic child that needs care will not automatically be cared for by a working parent – for example they may have a parent who does not work or another relative who can provide the care. Therefore it is not possible to extrapolate from this data to the affected population across the study area.

This information gives estimates of lost work productivity of between 1.5% and 5%, due to a range of causes, of working time for members of the workforce suffering additional allergic symptoms due to exposure to ragweed. It is unclear whether all these data relate accurately to the estimated population of such individuals in the study area, or if these percentages are additional to one another. For example, a worker could take 3.57 days of work *and* have further days when they are in work but have lower productivity.

For the purposes of this modelling it is assumed that the affected workforce in the study area lose between 1.5% and 5% of their annual work capacity due to the additional effects of ragweed. It is noted that this is potentially an underestimate due to not considering the combined effects of these causes of work productivity loss, (e.g. a worker may have symptomatic effects experienced in work and requirements to care for symptomatic children). It is also potentially an overestimate for two reasons. Firstly, these data may represent only the more severe cases, and so may not be applicable to all of the affected workforce in the study area. Secondly, in some sectors some workers (e.g. those who work flexible hours, or are self-employed) are likely to make up work time lost, mitigating productivity losses. It could be argued this would be at a cost to other activities or their quality of life, but economic analysis of these effects is highly uncertain.

The loss of productivity per worker can be valued in two ways. Firstly this can be based on the GVA per worker in each country. World Bank Country GVA Data were divided by the Total Labour Force (as above) to get productivity per worker in 2011 in US$ in 2000 prices, and were converted to € in 2011 prices using the World Bank Official exchange rate[6] and the Eurostat HICP Inflator for the EU 27[7]. Where GVA data for 2011 were not available (in ten countries), they were estimated by extrapolating the latest available data by the growth rate in GVA over the previous two years.

Secondly, loss of productivity can be valued through the average wage rate. Data on wage rates was mainly taken from the Key Indicators of the Labour Market (KILM) database of the International Labour Organisation (ILO)[8]. Where needed, rates were converted to Euros using the World Bank Official Exchange Rate and inflated to 2011 values using the EU HICP (as above).

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[6] Official exchange rate refers to the exchange rate determined by national authorities or to the rate determined in the legally sanctioned exchange market. It is calculated as an annual average based on monthly averages (local currency units relative to the U.S. dollar). http://data.worldbank.org/indicator/PA.NUS.FCRF

[7] Annual data, Harmonised indices of Consumer Prices (HICP), Eurostat http://epp.eurostat.ec.europa.eu/portal/page/portal/hicp/data/database

[8] http://kilm.ilo.org/kilmnet/ KILM rates were given in local currency units for 2005. Some wage rates were not available from the KILM database; wage rates for Greece, Ireland and Netherlands were obtained from the 'Average Annual Earnings' table in the Labour theme of OECD Stat Extract (http://stats.oecd.org/) and were given in 2009 USD for 2010 rates. Kosovo wage rates were obtained from the European Forum for Democracy

Wage rates reflect the opportunity cost of organising additional employees to undertake the work of those affected by ragweed. Loss of GVA per worker reflects the value of lost work capacity that is not made up for in other ways. Which of these values applies to an individual worker depends on the circumstances and skills of their job. Both valuation approaches are used to give a range across the different jobs across the study area.

Impact per worker in the future scenario (2032)

The calculations above were made for future scenarios in 2032. Population estimates were made using Eurostat population projections[9] where available, or World Bank average population growth rates[10] from the past 10 years.

The future calculations do not allow for changes in the proportion of the population that is part of the labour force. However, this is uncertain as it is subject to conflicting influences. On the one hand populations in the EU are ageing, and so the retired population is expanding and the working population reduced. On the other hand, retirement ages are being raised in some countries (e.g. the UK) so the working population will increase. There are also effects from population migration.

3.2.8 Additionality and other modelling assumptions

As with treatment costs, a further consideration in relation to individual health costs are that assumptions are required on interactions with other allergies. On the one hand allergic reactions may not be additional, if the patient was already experiencing reactions to other allergens (e.g. grass pollen). Indeed, it seems that people allergic to ragweed generally show allergies to other pollen (Task 4, Section 2.6). On the other hand the costs of direct health responses to impacts of *A. artemisiifolia* may underestimate the total costs. This is because exposure to *A. artemisiifolia* pollen can increase sensitisation to other allergens (see Task 4, Section 2.7), leading to increased health impacts at times when individuals are exposed to other allergens but not *A. artemisiifolia.*

For the economic modelling, the costs of *A. artemisiifolia* assessed above are assumed to be additional, but no further impacts from cross-sensitisation are estimated. To assess the costs

and Stability website (http://www.europeanforum.net/country/kosovo) and Montenegro wage rates were obtained from the Statistical Office of Montenegro website (http://monstat.org/eng/novosti.php?id=556).

[9] Population projections are what-if scenarios that aim to provide information about the likely future size and structure of the population. Eurostat's population projections is one of several possible population change scenarios based on assumptions for fertility, mortality and migration. The method used for population projections is the "cohort-component" method. Population refers to 1st January population for the respective years.
http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tps00002

[10] http://data.worldbank.org/indicator/SP.POP.GROW

resulting from *A. artemisiifolia* exposure increasing sensitisation to other allergens would require information on how much the costs previously associated with the other allergens increase by after exposure to *A. artemisiifolia* pollen. This depends on whether previous symptoms were serious enough to treat, or if treatment only became necessary after exposure to *A. artemisiifolia.*

A further complication is that the incidence of allergic responses to ragweed pollen interacts with other health factors, like levels of airborne pollutants such as ozone and particulates. The influence of these factors on the additional rates of health treatment required as a result of the presence of ragweed are not possible to model in this study.

There is no easy solution to these challenges in order to assess the effects of a single allergen like *A. artemisiifolia.* These factors mean that simplifying assumptions are required in the analysis of individual allergens, and that it is inappropriate to carry out analysis of impacts for several allergens separately and then aggregate the results. This study is considering *A. artemisiifolia* as the marginal allergen, but more accurate results would be obtained from modelling the effects of all allergens in a combined study.

Another variable is that the percentage of the population who will suffer increased allergic reactions to *A. artemisiifolia* may vary with different factors:

- Geographically (e.g. in urban/rural), levels of sensitisation might vary due to different exposure to pollen allergens during individuals lifetimes; and
- Demographically (e.g. young/old), different population segments may have different sensitisation or vulnerability.

Task 4 collates evidence for different susceptibilities in certain sectors of the population (children and those in urban areas – Section 2.4) and geographic variation in incidence (Section 2.1), but these aspects are not quantified sufficiently to incorporate in our modelling, and they are also very complex factors to model spatially. Therefore, for the economic modelling, a homogeneous response across populations is assumed.

3.2.9 Interaction of health with mapping

The basic approach is to multiply the affected population x costs per person x probability for each mapped 5 km^2 cell where there is a probability of ragweed establishing. The problem with this approach is that probabilities reflect climatic and habitat suitability for ragweed (see Task 6). Urban areas are classified as unsuitable habitat (even though some suitable habitat [e.g. bare ground in building sites, parks] can exist in urban areas). The size of population exposed is expected to be very sensitive to probabilities for urban areas.

Health effects are driven by airborne pollen, which can move considerable distances and certainly from urban-edge to urban areas, thus affecting urban populations (Task 4, Section 2.3; Task 6, Section 4.2). Therefore the analysis used a buffer around areas with ragweed to map the areas where ragweed pollen could occur in concentrations sufficient to generate health impacts (see Task 6, Section 6.2). Ideally more detailed modelling of pollen exposure would be used, but for the large study area analysed in this work this is not feasible.

3.3 Evidence for impacts on animal health (including veterinary effects, medication and work or production losses)

A. artemisiifolia is not currently recognised as causing any major health problems in European livestock. Under certain circumstances it could cause impacts on livestock when:

- Under adverse conditions it can accumulate nitrates, and
- Vulnerable livestock consume *A. artemisiifolia* containing high levels of nitrate. Livestock species are differentially susceptible to nitrate poisoning (e.g. cattle more than sheep, young animals more than old).

This section reflects on the evidence about potential impacts of this type from Task 4, Section 3, and identifies any areas where significant economic impacts are expected that require modelling.

A. artemisiifolia should not be a concern for well-managed pasture, as it typically requires broken soil for germination, and livestock will generally avoid it unless there is a shortage of forage. Risk of *A. artemisiifolia* colonisation may increase with overstocking and the resulting disturbance. Its presence many increase in forage due to climate change. This could be due to more arid conditions, which may result in more bare earth, and/or the extension of suitable growing conditions to higher altitudes.

Negative livestock health impacts due to ragweed have not been widely recognised or documented in Europe. For example, the European Food Safety Authority's Panel on the Contaminants in the Food Chain concluded that there is no evidence that *Ambrosia* species form secondary plant metabolites that are of clinical significance for livestock (EFSA, 2010).

Ragweed has been documented to have some nutritional value for livestock, although they do not typically choose to consume it (due to its bitter taste). According to scientific literature from the United States, under certain circumstances ragweed may accumulate nitrogen. When this occurs, the main potential livestock health impact of ragweed is nitrate poisoning (nitrates in the plants are metabolised to nitrites in the gastro-intestinal tract following consumption). It is not feasible to distinguish potential role of ragweed in this, as many other factors are involved (such as other risks of nitrate accumulating plants; level of drought [arid conditions increase the level of nitrate accumulation]; forage availability/shortage; livestock species, age of animal etc.)

While there is some literature recording ragweed allergenicity in dogs, cats and horses, few data were found on rates of impacts in domesticated species (Task 4, Sections 3.2, 3.3). Overall, evidence suggesting significant economic impacts as a result of the effects of *A. artemisiifolia* on animal health has not been found in this project. Overall, modelling is not feasible or justified for what is currently a poorly understood issue, impacted by a complex array of variables, Therefore no assessment is made of any direct costs associated with impacts on livestock or pets.

Indirect impacts on livestock production could arise through the impacts on crops discussed and modelled in Section 3.5. Impacts on crop prices could indirectly affect animal production systems through impacts on the availability of animal feed. The crops that are grown in the study area that can be used as animal feed were identified by the project team (Royal Agricultural College), and their areas and crop yields calculated. The impacts on crops that can be used as animal feed are substantial. Lost yields for these crops were estimated to be 9% of their total production in the study area. These impacts were concentrated in the large minority of countries where *A. artemisiifolia* presence is significant, with losses of between 10% and 20% of potential animal feed crop yields predicted in 16 of the 40 countries analysed.

A further potential impact on livestock farming could arise through restrictions on movements of agricultural feed as a measure for controlling the spread of *A. artemisiifolia*. The estimated yields of potential animal feed crops (after allowing for losses calculated above) that could be contaminated with *A. artemisiifolia* was also calculated. This contamination could impact approximately 200 million tonnes per year, or 28% of the yield from the crops involved.

3.4 Impacts on biodiversity and the wider environment

In general the literature review in Task 4 (Section 4) did not locate significant evidence of adverse effects from *A. artemisiifolia* on biodiversity in Europe. Ragweed tends to occur only in disturbed habitats, and the few examples of invasion of ragweed into protected habitats can be linked to disturbance, especially by humans. Furthermore, there was no evidence found for ragweed impacts on the wider environment (Task 4, Section 5).

Table 5.8. Assessment of ecosystem services impacts of ragweed, based on The Economics of Ecosystems and Biodiversity classification of ecosystem services.

Ecosystem Service	**Potential Impacts**	
1 Food (e.g. fish, game, fruit)	Yes – crops, livestock	
2 Water (e.g. for drinking, irrigation, cooling)		Possibly through change to vegetation cover
3 Raw Materials (e.g. fibre, timber, fuel wood, fodder, fertilizer)	Yes, fodder crops, maybe fibre crops	
4 Genetic resources (e.g. for crop-improvement and medicinal purposes)	Yes, if affecting relevant habitats	
5 Medicinal resources (e.g. biochemical products, models & test-organisms)		
6 Ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion)	Yes for pets. Could restrict artisan work or plant availability	
REGULATING SERVICES		
7 Air quality regulation (e.g. capturing (fine)dust, chemicals, etc)	Health impacts	Possibly through change to

Ecosystem Service	Potential Impacts	
8 Climate regulation (incl. C-sequestration, influence of vegetation on rainfall, etc.)		vegetation cover
9 Moderation of extreme events (e.g. storm protection and flood prevention)		
10 Regulation of water flows (e.g. natural drainage, irrigation and drought prevention)		
11 Waste treatment (especially water purification)		
12 Erosion prevention		
13 Maintenance of soil fertility (incl. soil formation)		
14 Pollination		
15 Biological control (e.g. seed dispersal, pest and disease control)		
HABITAT SERVICES		
16 Maintenance of life cycles of migratory species (incl. nursery service)		Possibly through changes to habitats
17 Maintenance of genetic diversity (especially in gene pool protection)	Where out-competing species directly	
CULTURAL & AMENITY SERVICES		
18 Aesthetic information		Possibly through changes to habitats
19 Opportunities for recreation & tourism	Restrictions on access due to exposure risk	
20 Inspiration for culture, art and design		
21 Spiritual experience	Restrictions on access due to exposure risk	
22 Information for cognitive development	Reduced learning due to restrictions on access due to exposure risk	Possibly through changes to habitats

The lack of significant evidence may be due to lack of investigation of such problems rather than a complete lack of their existence. In order to consider whether there are other areas that should be analysed in more detail, the potential impacts of *A. artemisiifolia* on ecosystem services are briefly assessed in Table 5.8 using an ecosystem services classification derived from The Economics of Ecosystems and Biodiversity (TEEB, 2010). The main impacts are on food crops, which are considered in detail in Section 3.5) below. Some impacts on cultural services (recreation and tourism) are possible (See Task 4, Section 7), and these are considered in Section 3.6).

All other impacts are indirect and assessed to be minor. For example, impacts on fuel and fodder crops are expected to be minor because they are usually produced in continuous cover regimes, which means that they do not provide the disturbances required by *A. artemisiifolia*. Although in general firm evidence is lacking of many potential impacts, there are few reasons to suspect adverse impacts on regulating or provisioning services (see Task 4, section 5). Therefore, further analysis of ecosystem services not covered in other parts of this modelling is not considered necessary

3.5 Impacts on agriculture and horticulture production systems

The main impacts of *A. artemisiifolia* on production systems identified to date relate to agricultural systems, particularly arable crops (Task 4, Section 6). The main costs can involve loss of output (lower crop yields), and changes to production systems to circumvent the impacts *A. artemisiifolia*. Changes to production systems can range from marginal changes, such as increased use of herbicides, to more fundamental changes, such as adoption of different tillage systems or changes to permanent-cover crops.

The impacts on animal production systems have been discussed in Section 3.3) above, and the direct impacts on livestock production are not thought to be significant. It is possible that there could be indirect effects on livestock production through impacts on the availability of animal feed, an impact which is considered further below.

For each vulnerable crop the impact of *A. artemisiifolia* is a function of the area of that crop where *A. artemisiifolia* is present and the resulting reductions in yield and/or additional actions required to address it. Different short-term and long-term actions can be identified.

3.5.1 Areas of crop impacted by *A. artemisiifolia*

The areas of crops impacted by *A. artemisiifolia* in the study area has been estimated taking into account the probability of *A. artemisiifolia* presence in an area, land cover, and the cropping patterns in different countries, within a GIS on a 5 km^2 grid (see Task 6). This is described in detail under control measures (Section 3.1.5) and the same area of agricultural land is used to estimate loss of crop yields in this Section.

3.5.2 Short-term costs of *A. artemisiifolia* in crops – loss of crop yield

The main short-term costs of *A. artemisiifolia* can involve loss of output (lower crop yields), and marginal changes to production systems such as additional applications of herbicide. Ideally, a cost curve would be estimated based on different levels of impact at different exposure levels to *A. artemisiifolia.* However, such curves would need to be constructed for each crop (or groups of similar crops), and the available data on levels of impact in individual crops do not allow this (see also Task 4, Section 6.4).

The value of yield affected by ragweed was calculated by multiplying the crop area affected by the yield of each crop in each country (data from FAOSTAT). This was then multiplied by the estimated yield loss from the presence of ragweed to get a total yield loss. The percentage loss of crop yield was estimated from a range of available data (see Task 4, Section 6.4). This suggested a typical loss of yield of around 50% if ragweed is uncontrolled. It was assumed that control measures (e.g. herbicide treatment) are undertaken where it is present, and therefore that this loss is reduced.

The typical reduction in yield loss as a result of using control measures is unknown, so it was estimated that is would halve the loss of yields. Therefore an assumed loss of 25% of crop yield was used in the calculations. Residual loss of output is therefore calculated at a fixed level from the expected loss of crop yield (tha^{-1}) due to *A. artemisiifolia* presence.

Table 5.9. Prices of agricultural crops affected by *A. artemisiifolia* across Europe.

	Soft wheat	**Maize**	**Sorghum**	**Sun flower**	**Soya**	**Sugar beet**	**Green peas: all qualities**	**Main crop potatoes**	**Rape**	**Other crops mentioned**
	€2009 prices per 100 kg (source: Eurostat)									
Austria	8.32	9.63	:	15.71	25.18	26.33	:	9.86	20.86	Pumpkin, beetle bean, summer and winter cereals, sudan grass, alfalfa, buckwheat
Belgium	11.05	:	:	:	:	30.51	:	6.22	:	
Bulgaria	10.76	10.68	14.42	19.59	41.98	28.33	59.68	:	27.4	
Croatia*		10.41		21.12	26.43	28.50				
Czech Rep	10.93	10.59	:	26.80	:	29.20	:	12.49	26.87	
Denmark	12.09	:	:	:	:	42.17	:	23.10	25.34	
France	11.11	10.90	:	24.71	30.23	30.23	52.69	20.56	29.68	
Germany	11.26	12.07	:	:	:	:	164.84	11.11	26.09	Cut flower crops
Hungary	10.62	10.41	11.52	21.12	26.43	:	107.15	17.10	25.54	
Italy**	15.38	13.13	:	23.28	29.26	33.53	:	34.36	:	Various other cereal crops
Latvia	11.31	:	:	:	:	44.21	:	13.45	23.93	
Moldova										Vineyards/orchards
Poland	11.16	10.33	:	:	:	26.73	:	9.37	25.01	
Romania	11.09	15.80	:	20.28	22.64	30.66	97.88	28.77	22.88	
Serbia$^{\alpha}$	10.86	13.11		20.70	24.54	30.66	102.52	22.94		Alfalfa, beans, onion, vine, apple orchards, vines
Switzerland										
Ukraine$^{\beta}$		15.80		20.28	22.64	30.66			22.88	Cereals, legumes

Key. blank = not applicable or real zero or zero by default : = not available
Notes:
* Unavailable on Eurostat, Uses prices from Hungary for Maize, Sunflower and Soya and average price between Austria and Romania for Sugar Beet.
** Unavailable on Eurostat. Uses average of available prices from all countries prices available on Eurostat
$^{\alpha}$ Unavailable on Eurostat. Uses average prices from Hungary and Romania on wheat, maize, sunflowers, soya, green peas, and potatoes, used Romanian price for Sugar beet.
$^{\beta}$ Unavailable on Eurostat. Uses Romanian prices.

This output loss is valued according to the current market price of the crops in $€t^{-1}$. Table 5.9 shows the November 2011 Eurostat market prices of crops for which *A. artemisiifolia* impacts have been identified. *A. artemisiifolia* is a bigger risk factor in row crops (where plants are sown with space between them) than in (much denser) cereals (Task 4, Section 6.2). The countries where impacts from *A. artemisiifolia* have been identified are highlighted for each crop. Not all crop/country combinations where there have been impacts have relevant price data, so these data have been estimated from the most comparable data within the set (as described in the Table footnotes). The data for producer prices are given in USD 2004-06, and are converted to Euros using 2005 conversion rates from World Bank data (0.805) and inflated to 2011 value from 2005 using HICP inflator values obtained from Eurostat (115.3%).

It should be noted that market prices for crops can be volatile and, particularly for modelling impacts in 2032, represent a significant source of uncertainty. Projections by the FAO suggest a 70% growth in food production will be needed by 2050[11]. Therefore it is unlikely that the value of crops will fall in future. Sensitivity analysis in Section 7 will consider the extent of future crop value increases.

A further consideration is that if ragweed had very significant effects on production, this could also influence prices. However, this potential impact has not been allowed for as ragweed effects are not expected to be of this order of magnitude.

3.5.4 Long-term costs of *A. artemisiifolia* in crops

In the longer-term, changes to production systems may be fundamental, such as adoption of different tillage systems or changes to crop types. Expert analysis by RAC suggests some potential changes to production systems in response to the presence of *A. artemisiifolia* include (see also Task 4, Section 6.5):

- The use of mechanical weeders in row crops. Crops managed in this way usually have relatively high value (or at least higher profitability) so farmers are more likely to be able to meet the capital costs of mechanical weeders. A typical 12 m weeder is expected to cost €12-14,000 new or €6-7000 second hand (4 to 5 years old). If a machine lasts 10 years and can service a 200 ha farm this equates to an approximate cost €6.5 ha^{-1} per year. However, it is noted that there is an opportunity cost to investing in this capital equipment, and that if borrowing is required to fund its purchase the costs may be more than this. Operating costs including fuel and labour are estimated to be €30-32 ha^{-1}, giving total costs of around €37.5 $ha^{-1}yr^{-1}$. Organic farming systems are highly likely to already be using mechanical weeders, and therefore the costs of *A. artemisiifolia* are the costs of additional use of mechanical weeders as a result of its presence.
- Changes to crop rotations to reduce the risk of *A. artemisiifolia* infestations. This might involve less frequent cultivation of row crops, and/or more alterations between winter and spring sowing. Row crops are usually more profitable than non-row crops, with the exception of sunflower and maize where oilseed rape and other small grain cereals could substitute and perform equally as well. A further consideration would be the savings a farmer could make on labour, building and machinery costs from switching away from

[11] Bruinsma (2009) and http://www.fao.org/ag/save-and-grow/en/1/index.html

produce that will need to be packed or stored or would need specialist machinery to sow or harvest. A switch away from potatoes, sugar beet or field vegetable crops with combinable crops, will drop gross margins by €400-500 ha^{-1}, but this might be offset by the savings mentioned above. The costs of such changes are very difficult to model and the likelihood of such changes will be dependent on individual farm circumstances. It is also possible that these changes may be made in response to drought which may occur more frequently in the future under climate change. If this is likely to happen, the costs should not be attributed to *A. artemisiifolia* as the cost would be incurred without the presence of *A. artemisiifolia*.

- A switch to permanent crops would avoid the annual cultivation which allows *A. artemisiifolia* establishment; however again this would depend on profitability and individual farm circumstances. Some fuel crops such as Miscanthus and coppice willow would be effective at smothering *A. artemisiifolia* and only need to be replanted every 20 years; however harvests are not produced until year 4. Grass or forage crops could also be grown; the profitability will depend on the animal enterprises using them. High yielding, well managed dairy herds may be profitable enough for farmers to switch to forage crops; however low input sheep or beef are unlikely to be profitable enough.
- The potential use of 'Roundup ready' crops. Crops which are bred/engineered to be resistant to 'Roundup' (glyphosate), could be used together with applications of glyphosate in response to ragweed.
- Zero-tillage systems, for example direct drilling and strip tillage (tilling only the portion of soil that is to contain the seed row). Direct drilling will only be suitable for commodity crops such as cereals, oilseeds, etc. and strip tillage might be considered for row crops grown on the flat, but not where ridges or beds are required (e.g. potatoes and carrots). Only soils with natural structure (e.g. self-structuring clays) are suitable for these methods; silts and light sands will need subsoiling (the process of deep tilling of the ground to 30-35 cm depth) regularly which will increase costs. These methods may lead to an increase in grass weed control methods (herbicide spraying) in cereals, and a need to apply extra slug pellets. The benefits of direct drilling are largely down to time saving and decreased fuel use but there has been mixed results in the UK with farmers reporting that the saving made by not ploughing is offset by more passes with the sprayer and increased slug pellet use. Similar to crop rotation, the use of zero and strip tillage methods may be used in response to drought. Again, should this happen, the added costs of using these methods should not be attributed to *A. artemisiifolia* as these actions would not be additional.
- Hand-pulling of weeds might be used, but is only effective at low population levels. Where there are more than 400-500 *A. artemisiifolia* plants ha^{-1} the damage done to the crop would probably outweigh the benefits of hand-pulling.

3.5.5 Mitigated and unmitigated costs of *A. artemisiifolia* in crops

The overall short-term and long-term costs of *A. artemisiifolia* in crops will be different depending on the responses to *A. artemisiifolia* adopted by farmers. If *A. artemisiifolia* occurs at low densities in areas where environmental conditions are such that it is unlikely to germinate and persist, farmers may not choose to take mitigation measures. However, in many areas farmers would be expected to take mitigation measures. There is therefore a difference between the mitigated and unmitigated impacts of *A. artemisiifolia*.

The unmitigated impact is the loss of crop yield when no mitigation measures are taken. The mitigated impact is the cost of mitigation measures, plus the residual loss of crop yield where mitigation is not 100% effective.

Whether farmers undertake control measures to mitigate the impact of *A. artemisiifolia* depends on advice and information they have been given. This in turn is influenced by control rates required to prevent spread and the probability of persistence in local environmental conditions (as described above). Farmers (and/or the advice they are given), are assumed to be rational, and to be averse to risks of loss of crop yields, so we expect farmers to implement controls wherever ragweed occurs at a noticeable density (even if it might not persist and if the value of crop losses were less than costs of control).

Therefore farmers would be expected to tackle ragweed with aggressive control measures, and therefore loss of yield may be low, but treatment costs (e.g. chemicals, machinery, labour) would be high.

3.5.6 Additionality of ragweed impacts in arable systems

In estimating the impacts of *A. artemisiifolia*, it is important to consider the additionality of the costs involved. As Athan (2005) points out, in assessing the additional impact of invasive alien weeds, consideration must be given to interactions with native weeds. Each of the major short-term costs (such as reduced crop yield, herbicide treatments), are already features of arable weed-control decisions. Therefore the impacts of *A. artemisiifolia* are the extent to which more of these activities are undertaken as a result of its presence.

This requires information on how much *A. artemisiifolia* displaces the impacts of existing (native and established non-native) weeds. Competition between weed species is a very complex area; it has been the subject of years of extensive analysis and simple rules to use in modelling have not been established (Cousens and Mortimer, 1995; Kim *et al.* 2006).

A. artemisiifolia will partly displace existing weeds, and partly create new problems. Separating these impacts is not feasible within our modelling. This analysis estimates the additional short-term costs of treating *A. artemisiifolia* compared to when it is not present through simplifying assumptions (e.g. that one extra herbicide application is required to tackle *A. artemisiifolia*).

For longer term responses, additionality is also an important question, but is more complex as the baseline may shift. Actions in response to *A. artemisiifolia* that are not currently being undertaken (e.g. different tillage methods, changes to crop rotations) are potentially additional, but also are potentially actions that will be undertaken anyway in response to other pressures. For example, climate change, other weeds, or other factors may necessitate a change to agricultural systems. In these cases gross costs can be calculated and a certain proportion of impact (50% - 100%) assumed to be additional.

3.6 Ragweed impacts on other relevant economic sectors – leisure and tourism

The presence of *A. artemisiifolia* at high densities in an area could have several different significant implications for leisure activities:

- In could deter people from visiting an area for leisure purposes in order to avoid the health impacts of exposure to *A. artemisiifolia*. This is most likely where people are aware of their sensitivity to it, and of whether they will be exposed to it in a certain location.
- It could cause welfare losses due to health effects or reduced enjoyment of leisure activities. This is most likely where people are unaware of their sensitivity to it, and/or of whether they will be exposed to it in a certain location. Note that some of these health impacts will not be additional (to people already suffering health impacts from *A. artemisiifolia*). Additional impacts are most likely for those travelling from areas where they are not exposed to *A. artemisiifolia* pollen, to areas where they are exposed (e.g. from Northern to Southern Europe for summer holidays).

These effects would be expected to be seasonal in line with the timing of pollen-production. As this could coincide with peak summer-holiday times, this could potentially have serious consequences for leisure and tourism activity in affected areas.

The impact would relate to the minority of the population susceptible to *A. artemisiifolia* pollen. However, as many leisure activities are undertaken by groups of people (e.g. families), the need for individuals to avoid *A. artemisiifolia* exposure could deter a much larger proportion of the population from undertaking leisure activities in an area.

It must be noted that, as with other impacts, the additional impact of *A. artemisiifolia* must be identified. Allergic reactions to other plant pollens may already shape the leisure activities of those susceptible to *A. artemisiifolia* pollen. However, Section 3.2 estimates the additional percentage of population experiencing health effects, so important impacts on the leisure and tourism sectors are considered a real possibility.

There is no evidence of *A. artemisiifolia* impacts on leisure and tourism (Task 4, Section 7), so no costs are calculated for this sector.

3.7 Ragweed impacts on the construction, transport and building infrastructure

Potential impacts from *A. artemisiifolia* are suggested in relation to the following activities:

- Construction and maintenance of transport infrastructure;

- Workforce health, and
- Changes to capital land values due to the presence of invasive species.

The main impacts identified in relation to these activities to date relates to control costs, which are described in Section 3.1, and workforce issues related to the health impacts discussed in Section 3.2. Overall there is very little evidence that *A. artemisiifolia* has impacts in transport, construction and infrastructure activities (Task 4, Section 7).

In theory, impacts from *A. artemisiifolia* could arise from controls required or workforce effects due to its presence at a construction site, or from workforce effects due to exposure to pollen from off-site populations.

We communicated further with the Serbian and Croatian national experts about possible impacts. Both suggest that *A. artemisiifolia* is not a problem in construction even in areas where it is spreading rapidly. In general, construction projects are not long enough for *A. artemisiifolia* to arrive, establish and produce pollen, and therefore to affect the workforce. There are instances of *A. artemisiifolia* arriving at construction sites through seeds transported via machinery and building materials. In these cases control measures may be required for *A. artemisiifolia* after completion of construction work.

Employer liability for workforce health effects due to exposure to pollen from on-site *A. artemisiifolia* is reduced by the high mobility of the pollen. This makes it impossible to shield the workforce from exposure in areas infested by *A. artemisiifolia*. It is possible that transport on equipment means that infestation only affects a building site and not the local area. However, equipment is very expensive to move, and *A. artemisiifolia* is highly mobile, so the scenario in which construction workforce exposure is mainly due to on-site presence of *A. artemisiifolia* is considered unlikely.

This suggests that on-site *A. artemisiifolia* is not usually a significant problem in the construction sector. However, construction projects can run for more than one year, therefore making *A. artemisiifolia* colonisation and workforce impacts more likely. The main risks in relation to construction activities may be in long term projects which keep the ground disturbed for more than one year. Such projects are likely to involve major infrastructure.

Nevertheless, there may be implications for these sectors, and other industries with a workforce operating outdoors, due to lost work productivity as a result of exposure to *A. artemisiifolia* generally (i.e. not specifically from on-site sources); see Section 3.2.7. This impact will arise to the extent that the susceptible workforce does not seek, or does not respond to, treatments for allergic reactions.

3.7.1 Changes to capital land values

Where control of *A. artemisiifolia* is required this can affect land values. Land being developed can be susceptible to *A. artemisiifolia* colonisation, for example when:

- Arable land is left fallow before development commences, and
- Disturbed earth is left for long periods during major construction projects, or when projects are suspended due to changes to economic conditions (e.g. as during the recent property market and economic downturn in Europe).

Over periods of time colonisation and therefore control requirements can become a liability associated with the land. This could reduce land values compared to areas not colonised. No evidence is available of this impact, and its costs have not been estimated.

4 Gaps in costs evidence

The analysis in this Task has identified a large number of gaps in economic knowledge and assumptions which are highly uncertain. In the main these relate to the need to establish a dynamic model that assesses the additionality of impacts of *A. artemisiifolia* and takes into account long-term responses of human systems to its presence. It should be noted that this is, to our knowledge, the first attempt to assess or model the economic impacts of an invasive species completely and transparently (e.g. not simply report costs of control). Thus, the gaps in evidence and knowledge are not surprising.

Key gaps in the economic evidence include:

Additionality

It is important that analysis of the impacts of *A. artemisiifolia* identifies the additional impacts it causes. Additionality is very difficult to assess in each of the major areas of impact analysed:

- Understanding the additionality of the human health impacts of *A. artemisiifolia* compared to other allergens is difficult as sensitisation data from different parts of the study area are compiled using different methods and this makes it hard to derive modelling assumptions. Assumptions are further complicated due to the possibility that *A. artemisiifolia* exposure increases sensitisation to other allergens.
- The additionality of impacts of *A. artemisiifolia* on cropping systems requires knowledge of interactions among different agricultural weeds. These have been studied for many years, but standardised rules suitable for use in modelling are not yet available.
- The additionality of control activities is similarly complicated to understand due to the interactions of different weed species that can be tackled through similar control requirements.

The assumptions used in the modelling are the best estimates of the additional impacts of *A. artemisiifolia,* but could be improved with greater knowledge in the areas above.

Exposure curves

In the analysis of both human health and agricultural impacts, the costs have been calculated using single point estimates of costs generated by the presence of *A. artemisiifolia*. This can be a reasonable assumption, if responses to *A. artemisiifolia* presence are assumed to be a simple on-off reaction (actions are either taken or not). In this case the costs of action are fixed.

However, in reality the extent of control options are a response to the extent of *A. artemisiifolia* impacts, and hence a curve linking the extent of *A. artemisiifolia* presence and the level of costs incurred would be a more realistic model. Constructing these curves is complex, and at present insufficient information is available to do so.

For example, in arable systems such curves would need to be constructed for each crop (or groups of similar crops), and the available data on levels of impact in individual crops do not allow this. For human health impacts, modelling would be needed of the different extent of pollen density exposure of the population across the study area, and how rates of sensitisation and severity of allergic symptoms vary in response to this.

Loss of QALY

Quality adjusted life years (QALYs) provide a quantified measure of health impacts on quality of life and can be valued through data on the average value of a QALY. Loss of quality of life (e.g. reduced sleep) can clearly be identified within the health impacts of *A. artemisiifolia*. However, this impact has not been quantified in terms of QALYs, and therefore valuation of health effects of in this way is not currently possible.

Cropping patterns

The modelling assumes that *A. artemisiifolia* presence occurs in all crops to an equal extent, and that choices of crops are not influenced by the presence of *A. artemisiifolia.* Both these assumptions could be revised with better information.

There may be relationships between the risk of *A. artemisiifolia* invasion and crop types. For example, some crop types may be more prevalent under environmental conditions more conducive to *A. artemisiifolia*, or their cultivation methods may make them more susceptible to invasion.

In reality, at high densities of invasion, agricultural systems would be expected to be adapted to respond to ragweed presence (e.g. by changing crops or adopting continuous cover agricultural systems). Such adaptations are difficult to predict, particularly as over long time periods (20 years or more) they will occur against an uncertain dynamic baseline of agricultural change in response to climate change, food security needs and policy.

Leisure and tourism impacts

There is little knowledge on whether *A. artemisiifolia* presence is influencing (or may influence) people's choice of locations for undertaking recreational activities, or the benefits they derive from recreation. Any impact of this kind could have important consequences for leisure and tourism sectors across the study area.

Relationship between controls and costs

The analysis looks at a 'controls on' scenario in which control measures are undertaken but residual impacts of *A. artemisiifolia* persist. This is compared to a 'controls off' scenario. These two scenarios can be viewed as opposite ends of a scale of 0 to 1 reflecting the extent to which controls are undertaken. Intermediate points on this scale could have their impacts estimated. For example, at point 0.5, control costs and impacts might each be 50% their totals). This assumes a linear relationship between control effort and both control costs and impacts. However, this relationship is unlikely to be linear; there are likely to be important fixed costs associated with control strategies (so marginal control costs may decline over relevant ranges) and the benefits of control may also be nonlinear (for example with thresholds for certain damages), but further work is needed to understand its functional shape. Without knowledge of this function, it is not possible to examine an optimisation of control efforts.

Land use patterns

There is a gap in knowledge as to whether the presence of *A. artemisiifolia* will change land use practices. In turn, these changes, or control requirements associated with *A. artemisiifolia*, could change land values, especially for land zoned for development. Potential impacts on land values are also not understood.

5 Modelling costs of ragweed impacts

This section reports how the economic evidence from the preceding Sections has been used to calculate the potential costs of ragweed in Europe. The calculations have been constructed in an excel-based model at a country level, and then summed across the study area.

The economic results have been produced for the following scenarios taken from the modelling of ragweed spread in Task 6. The control scenarios are taken from Task 6, Section 6.

Current situation reflecting distribution mapping based on 1990-2010 data, and representing the current impacts of *A. artemisiifolia* in the study area.

Future uncontrolled using predictions from the distribution modelling when no controls in place to represent the impacts of *A. artemisiifolia* in 2032 without any additional actions being taken to control its spread.

Future controlled (based on the 'Dynamic control modelled in Task 6, Section 6) using predictions from the distribution modelling to represent the impacts of *A. artemisiifolia* in 2032 given that a programme of action to control its spread (plant controls are undertaken in the 5% most invadable grid cells in the current year and restrictions on seed imports are in place).

These analyses were undertaken for a future date of 2032 because it gives a time-point when:

- It is realistic for control strategies to have taken effect.
- It is a reasonable long-term period over which to model economic costs. Over much longer timescales, economic modelling becomes highly uncertain.

Important information is generated for decision-makers through comparisons between these scenarios. For example the difference between the ***Future controlled*** and ***Future uncontrolled*** scenarios represent the benefits of control, which can then be compared to the costs of control.

The mapping work from Task 6 is the basis for all the subsequent analysis, as maps of current and predicted future (2032) extent of ragweed in Europe have identified in which areas impacts arise. The ‘extent’ of ragweed needs to reflect not just its presence, but its presence at a sufficient density to produce impacts. This is reflected in the population spread modelling that includes not only the expected extent of *A. artemisiifolia,* but also environmental conditions that allow it to persist and flourish. This is described in more detail in Task 6.

The modelling outputs for 2032 were done for a scenario reflecting current climate conditions, and for three future climate scenarios from Task 6 (refer to that chapter for a full description). It is not feasible to compare the results of all climate and control options. For the scenarios including climate change, the results presented are the mean of the three values used, with the maximum and minimum values given in parentheses.

All the data from the calculations cannot be presented in this report. To illustrate the calculations, they have been described for one country (Italy) in more detail in Annex 9.

6 Results

6.1 Current economic costs of impacts of A. artemisiifolia *in the study area*

We estimated the current costs of *A. artemisiifolia* in terms of human health and agriculture in the study area as a whole (the EU27, Albania, Belarus, Bosnia and Herzegovina, Croatia, Kosovo, Macedonia, Moldova, Montenegro, Norway, Russia, Switzerland, Turkey, Ukraine) and specifically for the EU27. All the costs are in Euros at 2011 prices. Future costs have been discounted to 2011 prices at a rate of 3.5%.

The human health impacts are estimated to affect between 0.84 and 4.18 million people, and estimated to cost between €288 and €1,442 million per year over the study area (Table 5.10). Within the EU these figures are 0.42 and 2.09 million people, and estimated to cost between €143 and €714 million per year (Table 5.10).

Table 5.10. Total estimated medical costs due to *A. artemisiifolia* in the study area in 2011.

(€ million, 2011)	Medication Costs	Treatment Costs	Total Costs
Medical impact scenario			
Small % of the population experiencing health impacts (2%)	253	35	288
Medium % of the population experiencing health impacts (5%)	633	88	721
Large % of the population experiencing health impacts (10%)	1,265	177	1,442

Table 5.11. Total estimated medical costs due to *A. artemisiifolia* in the EU in 2011.

(€ million, 2011)	Medication Costs	Treatment Costs	Total Costs
Medical impact scenario			
Small % of the population experiencing health impacts (2%)	127	16	143
Medium % of the population experiencing health impacts (5%)	317	40	357
Large % of the population experiencing health impacts (10%)	635	79	714

The estimated number of workers experiencing additional medical impacts from ragweed was estimated as between 397 to 991 million in the study area, and 195 to 487 million in the EU. The costs of productivity losses from these impacts on the workforce are shown in Table 5.12.

Valuing impacts based on GVA produces a much higher estimate, particularly within the EU. The broad range between the high and low estimates reflects the high uncertainty in this calculation.

Table 5.12. Total estimated workforce productivity costs due to *A. artemisiifolia* in the study area and EU in 2011.

(€ million, 2011)	Study Area		EU	
	Low Estimate	High Estimate	Low Estimate	High Estimate
Valued by GVA/ worker	178	1,480	164	1,361
Valued by average wage rate	67	529	49	388

The agricultural impacts in the study area are estimated t357o effect 17.8 Mha of cropland (approximately 10% of the total), and 20 million tonnes of harvest. The agricultural impacts in the EU are estimated to involve 7.2 Mha of cropland (approximately 8% of the total), and 8.4 million tonnes of harvest. The costs of lost yield are shown in Table 5.13 below. It should be noted that over half of the EU costs are estimated to occur in just two countries (Hungary and Romania).

Table 5.13. Total estimated agricultural costs due to *A. artemisiifolia* in 2011.

(€ million, 2011)	Study Area	EU
Agricultural Impacts	3,559	1,846

In addition the agricultural impacts could extend to the livestock sector through impacts on crops that can be used as animal feed. *A. artemisiifolia* could cause lost yields for these crops, estimated to be 2.2% of their total production and contaminate 6.5% of their total production, in the study area. In the EU this is estimated to be 1.6% of their total production and potential contamination 4.8% of their total production.

The estimated total agricultural, workforce productivity and human health costs are shown in Table 5.14. These data are based on the mid-range (5%) health impact assumption, and the lower estimate of the % of an affected workers' productivity loss (1.5%). **The total impacts across the study area are valued at €4.46bn per year, with €2.37bn (53%) being within the EU. Over 80% of these impacts are lost crop yields.**

Table 5.14. Estimated agricultural, human health, workforce and total costs by country, 2011.

€ million, 2011	Agricultural	Medical	Workforce Productivity	Total
Albania	7.0	1.0	0	8.0
Austria	56.0	17.8	9.4	83.2
Belarus	1.0	0.2	0	1.2
Belgium	-	0.0	0	0.0
Bosnia and Herzegovina	73.0	13.9	0.6	87.5
Bulgaria	175.0	25.8	1.5	202.3
Croatia	88.0	30.5	3.8	122.3
Czech Republic	3.0	1.1	1.8	5.9
Denmark	-	0.1	0	0.1
Estonia	-	0.0	0	0.0
Faroe Islands	-	0.0	-	0.0
Finland	-	0.2	0.1	0.3
France	170.0	54.3	23.9	248.2
Germany	34.0	21.8	11.7	67.5
Greece	17.0	0.6	0.2	17.8
Hungary	436.0	75.8	93.2	605.0
Ireland	-	0.0	0	0.0
Italy	190.0	25.1	8.9	224.0
Kosovo	-	8.2	-	8.2
Latvia	-	0.0	0	0.0
Lithuania	-	0.0	0	0.0
Luxembourg	-	0.0	0	0.0
Macedonia	-	2.7	0.1	2.8
Moldova	110.0	43.4	0.5	153.9
Montenegro	1.0	0.3	0	1.3
Netherlands	-	0.0	0	0.0
Norway	-	0.1	0	0.1
Poland	11.0	4.7	0.6	16.3
Portugal	1.0	0.0	0	1.0
Romania	657.0	104.1	7.2	768.3
Russia	203.0	57.1	3.5	263.6
Serbia	339.0	36.0	0.9	375.9
Slovakia	76.0	19.7	3.6	99.3

€ million, 2011	Agricultural	Medical	Workforce Productivity	Total
Slovenia	12.0	4.8	1.2	18.0
Spain	9.0	0.4	0.1	9.5
Sweden	-	0.7	0.4	1.1
Switzerland	3.0	1.1	0.8	4.9
Turkey	64.0	0.6	0.1	64.7
Ukraine	823.0	168.9	3.8	995.7
United Kingdom	-	0.0	0	0.0
TOTAL	**3,559**	**721**	**178**	**4,458**

6.2 Potential current monitoring and control costs for A. artemisiifolia *in the study area*

Control costs for the study area were estimated for agricultural and urban areas. This assumed that controls were undertaken on all affected cropland through one additional application of herbicide. Good agricultural data helped inform this model. A theoretical model of urban plant control was developed. This was necessary due to a lack of robust data in this area, and gives an indicative cost of this activity.

Monitoring costs were partially estimated for the study area (Table 5.15) in relation to:

- The need to communicate about *A. artemisiifolia* risks with three key sectors (agriculture, construction and households), estimated to cost at least €7.2m per year, and
- Developing a citizen science reporting process, with one-off establishment costs of €4.1m, and annual costs of €2.7m.

Table 5.15, Monitoring and control costs in the study area and EU, based on current spread of ragweed.

€m 2011/ year	Monitoring	Agricultural Control	Urban Control	Total Monitoring and Control
Study Area	Communications: €7.2m Citizen science: (One-off setup: €4,1m) Annual operation: €2.7	386	0.04 – 2.71	389
EU		179	0.02 – 1.55	179

The urban control data are a rough estimate of the costs of this activity. As a sense check, the cost can be compared to the 113 grid squares of 5 x 5 km in the spatial modelling in which these controls are undertaken (as part of a strategy to target the 5% most vulnerable cells in terms of ragweed colonisation). The high end costs of €2.71m are equivalent to €24,000 per square per year. This is roughly the employment and machinery cost of one full time person undertaking ragweed controls. Given that these controls are only needed in around 3 months of the year, this can be thought of as a team of 4 full-time staff undertaking ragweed control in a 5 x 5 km area. This seems realistic, as it would be expected such efforts would have an impact on the spread of ragweed, in line with the spatial modelling results. Therefore the higher costs are used to represent the best indication of potential urban control costs.

6.3 Future economic costs of impacts of A. artemisiifolia *in the study area*

The estimated future costs of *A. artemisiifolia* in terms of medical treatment, work productivity and agriculture in the study area in 2032 with and without controls in place are shown in Tables 5.16 and 5.17. The workforce productivity data are based on the calculation using 1.5% of annual work time lost, and that values lost time with GVA per worker.

The data show that without controls, the influence of climate change is predicted to worsen the medical and work productivity costs, but the agricultural costs reduce. This suggests that climate change decreases the agricultural area, but increases the population, impacted by ragweed. The decrease in agricultural impacts is examined in Task 6, Section 4.6, and occurs mainly outside the EU where modelling data is less certain, so this result has greater uncertainty. However, this means that the climate change impact is more significant in the EU than in the study area as a whole (Table 5.17). The impact of climate change is therefore that it makes the impacts in the EU greater as a proportion of the total impacts in the study area. This reflects the productivity impact within the EU, and impacts on agricultural areas to the north of ragweed's current range in the EU.

As a result of this population impact increase, workforce productivity impacts rise by significantly more than medical costs. This is due to more impacts occurring in countries which have substantially higher GVA/worker. In particular, climate change will increase the workforce exposed to ragweed in Germany by over 200,000.

The effect of controls is to reduce the predicted costs substantially. This reduction is greatest when climate change is included in the model. This is unsurprising, as climate change shifts the geographical range of ragweed its impacts in some locations will decrease, but controls will reduce its ability to colonise, and cause impacts in, new locations.

Table 5.16. Total estimated costs due to *A. artemisiifolia* in the study area in 2032 according to the specified scenarios.

(€ million, 2011)	**Medical Costs***	**Agricultural Costs**	**Workforce Productivity****	**Total Costs**
No controls, no climate change	315	2,242	128	2,685
No controls, climate change	438 (358 - 482)	1,979 (1,656 – 2,157)	379 (327 – 455)	2,796
Controls, no climate change	68	1,359	44	1,471
Seed import restrictions only, climate change	305 (245 – 356)	1,522 (1,304 – 1,721)	275 (236 - 317)	2,102
Urban control only, climate change	46 (33 – 59)	1,415 (1,173– 1,549)	41 (25- 56)	1,502
Controls, climate change	29 (21 – 42)	1,050 (905 – 1,198)	24 (13 – 38)	1,103
* % of population experiencing health impacts = 5% ** for sensitised workforce, average of 1.% of working year lost.				

Table 5.17. Total estimated costs due to *A. artemisiifolia* in the EU in 2032 according to the specified scenarios.

(€ million, 2011)	**Medical Costs** (popn. experiencing health impacts = 5%)	**Agricultural Costs**	**Workforce Productivity**	**Total Costs**
No controls, no climate change	123	987	93	1,203
No controls, climate change	296 (253 – 343)	1,243 (1,043 – 1,516)	340 (297 – 412)	1,879
Controls, no climate change	32	805	37	874
Seed import restrictions only, climate change	219 (184 - 243)	925 (784 – 1,061)	254 (220 – 247)	1,398
Urban control only, climate change	31 (21 – 41)	814 (595 - 926)	35 (21 - 37)	880
Controls, climate change	20 (12 – 29)	557 (403 - 693)	21 (11 – 33)	598

Tables 5.16 and 5.17 also show the effects of the two different parts of the control strategy modelled. For simplicity the mean value across the climate scenarios is shown (where relevant). This shows that the urban controls have the greatest effect: on its own seed import restrictions could reduce the expected impacts by around 25%, but urban controls alone could reduce impacts by around 50%. Unsurprisingly urban controls are more effective than a seed import restrictions against health and workforce productivity impacts (which will be greatest for larger populations, i.e. in urban areas). For agricultural impacts, the two control actions are more complementary.

Table 5.18. Estimated total costs by country, 2032, no controls including climate change.

€ million	Total current costs	Total undiscounted costs 2032, with climate change	Change in costs	% Change in Costs
Albania	8.0	4.1	-4.3	-51%
Austria	83.2	78.1	-13.4	-15%
Belarus	1.2	142.7	141.6	12,874%
Belgium	0.0	87.1	87.1	
Bosnia and Herzegovina	87.5	46.2	-41.7	-47%
Bulgaria	202.3	16.7	-167.9	-91%
Croatia	122.3	15.3	-105.2	-87%
Czech Republic	5.9	81.5	75.3	1,214%
Denmark	0.1	2.9	2.8	2,824%
Estonia	0.0	2.3	2.3	
Faroe Islands	0.0			
Finland	0.3	18.2	17.9	5,952%
France	248.2	1,000.8	717.8	254%
Germany	67.5	1,112.5	1,046.7	1,591%
Greece	17.8	0.7	-17.2	-96%
Hungary	605.0	42.3	-546.9	-93%
Ireland	0.0			
Italy	224.0	18.8	-221.5	-92%
Kosovo	8.2	2.9	-10.1	-77%
Latvia	0.0	1.8	1.8	
Lithuania	0.0	3.7	3.7	
Luxembourg	0.0	3.8	3.8	
Macedonia	2.8	0.1	-3.3	-98%
Moldova	153.9	17.3	-127.6	-88%
Montenegro	1.3	4.1	2.8	218%
Netherlands	0.0	15.4	15.4	
Norway	0.1	7.1	6.9	3,436%
Poland	16.3	793.3	777.1	4,797%
Portugal	1.0	0.2	-0.8	-77%
Romania	768.3	308.3	-423.8	-58%
Russia	263.6	705.5	460.0	187%
Serbia	375.9	73.4	-291.0	-80%
Slovakia	99.3	97.4	-4.0	-4%
Slovenia	18.0	20.1	0.7	4%
Spain	9.5	8.6	-1.3	-13%
Sweden	1.1	24.9	23.4	1,559%
Switzerland	4.9	120.3	114.4	1,939%
Turkey	64.7	0.0	-65.4	-100%
Ukraine	995.7	685.7	-198.9	-22%
United Kingdom	0.0	0.0	0.0	
TOTAL	4,458	5,564		
Assumptions are as in Table 5.15				

The distribution of changes across countries in the study area under a scenario with no controls in place but including climate change is shown in Table 5.18. These data represent averages of the three future climate scenarios used in Task 6, and reflects countries future agricultural and health risks if no controls of *A. artemisiifolia* are undertaken.

The data show some very high percentage changes, but these are not as informative as the absolute cost data, as they reflect change from a very low starting point. The data show significant increases in impacts in countries to the north of the current range of *A. artemisiifolia*, (e.g. Germany, France, Poland) and reductions within its current range, as climate change brings a northward range shift.

7 Sensitivity analysis

Sensitivity analysis examines how the results of the economic modelling would change if specific assumptions in the modelling were varied. A number of assumptions are subject to sensitivity analysis in the main areas of analysis:

Human Health

Two key aspects of the health calculation are tested using sensitivity analysis. Firstly, the assumption about the percentage of the exposed population that experiences additional allergic symptoms as a result of ragweed is modelled using three parameters (2%, 5% and 10%). The 5% figure is used to generate the models main results. As shown in Table 5.10, the other figures change the total medical and work productivity impacts proportionately; by -€433m (-60%) and €721m (+100%) respectively. These changes are equivalent to -9% and +16% of the total current impacts making this variable a significant one to the models results.

The medical costs are made up of two factors; the cost of medical consultations and the cost of medications. The latter account for just 12% of the total medical costs, so assumptions about the cost or frequency of medical consultations are not significant to the results. The cost of medications is more important: increasing it by 10% increases the overall medical costs by 10%. However, this only changes the overall results of the modelling by 1%, so is not significant to the overall results.

Agriculture

The majority of the modelled costs are in relation to agriculture, and therefore several assumptions are important here. The prices of crops have been very unstable in recent years. For each crop analysed in the model:

- The range of prices from the study area over the last 5 years was obtained from the same source as the current price data used in the model.
- The % variation between its maximum and minimum prices was calculated, and then halved to represent the effects of a possible food price spike.
- The model was recalculated using these maximum prices. The average price rise across the crops analysed was 55%[12].

The results show that a significant food price spike, in line with maximum recent price volatility, would substantially increase the potential costs of ragweed to agriculture, to €5.96bn from the estiamted €3.56bn in the current scenario, an increase of 40%. The future of agriculture prices is uncertain in the face of climate change and population growth. Therefore this level of price fluctuation is not inconceivable. In response to these changes agricultural systems would be expected to adapt (e.g. more weed control would take place to protect yields) so the results obtained may not be entirely realistic. However, the data demonstrate the importance of assumptions about crop prices in the model.

Another key assumption in the agricultural modelling is the extent of residual crop losses of 25%. The model assumes that additional herbicides are used once to tackle ragweed, but that this does not completely eradicate it, leaving residual impacts on the crop. The level of residual losses is a very complex question for which agronomists have no straightforward rules that would inform model assumptions (RAC pers comm). Data gathered through this study suggests potentially very high residual losses, but it is hard to know if this is typical in crops invaded by ragweed across the study area, or reflects more extreme conditions.

Varying the level of residual losses to 15% and 35%, varies the total crop losses by -€569m (-16%) to €1,425m (+29%); demonstrating very high sensitivity to residual crop loss assumptions.

Control Costs

The main variable in the control costs is in agricultural controls. They make up the majority of the estimated control costs, and at an estimated €386m, are over 10% of the value of the agricultural impacts of ragweed (€3,559m). Therefore, additional requirements for agricultural control measures can be significant in the context of the overall economic results.

Another variable in agricultural controls is the existence of organic land, for which controls using herbicides is not feasible. A likely alternative method of control on organic land, particularly for row

[12] Source: FAO Statistics Division, 29 May 2012.

crops, is with a mechanical weeder. Expert judgement (RAC pers comm and Nix, 2011) suggests that control using a mechanical weeder costs €37 per ha, which is over double the average costs of control using herbicide modelled in this study.

However, the percentage of organic land in the study area in generally low (being around 3% in the EU[13]). Therefore, while not allowing for different requirements for organic land in the agricultural controls model will underestimate the impacts, this is a small error (around 4%), which is within the ranges and uncertainties already present in the calculations. Therefore it is not considered a significant omission from the model.

8 High and low scenarios

As the preceding sensitivity analysis illustrates, there are a large number of assumptions in the economic modelling to which the results are sensitive. Therefore, to reflect this uncertainty in the conclusions, two scenarios with high and low assumptions have been constructed. These do not reflect the maximum and minimum costs that could be estimated from the models, but indicate a range within which impacts are expected to lie.

The assumptions varied in these high and low scenarios are shown in Table 5.19, and the results are in Table 5.20. They give what is considered a realistic range for the models results, at between 33% less and 100% more than the central results from Section 6. The breadth of this range reflects the significant uncertainties involved in constructing the calculations.

Table 5.19. Range of assumptions used to estimate high and low scenarios.

Assumption	Central Assumption in Modelling	Low Scenario	High Scenario
Health impacts			
% of population with additional allergic symptoms as a result of exposure to ragweed	5	2	10
Number of medical consultations per patient	2	1	3
Cost of medical treatment per patient (€/yr)	303	273	333
Incidence of agricultural impacts across crop types	Evenly distributed	Lowest value crops	Highest value crops
Food prices	Current price data	Minimum and maximum of last five years volatility	
Work productivity – loss of annual work time	Range	1.5%	5%

[13] Eurostat, Certified Organic Crop Area http://epp.eurostat.ec.europa.eu/portal/page/portal/agriculture/data/database

Table 5.20. Total estimated medical, workforce and agricultural costs due to *A. artemisiifolia* in the study area in 2011 according to the specified scenarios.

(€ million, 2011)	**Medical Costs** (popn. experiencing health impacts = 5%)	**Agricultural Costs**	**Workforce Productivity**	**Total Costs**
Study Area High	1,537	6,002	1,480	9,019
Study Area Central	721	3,559	178	4,458
Study Area Low	237	2,645	67	2,949
EU High	763	3,307	1,361	5,431
EU Central	357	1,846	164	2,367
EU Low	118	1,302	49	1,469
The figures are based on a scenario with no controls of Ragweed in place, including the effects of climate change				

9 Conclusions

This Task has described the construction of an economic model of the costs of ragweed in Europe. The model is subject to significant assumptions and uncertainties. Costs have been estimated in relation to:

- Control costs, involving additional applications of herbicides within agricultural systems, and control of ragweed in urban areas;
- Farming, in relation to loss of crop yields (residual to the application of herbicides);
- Human health, in relation to increased costs of medication and of medical staff time to give treatment;
- Workforce productivity, in relation to the lost work time when workers suffer allergic symptoms; and
- Monitoring effort, involving information campaigns and establishing citizen-science reporting methods via the internet.

The current agricultural costs are estimated to be of the order of billions of Euros per year, and the current health and workforce productivity costs are estimated to be of the order of 100s of millions of Euros per year. These costs are large, but are not unexpected in the context of previous economic analysis of the costs of invasive species in Europe. The analysis by Kettunen *et al*. (in Shine *et. al.*, 2011) identifies costs for invasive species in Europe of €12bn/yr, around three-quarters of which is damage costs, the remainder being costs of controls. However, they state that these figures are a significant underestimate. Given the extent of ragweed in the study area, the fact that it results in both human health and agricultural costs, and our attempt to analyse costs comprehensively, impacts of billions of Euros are considered realistic.

Actions to control ragweed include agricultural herbicide applications (cost estimated at over €300m per year) and controls costing up to €2.7m per year on the, up to, 3,400 ha of land in urban areas in the 5% of the study area most vulnerable to ragweed colonisation. This urban control cost is highly uncertain, but is a key part of a ragweed control strategy (see Table 5.15).

As Table 5.21 demonstrates, within the model control strategies present highly cost-effective management options. The difference between the costs of ragweed in 2032 under controlled and uncontrolled scenarios is estimated at €1.5bn per year, against annual control costs of under €0.4bn. This modelling is sensitive to several key assumptions, and therefore the range of figures (-33% to + 100%) in Table 5.20 most be considered. Even if the costs were 33% lower, the gains from control, at around €1bn/yr in 2032, would still outweigh current control costs even if they doubled to €0.78bn/yr. Therefore, the cost-effectiveness of undertaking a control strategy for ragweed seems robust, even in the context of the considerable uncertainties present in the model.

Table 5.21. Summary of economic modelling results for whole study area.

(€ million, 2011)	**Key Sensitivities**	**Current**	**2032 with Climate Change**	
			Uncontrolled	**Controlled**
Impacts	Central figures (low – high scenario)			
Medical costs	% of exposed population with additional symptoms due to ragweed exposure	721 (237 – 1,537)	438	29
Agricultural costs	Residual loss of crop yield after herbicide treatment	3,559 (2,645 – 6,002)	1,979	1,050
Workforce productivity	Additional effects of ragweed on worker productivity	178 (67 – 1,480)	379	24
Total		4,458 (2,949 – 9,019)	2,685	1,103
Controls				
Agricultural	Additional herbicide treatments required	386	-	138
Urban	% of urban area requiring controls	Up to 2.7	-	9.1
Total control costs		389		147
Key unquantified impacts	Impacts on construction and leisure and tourism sectors. Costs of restrictions on seed trade.			
Total costs of impacts and controls		4,759	2,685	1,150
Note: 2032 prices are discounted to 2011 prices, and therefore can be compared to current control costs, but not to current impacts.				

The data in Table 5.22 supports the same conclusion for the EU only: the difference between the costs of ragweed in 2032 under controlled and uncontrolled scenarios is estimated at approximately €700m per year, against current annual control costs of under €200m. In 2032, although agricultural impacts still dominate, the urban impacts in the EU become more significant. Both the urban control costs and the workforce impacts without controls increase in relative importance. It is also interesting to note that the current annual control costs for the entire study area are less than the annual benefits from control in 2032 for the EU only.

Table 5.22. Summary of economic modelling results for the EU.

(€ million, 2011)	Key Sensitivities	Current	2032 with Climate Change	
			Uncontrolled	Controlled
Impacts	Central figures (low – high scenario)			
Medical costs	% of exposed population with additional symptoms due to ragweed exposure	357 (118 – 763)	296	29
Agricultural costs	Residual loss of crop yield after herbicide treatment	1,846 (1,302 – 3,307)	1,243	1,050
Workforce productivity	Additional effects of ragweed on worker productivity	164 (49 – 1,361)	340	24
Total		2,367 (1,439 – 5,431)	1,879	1,103
Controls				
Agricultural	Additional herbicide treatments required	179	-	66
Urban	% of urban area requiring controls	Up to 1.6	-	Up to 8
Total control costs		180		74
Key unquantified impacts	Impacts on construction and leisure and tourism sectors. Costs of restrictions on seed trade.			
Total costs of impacts and controls		2,548	1,879	1,177
Note: 2032 prices are discounted to 2011 prices, and therefore can be compared to current control costs, but not to current impacts.				

An interesting issue in the interaction between control costs and impacts is their distribution inside and outside the EU. Obviously costs inside the EU will be reduced most directly by controls inside the EU, but further research on the impacts of controls inside the EU on impacts outside the EU, and *vice versa*, could help inform the optimal geographical scope of control strategies.

When expected climate change is included in the analysis and there is no control of ragweed, the impacts in 2032 rise slightly compared to a future scenario without climate change. When controls are introduced, there is a significant decrease (over 25%) in the impacts when climate change is included. As discussed in Task 6, the distribution of ragweed is expected to change substantially across the study area by 2032. The distribution of costs across the study area is predicted to shift northwards across the study area with climate change. In southern parts of the study area, conditions become less suitable, and its economic impacts fall. The main areas of impact are predicted to shift north, with substantial increases in costs in some areas (e.g. Germany, France, Poland). A control strategy would restrict the ability of ragweed to colonise, and cause negative impacts in, new areas of climatic suitability. Within the study area, the main locations vulnerable to this climate-change assisted colonisation are within the EU (see Table 5.16).

Some potentially significant costs have not been included in the model. Impacts on the construction sector have not been included but may not be significant. Impacts on leisure and tourism industries may (currently and/or in the future) be significant, but are very poorly understood. Impacts of controls on seed imports could also be significant, but have not been calculated.

There are several limitations in terms of data availability and of knowledge of the assumptions necessary to construct an economic model. Unsurprisingly given the scale of the modelling undertaken, aspects of the results are highly uncertain. Further refinement of this economic model would give better insights into optimal approaches for the management of ragweed, but is probably more realistic for smaller geographical areas (e.g. EU Member States).

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Task 6: Models estimating the spread and the harmful effects of ragweed across the EU for different climatic and policy scenarios

1 Introduction

To predict the future spread and impact of ragweed within the EU we will model climatic, land use and policy influences on both its spatial range dynamics and the production and atmospheric transport of its pollen. Pollen allergies form one of ragweed's major impacts and its pollen can be transported over large distances (Task 4). Therefore a model of population spread will not fully indicate the area at risk because pollen will move beyond that area. Fortunately there is a large body of data and literature on ragweed that will allow us to develop very detailed and accurate models for both of these processes. In this report we go beyond previous models to create a high-resolution spatially explicit model for ragweed's spread and impacts under alternate climate change and policy scenarios, including preventative and mitigation measures. The current models are insufficient for a number of reasons. Some are static representations of habitat preferences (Chen *et al.* 2007a, b; Essl *et al.* 2009) so do not represent temporal range dynamics. Others model colonisation from extant populations (Vogl *et al.* 2008; Dullinger *et al.* 2009; Smolik *et al.* 2010) but do not include human introductions far from existing populations, local extinctions or seed bank dynamics. They are also restricted to national rather than continental scales (Vogl *et al.* 2008; Dullinger *et al.* 2009; Essl *et al.* 2009; Smolik *et al.* 2010) so their predictive ability across the EU is debatable. Furthermore, no existing models predict aerial pollen concentrations.

To address these gaps, we developed the following three models for predicting the spread and impacts of common ragweed *Ambrosia artemisiifolia* across Europe:

- A mechanistic phenology model that predicts where ragweed can complete its annual lifecycle before being killed by frost in the autumn. This is adapted from an existing phenology model, parameterised from field trials in north of ragweed's native range, but has been adapted to allow landscape-scale prediction from long term average temperature and photoperiod data.

- A spatially explicit spread model based on established metapopulation theory, which simulates the European invasion on a high-resolution gridded landscape. A novel feature of the model is that it includes three dispersal pathways – local dispersal around established populations, dispersal as a contaminant in the international seed trade and dispersal through time in the seed bank. The model also includes climatic and land use effects on the metapopulation dynamics and has been calibrated to reproduce the current day distribution with a high accuracy.

- An atmospheric dispersion model for simulating ragweed impacts via long-range transport of its highly allergenic pollen. This includes algorithms to determine the quantity and phenology of pollen emission, and equations to disperse the pollen via air mass movements as simulated by meteorological models. The model has been calibrated against pollen monitoring data from the European Aeroallergen Network. Human exposure to the pollen is estimated by overlaying the pollen cloud with gridded population density data. Simulations into the future use the outputs of the spread model to evaluate how *A. artemisiifolia* range shifts will affect the pollen cloud and its impacts.

The models were used to simulate the spread and impacts of *A. artemisiifolia* from the current day up to 2080 under four alternative scenarios of climate and land use change, based on SRES scenarios of the IPCC 4th assessment.

2 Model overview

We have defined a model for the spread and impacts of *Ambrosia artemisiifolia* that is both representative of ragweed's ecology but sufficiently generic that it can be applied to other invasive species (Fig. 6.1). There are three main submodels simulating ragweed's phenology, range dynamics and pollen dispersion.

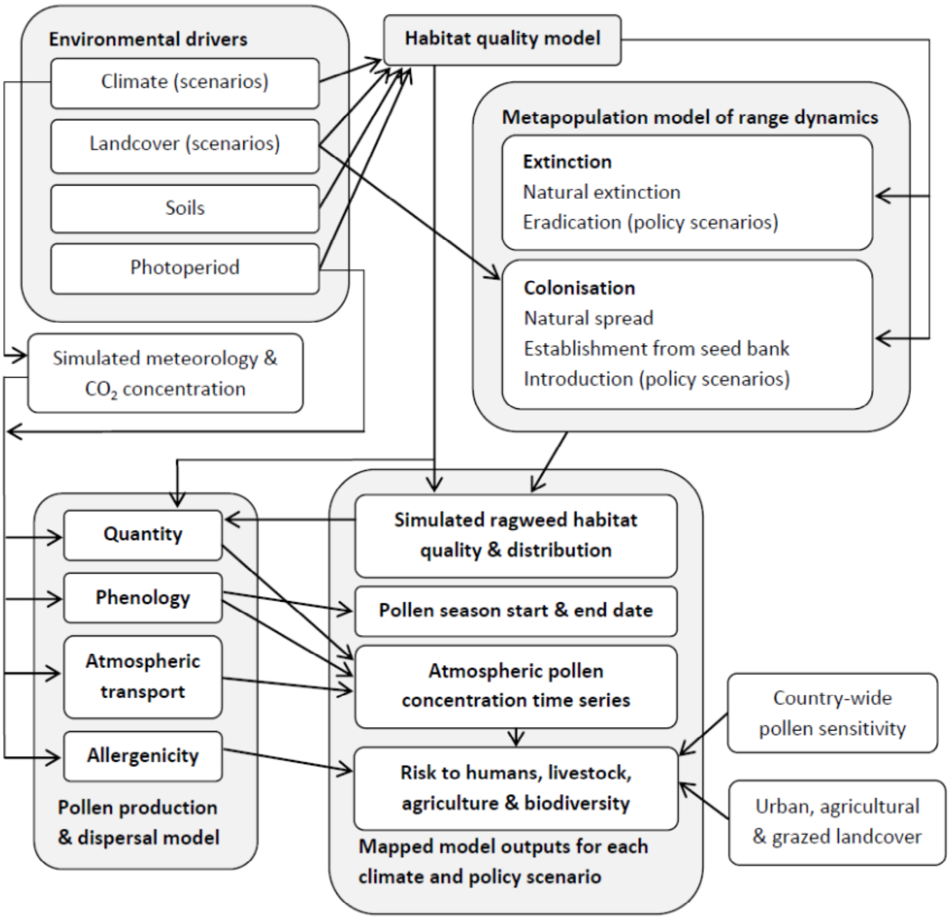
The phenology model is an adaptation of one developed for growth trials in North America (Deen *et al.* 1998a; Deen *et al.* 1998b; Deen *et al.* 2001). We modified the model to allow prediction from gridded long term average temperature data and applied it in a novel context, to predict the area in which ragweed can complete its lifecycle before being killed by autumn frost.

The range dynamics submodel is an extension of the incidence function metapopulation model (Hanski *et al.* 1996) with explicit modelling of plant phenology, fecundity and multiple colonisation mechanisms. The IFM is an established method for modelling spatial range dynamics with ecological realism, but has rarely been employed for simulating distribution shifts under climate change. It is relatively simple compared to individual-based or population dynamic models and simulates presence/absence distributions that are compatible with data on species' ranges.

The system developed for ragweed pollen dispersion modelling is based on the System for Integrated modeLling of Atmospheric coMposition (SILAM, http://silam.fmi.fi; Sofiev *et al.* 2008; Sofiev *et al.* 2012). This is currently used to make European forecasts of allergenic birch and grass pollen levels (Sofiev *et al.* 2006a; Siljamo *et al.* 2008a; Siljamo *et al.* 2008b; Veriankaitė *et al.* 2010) and was adapted to account for the spatio-temporal distribution of ragweed pollen emissions, and physical characteristics of the pollen grains.

The models have been calibrated using both the observed ragweed distribution, as documented in Task 3 and pollen monitoring station data kindly supplied by the European Aeroallergen Network (EAN). Following calibration, the models have been run up to 2080 under SRES climate change scenarios A2a, A1b and B2, using equivalent land use change from the ALARM project (Rounsevell *et al.* 2005; Rounsevell *et al.* 2006). We have also used the model to investigate the potential for increased biosecurity (eliminating contaminated seed imports) and control (eradication of ragweed populations) to limit the spread of the species over the next 20 years (see Tasks 7,9).

Figure 6.1. Overview of the model for ragweed invasion and pollen dispersal.



3 Mechanistic phenology and range limit model

We adapted the phenological model of ragweed development proposed and parameterised by Deen et al. (2001) to predict continental scale phenology and the region where ragweed can complete its development before being killed by frost. Key features of the model are:

- Ragweed development is driven by hourly air temperature and photoperiod. For our application of the model, high-resolution gridded long-term average monthly minimum and maximum temperatures from WorldClim (Hijmans *et al.* 2005) were downscaled into average daily temperature extremes by fitting bias-corrected smoothing splines to the monthly averages. From this, hourly average temperature time series were created by warping a sine function to pass through the spline-predicted daily minima and maxima at 12-hour intervals. Photoperiods were calculated from grid cell latitudes. All data was projected to a 5 x 5 km resolution grid with ETRS 1989 Lambert Azimuthal Equal Area projection.

- The model represents the effect of temperature and photoperiod on ragweed development by assuming that each hour contributes $r(T)\lambda(L)$ 'biological hours' of development, i.e. chronological hours at optimal temperature T and photoperiod L. The functions r and λ describe how the rate of development varies with T and L respectively (Fig. 6.2). Each development phase has a characteristic duration in 'biological days' (24 x biological hours) (Table 6.1), allowing the estimation of the day at which each stage can be reached in a particular location.

- The original model used an unrealistic triangular response of development rate to hourly temperature (Deen *et al.* 2001). This has been replaced with a generalised plant growth response function based on cardinal temperatures (Yin & Kropff 1996). The new model was fitted to data from three published datasets (Deen *et al.* 1998b; Shrestha *et al.* 1999) by least squares (R^2 = 0.956) and is shown in Fig. 6.2a. Specifically, $r(T)$ is,

$$r(T) = \begin{cases} 0 & \text{if } T < T_{\min} \\ \left(\dfrac{T - T_{\min}}{T_{opt} - T_{\min}} \left(\dfrac{T_{\max} - T}{T_{\max} - T_{opt}} \right)^{\frac{T_{\max} - T_{opt}}{T_{opt} - T_{\min}}} \right)^{c_T} & \text{if } T_{\min} \le T \le T_{\max} \\ 0 & \text{if } T > T_{\max} \end{cases}$$

- Fitted parameters are the minimum, maximum and optimum temperatures for growth (T_{min} = 4.883, T_{max} = 42.917, T_{opt} = 30.650 °C) and a scaling parameter C_T = 1.696. These cardinal temperatures are close to values of T_{min} = 0.9 °C, T_{max} = 40 °C and T_{opt} = 31.7 °C used in the original triangular model (Deen *et al.* 2001), but limit low temperature growth more strongly.

- The photoperiod response $\lambda(L)$ causes flowering to be delayed when the day is longer than 14.5 hours, which occurs in summer at latitudes above 36.5 °N. The response is a function of the current day length (L hrs) with a sensitivity parameter L_S that varies with the developmental stage s of the plant (Table 6.1, Fig. 6.2b),

$$\lambda(L) = \begin{cases} \exp\left((L = 14.5) \ln(1 - L_s) \right) & \text{if } L \ge 14.5 \\ 1 & \text{if } L < 14.5 \end{cases}$$

- Biological day accumulation begins once seed dormancy is broken. We assumed that this would occur once the average daily minimum temperature exceeds T_{min} or on the spring equinox at the earliest, to prevent unrealistically early germination in very warm areas (though this rarely applies in Europe).

- Cool temperatures and long days at high latitudes mean that the model produces a positive correlation between latitude and flowering date. However, pollen season start dates in 1995 and 2009 reported for 10 North American monitoring stations between 30 and 52 °N are not significantly correlated with latitude (n = 20, r = -0.236, P = 0.316) and have changed little over that period compared to end dates (mean of 2.7 days earlier, which is within the start date estimation error) (Ziska *et al.* 2011). A similar pattern could be seen in the EAN pollen station data for Europe. Furthermore, the original model predicts that flowering can occur before the summer solstice in warm low-latitude areas, which is unrealistic given *A. artemisiifolia*'s 'short day' nature (Bassett & Crompton 1975). The biological explanation for this is likely to be local adaptation of the photoperiod response causing temporal synchronisation of flowering (Dickerson & Sweet 1971; Hodgins & Rieseberg 2011; Fenesi & Botta-Dukát in press). Since there are insufficient data to model this, we enforce a fixed minimum anthesis date of day 208 (27 July) which is the median pollen season start date for the 10 American stations (Ziska *et al.* 2011). Flowering end dates are not predicted by the model.

- We assume that ragweed plants are killed by frost once the average daily minimum temperature reaches 0 °C (Dahl *et al.* 1999).
- Model outputs include the dates of the principal growing season (germination to anthesis, or frost death if this occurs before anthesis) and the date at which the seeds mature (if not killed by frost).

Figure 6.2. The maximum rate of *A. artemisiifolia* phenological development as a function of (a) hourly temperature and (b) photoperiod (during photosensitive development stages only).

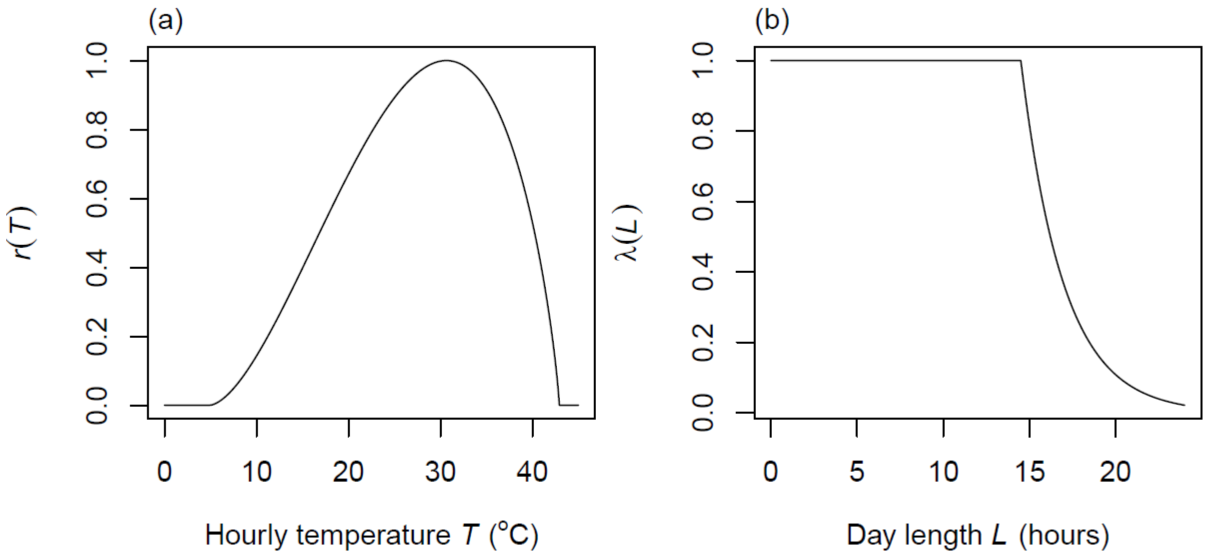


Table 6.1. Phase durations and photoperiod sensitivity in the ragweed phenology model, as described by Deen et al. (2001). Durations are in biological days (BD).

Phase (*s*)	**Photoperiod sensitivity (L_s)**	**Duration (BDs)**
Germination	0	3.5
Germination to seedling emergence	0	1*
Emergence to end of juvenile phase	0	7
End of juvenile to main-stem terminal bud	0.333	4.5
Main-stem terminal bud to pistillate flower	0.333	4.5
Pistillate flower to anthesis	0	4.5†
Anthesis to seed set	0	14.5

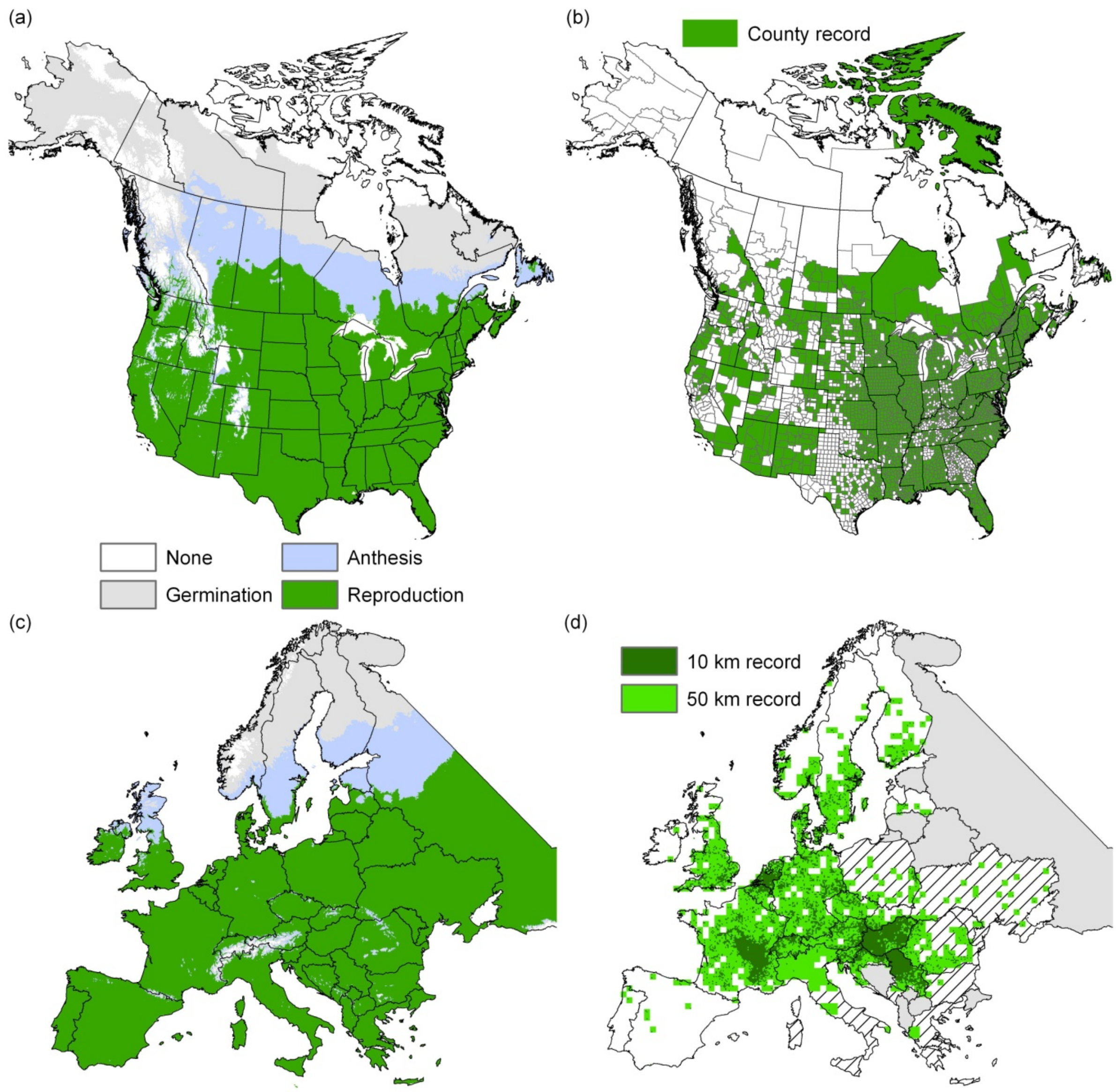
* Assuming a burial depth of 1 cm (Fumanal *et al.* 2008).

† The onset of anthesis is delayed until day 208 at the earliest (Ziska *et al.* 2011).

In both North America and Europe, the phenology model makes a good prediction of ragweed's northern and high-elevation range limit as the region where reproduction is achieved before frost death in the average year (Fig. 6.3). Nearly all occupied North American counties contain regions where ragweed is predicted to reach maturity and produce seed in an average year (Fig. 6.3a-b). Occurrences further north probably represent casual or adventive populations in favourable microclimates not well-captured by the macro-climatic surfaces used in the model. For example, occupied counties in the east of Canada are restricted to the shores of the St. Lawrence river (Lavoie *et al.* 2007) while the occupied county in the far north of Canada is generated from a single coastal record (http://data.gbif.org/occurrences/78348164). Their close proximity to large water bodies may create a microclimate buffered against cold temperatures during the growing season.

In Europe, most of the 10 km records of the species also fall within the region where reproduction is predicted to occur before frost in an average year although there are a substantial number of records beyond the predicted range margin (Fig. 6.3c-d). The model predicts that *A. artemisiifolia* will be able to germinate nearly everywhere except in the Alps and mountains of Scandinavia. Thus, given seed import from North America or other areas where ragweed is well established, it should be possible to obtain a presence record for the species in almost any part of Europe, which may explain these northern records. The model predicts that seed set should fail in an average year in most of Scandinavia, the northern Baltic region and northern Britain. This is consistent with literature reports of failure to set seed to the north of the predicted range (Dahl *et al.* 1999; Saar *et al.* 2000; Déchamp *et al.* 2009), and reports of mature seed production in the northern part of the predicted range (Rich 1994; Dahl *et al.* 1999; Saar *et al.* 2000; Brandes & Nitzche 2006; Déchamp *et al.* 2009; Tokarska-Guzik *et al.* 2011). Despite this, populations in the north of the predicted range are often described as casual in the literature, suggesting that other factors are preventing the establishment of persistent populations.

Figure 6.3. The developmental stages predicted to be reached before the average day of the first autumn frost in (a) North America and (c) Europe, according to the phenology model. (b) and (d) show records of ragweed in both continents. North American data were assembled using the Global Biodiversity Information Facility (http://www.gbif.org/) as a starting point and expanding this with supplementary records from reliable online sources (e.g. online state herbaria, Kartesz 2011) and the literature (Swieringa & Wilson 1972; Bassett & Crompton 1975; Edgin & Ebinger 2000; Lavoie *et al.* 2007; Miller-Rushing & Primack 2008; Thomas *et al.* 2010; Gaudeul *et al.* 2011; Ziska *et al.* 2011). European distribution data were obtained in Task 3. In (d) countries are shaded according to the quality of the distribution data (grey = no data, hatched = poor 10 km resolution data, white = good 10 km data).



4 Ragweed spread model

We have programmed a spatially-explicit, stochastic simulation model that runs over the same 5 x 5 km grid as the phenology model and determines which grid cells are occupied by ragweed in any given year with an annual time step. Changes in grid cell occupancy are the product of Bernoulli trials using locally-calculated probabilities of colonisation or extinction, allowing the stochastic simulation of ragweed invasion. The model has been calibrated to predict the observed recent distribution of ragweed, as documented in Task 3, and has been used to simulate ragweed's ongoing invasion up to 2080, using four scenarios of climate and land use change.

Table 6.2. Variables used in the spread model.

Variable	Meaning
h	Growing season heat sum
M	Growing season moisture index
ψ	Temperature seasonality
Q	Climatic quality
C	Overall colonisation probability
C_N	Colonisation probability from neighbouring populations
C_S	Colonisation probability from the seed bank
C_I	Colonisation probability from contaminated seed imports
Θ	Occupancy state of the cell (0 = ragweed absent, 1 = ragweed present)
H	Proportion cover of invadable habitat, which may be split into crops (H_c) and urban (H_u) land
d_{ij}	Geodesic distance between grid cells *i* and *j*
S	Neighbourhood connectivity (dispersal-weighted density of invaded grid-cells surrounding the focal cell)
G	Germinability factor, derived from the phenology model (0 = germination not possible in an average year, 1 = germination possible)
R	Reproduction factor, derived from the phenology model (0 = seed set not possible in an average year, 1 = seed set possible)
Y_R	Number of years since ragweed last reproduced in the grid cell
$I_{X\rightarrow Y}$	Planting seed import volume from country X to country Y (tonnes)
$C_{n\rightarrow c}$	Probability of cropland colonisation via imports from the native range (USA).
$C_{n\rightarrow u}$	Probability of urban land colonisation via imports from the native range (USA).
$C_{i\rightarrow c}$	Probability of cropland colonisation via imports from the invaded range (Europe).
$C_{i\rightarrow u}$	Probability of urban land colonisation via imports from the invaded range (Europe).
Ω_X	Relative ragweed contamination of planting seed exported from European country *X*
E	Local extinction probability

In overview, the model allows unoccupied cells to be colonised by three mechanisms – seed dispersal from neighbouring ragweed populations (promoted by close proximity to many populations in high-quality grid cells), germination from the seed bank (promoted by recent successful seed set) and import of seed as an agricultural contaminant from the USA and invaded European countries. Colonisation can only occur where seeds are able to germinate and where there is available habitat for colonisation. Occupied cells suffer extinction if the phenology model predicts they cannot reproduce or through stochastic reproductive failure due to low climatic quality. Further details of how these processes are modelled are given below and in a table of the model variables (Table 6.2).

4.1 Climatic quality

The phenology model suggested that there are many European areas where ragweed can complete its lifecycle but where populations are casual and it is not actively invading or causing severe harm. We hypothesised that this was because of effects of climatic factors on the probability of ragweed growth or survival, fecundity and ultimately population persistence. Since this should be a key driver of the spread model, we defined a climatic quality index for use in the model.

For the sake of simplicity, we decided to include only three climatic variables in the index. The first was a growing season heat sum *h*, describing the thermal energy available for growth between germination and anthesis, which is when nearly all biomass is accumulated (Deen *et al.* 2001). The heat sum was calculated as a function of long-term average hourly temperatures during the growing season (germination to anthesis) T_i as,

$$h = \sum_{\substack{i \in \text{growing} \\ \text{season}}} r(T_i)/24$$

where *i* represents hours and *r* is the phenological response function given in section 6.2.

As a simple measure of soil moisture availability we estimated the climatic moisture index *M* (Willmott & Feddema 1992) over the growing season. This is a ratio between precipitation to potential evapotranspiration (PET), rescaled on the range -1 (very dry) to 1 (very wet), calculated as,

$$M = \begin{cases} \dfrac{\sum_j^{12} \text{prec}_j w_j}{\sum_j^{12} \text{PET}_j w_j} - 1 & \text{if } \sum_j^{12} \text{prec}_j w_j \le \sum_j^{12} \text{PET}_j w_j \\ 1 - \dfrac{\sum_j^{12} \text{PET}_j w_j}{\sum_j^{12} \text{prec}_j w_j} & \text{if } \sum_j^{12} \text{prec}_j w_j > \sum_j^{12} \text{PET}_j w_j \end{cases}$$

where *j* represents months, prec is monthly total precipitation (mm), PET is the monthly potential evapotranspiration (mm m^{-2}) and w_j is the proportion of month *j* falling inside the local ragweed growing season (germination to anthesis). Average monthly precipitation data were obtained from the WorldClim database (Hijmans *et al.* 2005). Monthly PET was estimated from the WorldClim minimum and maximum temperatures following Hargreaves *et al.* (1985), with incoming solar radiation estimated as per Allen *et al.* (1998). This method has been evaluated as superior to four alternative methods for predicting continental scale PET (Zomer *et al.* 2006).

The third climatic variable was an index of seasonality ψ, as ragweed is a species of continental climates needing a pronounced winter to break seed dormancy (Pickett & Baskin 1973). For this we used the standard deviation in monthly mean temperatures (average of minimum and maximum) (Hijmans *et al.* 2005).

The quality model was initially formulated as the product of sigmoidal responses to each variable, where if the data values were below a threshold value then climatic quality was curtailed. These were expressed as half-Gaussian functions,

$$f(x) = \begin{cases} \exp\left(-\frac{(x-\mu)^2}{2\sigma^2} \right) & \text{if } x \le \mu \\ 1 & \text{if } x > \mu \end{cases}$$

where μ is the threshold (equivalent to the Gaussian mean) and σ is the steepness of the loss in quality below the threshold (equivalent to the Gaussian standard deviation). As can be seen, $f(x)$ increases from near 0 at low values of x up to an asymptote of $f(x) = 1$ whenever $x \geq \mu$.

During preliminary model development, we elected to replace the half-Gaussian response to the heat sum with a full Gaussian function peaking at μ, i.e.,

$$g(h) = \exp\left(-\frac{(h-\mu_h)^2}{2\sigma_h^2} \right)$$

The reason for this was EAN pollen stations in certain areas where the model was predicting the climate to be highly suitable for the species (e.g. northern Italy, southern Romania and northern Bulgaria) were registering comparatively little pollen. Examination of the three climatic variables suggested that these areas were very hot in summer, and that using a full Gaussian function would model a decline in climatic suitability through exposure to high temperatures.

Thus, our model for climatic quality Q was,

$$Q = g(h)\, f(M)\, f(\psi)$$

where h is the heat sum, M is the moisture index and ψ is the seasonality index. The model has six parameters (three means and three standard deviations), which were calibrated along with the spread model (see below).

4.2 Colonisation of uninvaded cells

Grid cell colonisation by ragweed can only occur where the phenology model predicts germination to be possible. As suggested in Tasks 1 and 2, seed is transported into the grid cell through three main mechanisms:

- Colonisation from neighbouring populations (with probability C_N) either by 'natural' or human-aided seed dispersal (e.g. through the movement of agricultural machinery or soil).
- Colonisation by germination from the seed bank (C_S), if the cell has previously been occupied but the population went extinct.
- Colonisation by germination of ragweed seed imported as a contaminant of seed sown as crops or used for bird feed (C_I).

Accounting for all three mechanisms, the overall colonisation probability is:

$$C = 1 - (1 - C_N)(1 - C_S)(1 - C_I)$$

Models for the three separate colonisation pathways are described below.

4.2.1 Colonisation from neighbouring populations

We assume neighbourhood dispersal probability will decline with increasing distance from the source of seed. Following established metapopulation theory (Hanski *et al.* 1996; Moilanen 1999) we model the colonisation probability as a function of the connectivity of the grid cell to existing ragweed populations, *S*,

$$S_i = \sum_j^N \Theta_j Q_j H_j K(d_{ij})$$

where:

- *N* is the set of cells within the colonisation neighbourhood of cell *i*. We set the neighbourhood to contain all cells within 100 km of *i*. This precludes very long distance colonisation but massively improves computational efficiency of the model.
- Θ_j codes whether a cell *j* contains a ragweed population that reached reproductive maturity in the previous year (1 = yes, 0 = no).
- Q_j is the climatic quality of cell *j*, which we assume scales the numbers of seeds produced there.
- H_j is the amount of ragweed habitat in cell *j*, which should also relate to the amount of seed produced. We assumed that ragweed can only invade cropland and urban/artificial land and used the proportion cover of each from a projected version of the Global Land Cover 2000 map (European Commission 2003).
- $K(d_{ij})$ is the 'dispersal kernel' – a monotonically decreasing function of d_{ij}, the geodesic distance between *i* and *j* in km. A previous model for ragweed spread in Austria used a Gaussian kernel $K(d_{ij}) = \exp(-d_{ij}^2 / 2\sigma^2)$ where standard deviation σ scales the range of dispersal (Smolik *et al.* 2010).

The probability of colonisation from neighbours is specified as a monotonically increasing sigmoidal function of connectivity (Hanski *et al.* 1996),

$$C_N = GH \frac{S^2}{S^2 + S_{0.5}^2}$$

where G is a germinability factor derived from the phenology model (1 = germination possible in the average year, 0 = germination not possible) and $S_{0.5}$ is the connectivity causing a 50% chance of colonisation.

4.2.2 Colonisation from the seed bank

Deeply buried dormant ragweed seeds can remain viable for up to 40 years (Baskin & Baskin 1977; Telewski & Zeevaart 2002) but require soil disturbance to raise deeply buried dormant seeds close to the soil surface where germination is possible (Fumanal *et al.* 2008). The model assumes that the probability of colonisation from the seed bank increases with:

- A small number of years since reproduction was last achieved in the grid cell.
- A high cover of disturbed habitats (since disturbance is needed for large population sizes and germination of buried seeds).
- High climatic quality (giving higher seed set during the last reproductive event).
- The phenological model permits germination.

A simple model for colonisation from the seed bank was formulated as,

$$C_N = GH^2Q\left(1 - \frac{Y_R^2}{Y_R^2 + Y_{0.5}^2}\right)$$

where G, H and Q are defined as above, Y_R is the number of years since reproduction was last achieved in the grid cell and $Y_{0.5}$ is the years at which the probability of seed bank germination falls to 0.5. Note that the quadratic exponent of H reflects the dual role of invadable habitat in promoting a large seed bank (though a high population size) and encouraging its germination through disturbance to the soil.

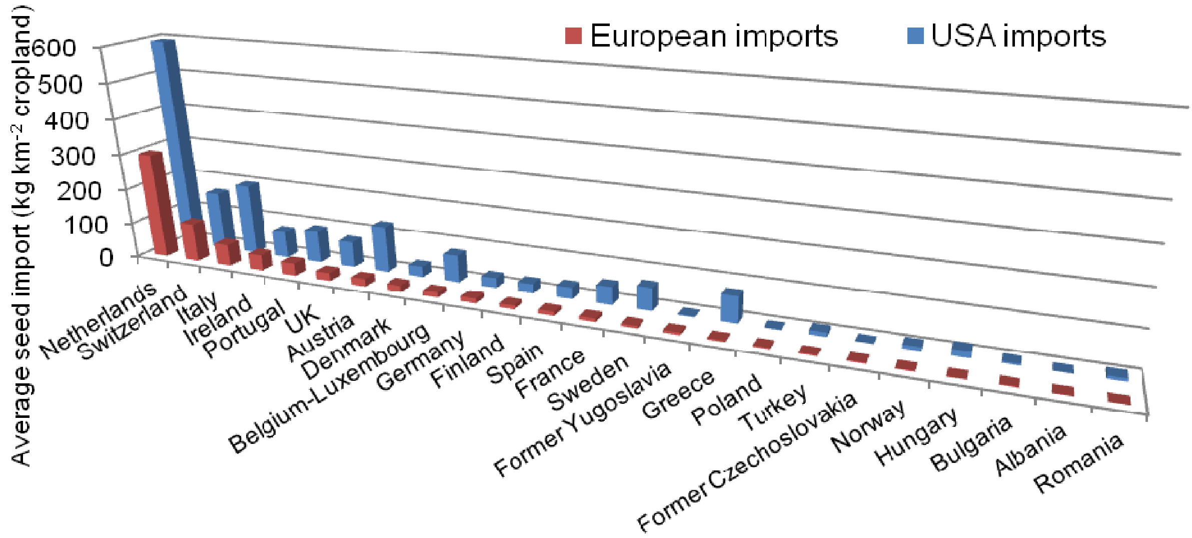
4.2.3 Colonisation through contaminated seed imports

The model for colonisation through contaminated seed imports factors in both imports from the native range and imports from invaded parts of Europe. The model is based on actual planting seed import volumes per country, converted into rates per km^2 for cropland (in which the seed is used) and urban areas (through which the seed is transported), assuming an even spatial usage (Fig. 6.4). Data on planting seed imports to each modelled country were obtained from:

- The United States Department of Agriculture's Foreign Agriculture Service Global Agricultural Trade System (http://www.fas.usda.gov/gats/). This gave import data from the USA, which represents nearly all of the native range (Fig. 6.3b). Average annual import volumes (tonnes) from 1967 to 2010 were extracted. The former Soviet, Czechoslovak and Yugoslav states were grouped in the older data, so we assumed the imports were distributed evenly within each grouping.

- The Trade Map database (http://www.trademap.org/), from which the 2001-2010 average annual volumes of seed traded between European countries was extracted. Older data were not available.

Figure 6.4. Seed import rates per unit area of cropland, for selected countries in the model. European imports are summed across the individual imports from all the modelled countries.



The import data were used as the basis for a simple model of colonisation via seed imports from the native range as,

$$C_{n\to c,j} = \min\left(\beta_{n\to c}\frac{I_{USA\to W}}{\sum_{k\in W} H_{c,k}} H_{c,j}, 1\right)$$

$$C_{n\to u,j} = \min\left(\beta_{n\to u}\frac{I_{USA\to W}}{\sum_{k\in W} H_{u,k}} H_{u,j}, 1\right)$$

where C is the colonisation probability and subscripts refer to import from the native range (n) to crops (c) and urban (u) land in focal grid cell j. Parameter β scales the colonisation probability against the seed import volume from the native range (USA) to country W (to which j belongs), $I_{USA\to W}$.

The model for import colonisation within the invaded range is more complex, and accounts for the relative degree of contamination of seeds from each potential source country. This depends on the level of ragweed infestation and climatic quality of the cropland in that country. The contamination rate Ω for seed exports from country V is calculated as,

$$\Omega_V = \frac{\sum_{j \in V} H_{c,j} \Theta_j Q_j R_j}{\sum_{j \in V} H_{c,j}}$$

where *j* relates to the individual grid cells within the country, H_c, Θ and *Q* are defined as above and *R* is a reproduction factor from the phenology model, coding whether or not seed set is achieved in the grid cell in an average year (0 = no, 1 = yes).

Assuming that the imported seed is distributed evenly across the crop and urban land, the probabilities of colonisation by seed imported from the invaded range are formulated as,

$$C_{i \to c,j} = \min\left(\frac{H_{c,j}}{\sum_{k \in W} H_{c,k}} \beta_{i \to c} \sum_{V \neq W} I_{V \to W} \Omega_V , 1 \right)$$
$$C_{i \to u,j} = \min\left(\frac{H_{u,j}}{\sum_{k \in W} H_{u,k}} \beta_{i \to u} \sum_{V \neq W} I_{V \to W} \Omega_V , 1 \right)$$

The subscripts on *C* refer to imports from within the invaded range (*i*) to crops (*c*) and urban (*u*) land in focal grid cell *j*. The first fractions on the right hand side of the equations give the proportion of country *W*'s crop and urban land found in the focal grid cell *j*. This gives the proportion of that countries imported seed used in both land use types in the focal grid cell. Parameter *β* scales the colonisation probability against the contaminated seed import volume from the invaded range. The contaminated import volume is evaluated by the summation of the product of national import volumes and contamination levels at the end of the equation. These summations are across all other European countries, indexed by the letter *V*.

The overall probability of colonisation through the international seed trade network is therefore calculated as one minus the probability of failure to colonise through all four import sources,

$$C_I = G\left[1 - \left(1 - C_{n \to c}\right)\left(1 - C_{n \to u}\right)\left(1 - C_{i \to c}\right)\left(1 - C_{i \to u}\right)\right]$$

4.3 Extinction within invaded grid cells

Extinction occurs if the phenology model predicts ragweed cannot reach reproductive maturity or stochastically with a greater probability in cells with low climatic quality, because of low seed production. We did not include an effect of habitable area on extinction since ragweed can persist in very small amounts of habitat (e.g. a single field edge). A simple model calculates the extinction probability as,

$$E = \left(1 - Q^e\right)^R$$

where parameter $e > 0$ scales a negative relationship between quality *Q* and extinction, and *R* is the reproduction factor defined above.

4.4 Model simulation procedures

The model runs with a 5x5 km Lambert Azimuthal Equal Area grid and is initiated with a ragweed-free Europe so initial colonisation must occur through import from the native range.

In each year, the ordering of events is as follows:

- In unoccupied grid cells, calculate the probability of colonisation and realise colonisation events through Bernoulli trials.
- Output the distribution of where ragweed is growing in that year.
- In occupied grid cells (including those just colonised) calculate the probability of extinction and realize extinction events with Bernoulli trials.

4.5 Calibration of model parameters

The model has 14 parameters (Table 6.3), which were calibrated against the recent 10 km records of ragweed within countries that had high quality distribution data, as documented in Task 3 (Fig. 6.3d). Our approach to calibration can be summarised as follows:

- Decide upon sensible ranges for the parameter values.
- Simulate the model a large number of times with random parameter values drawn from those ranges.
- Compare the simulated distributions to those observed for the period 1990-2010 (for which Task 3 has mapped the distribution).
- Select a set of random parameterisations giving close correspondence to the observed distributions.
- Average model outputs over this set of 'well-fitting' parameters.

Note that this approach does not yield a single parameter estimate, but instead averages over a range of good alternative parameterisations. In this way uncertainty about the exact choice of parameters is accommodated (Chapman *et al.* 2009).

To perform the calibration, we ran simulations with 1500 unique parameterisations for a 50-year period starting in 1960, which is the approximately when ragweed began to invade explosively (Chauvel *et al.* 2006; Déchamp *et al.* 2009). We evaluated their fit based on two criteria. First any parameterisation where ragweed manifestly spread too rapidly or too slowly was discarded. We decided that valid rates of spread would be captured in the parameterisations where it took between 20 and 40 years for the total number of invaded grid cells to reach 90% of the maximum number. Of the 1500 parameterisations 893 met this first test.

Of these, we computed a measure of the correspondence between the observed 10 km ragweed records in the good data region from the period 1990-2010 (Fig. 6.3d) and the simulated occupancy rates over the same period. Since the model runs on a 5 km grid, aggregation of the 20-year occupancy rates to a 10 km resolution allows the estimation of equivalent occupancy rates for each simulation in 80ths.

Table 6.3. Parameters of the spread model, including the ranges over which random parameterisations were generated and the median of the calibrated well-fitting parameter set (see main text). As a measure of the sensitivity of model fit to the parameter values, the distribution of parameter values in the 30 top-fitting parameterisations was compared to the uniform distributions from which they were generated with one-sample Kolmogorov-Smirnov tests. The test statistic is reported as a measure of sensitivity.

	Parameter	**Meaning**	**Value range**	**Median calibrated value**	**Sensitivity**
Climatic quality	μ_h	Optimal value of the growing season heat sum.	50-55	51.49	0.382
	σ_h	Standard deviation of Gaussian response to the heat sum.	1-20	15.56	0.491
	μ_M	Threshold value of the growing season moisture index.	-0.7--0.6	-0.639	0.255
	σ_M	Standard deviation of half-Gaussian response to the moisture index.	0.01-0.15	0.075	0.129
	μ_ψ	Threshold value of the temperature seasonality index (°C).	6.0-6.5	6.349	0.270
	σ_ψ	Standard deviation of half-Gaussian response to the temperature seasonality index (°C).	0.1-2.0	0.697	0.283
Colonisation	σ	Gaussian dispersal kernel scaling parameter (km).	5-30	19.50	0.233
	$S_{0.5}$	Neighbourhood connectivity giving a 50% chance of colonisation.	0.1-100	64.26	0.220
	$Y_{0.5}$	Number of years since last reproduction when the probability of seed bank germination falls to 50%.	0-1	0.392	0.261
	$\beta_{n \rightarrow c}$	Scaling of cropland colonisation via contaminated imports from the native range (USA).	0-0.4	0.220	0.149
	$\beta_{n \rightarrow u}$	Scaling of urban colonisation via contaminated imports from the native range (USA).	0-0.4	0.221	0.110
	$\beta_{i \rightarrow c}$	Scaling of cropland colonisation via contaminated imports from the invaded range (Europe).	0-0.4	0.216	0.210
	$\beta_{i \rightarrow u}$	Scaling of urban colonisation via contaminated imports from the invaded range (Europe).	0-0.4	0.274	0.325
Extinction	e	Scaling of the relationship between extinction climatic quality and probability	0-2	0.958	0.130

The relationship between occupancy rate and probability of recording the species depends nonlinearly on recorder effort, which is likely to vary in space and time. Since we have no way to estimate effort, we instead assess the correspondence between observed presence or ‘absence’ and the occupancy rate using the AUC statistic (probability that a cell with a record has higher predicted occupancy than a cell without a record) and Cohen's κ (with a threshold selected to maximise κ). Both statistics are calculated in two ways. First global statistics (G) were calculated for the entire model region, and second local statistics (L) were calculated for each country and summarised as the area-weighted mean across all countries. In the calculation of the local κ, country-specific optimal thresholds were selected. These statistics were rescaled to the same ranges and summed to give an overall measure of 'fit'. We found that using all four measures gave a more balanced measure of model fit than using any one measure alone.

After the fit statistic was calculated, the top 30 parameterisations (top 2% of the original 1500) were selected as the calibrated parameter set (Table 6.3). Comparing the distributions of parameter values within this set to the uniform distributions from which parameters were generated, identified that model fit was most sensitive to the effects of the heat sum and temperature seasonality on climatic quality, seed imports to urban areas from invaded countries and the rate of decay of the seedbank (Table 6.3). However, it is important to note that relative differences in sensitivity may reflect variation in the ranges of the parameters simulated.

All further model results were obtained by averaging over the top 30 parameterisations. As shown in Fig. 6.5a, the calibrated climatic quality model highlighted southern France and Pannonian Plain in south-eastern Europe as being particularly suited to ragweed. Extrapolation of the model away from the 'good data region' suggested that parts of northern Italy, Bulgaria, Romania, Moldova, Ukraine and southern Russia were also very suitable for ragweed. Low temperatures were identified as the main limiting factor on climatic quality over most of Europe, although drought was important in the far south and lack of seasonality suggested as important in the Atlantic west (Fig. 6.5b). Very few areas had a strong limitation of climatic quality by high temperatures.

The modelled extinction probabilities, which are a function of climatic quality, indicate that introduced or colonising populations in the highest quality areas will have a good chance of persisting, while populations will rarely persist for more than a few years outside of these hot-spots (Fig. 6.6).

The simulated distribution showed a good correspondence to the observed distribution (Fig. 6.7). Within the 'good data region' we calculated global AUC = 0.834, global κ = 0.478, local AUC = 0.736 and local κ = 0.267. The model predicted invasion of most of the high climatic quality regions identified above (Fig. 6.7a), although the invasion of southern France was more restricted in the model than the distribution data. This was because the land cover map indicated that there was very little invadable habitat outside of the Rhône valley (south east France), although the distribution data indicate ragweed has got there. The modelled invasion into Russia was retarded by fragmented crop cover and low seed import rates, although we have no detailed data on the spread of the species in this region (Déchamp *et al.* 2009; Reznik 2009). Intriguingly, some areas with low climatic quality had sufficient seed imports to generate very high occupancy. Examples of this include the Netherlands, Belgium and other urbanised areas of northern Europe.

Figure 6.5. (a) The calibrated climatic quality surface for ragweed. (b) The climatic variable most strongly limiting quality. Note that there are very few areas where high temperatures cause a large reduction in climatic quality.

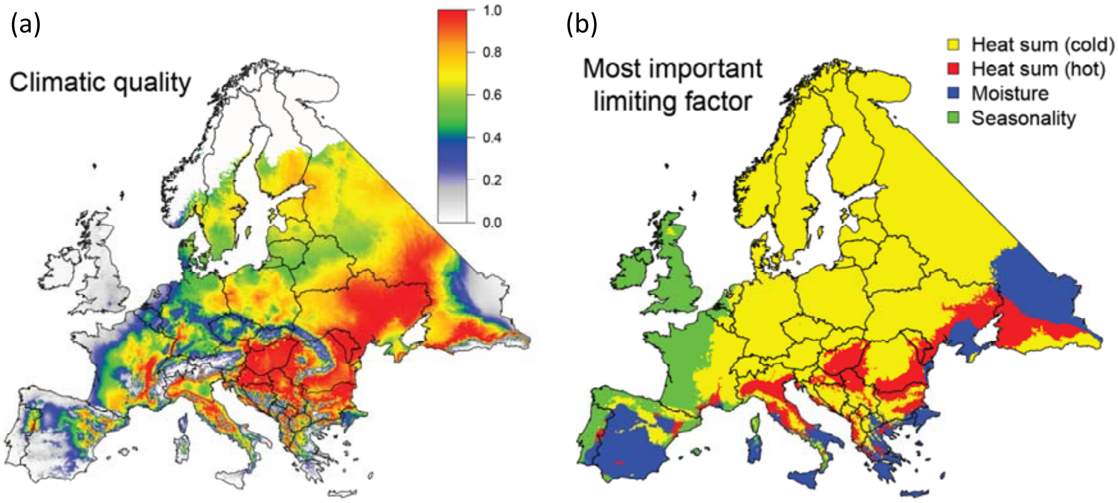


Figure 6.6. Annual probability of extinction for established ragweed populations, according to the calibrated model of extinction as a function of climatic quality (Fig. 6.5a) and the phenology-model prediction of ability to set seed (Fig. 6.3c).

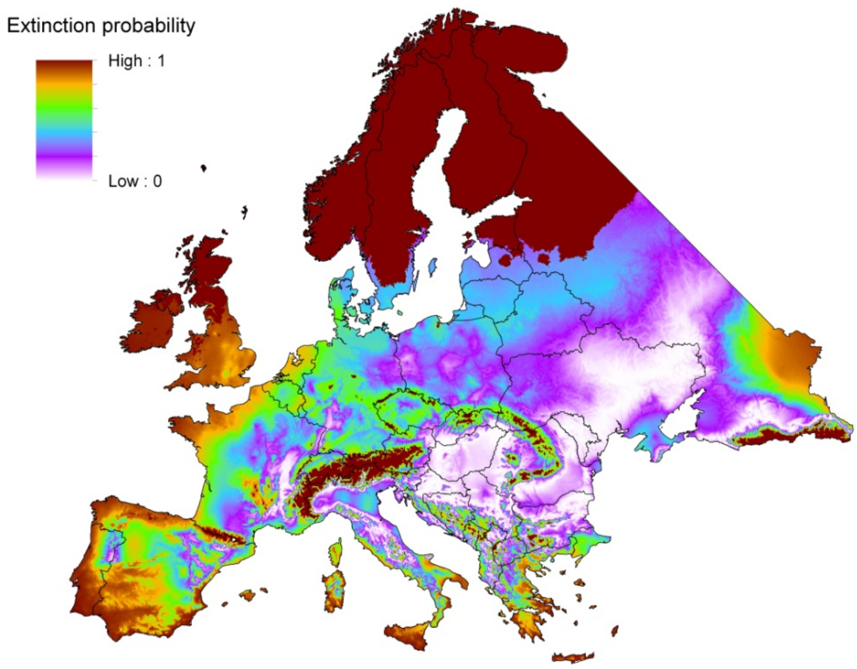
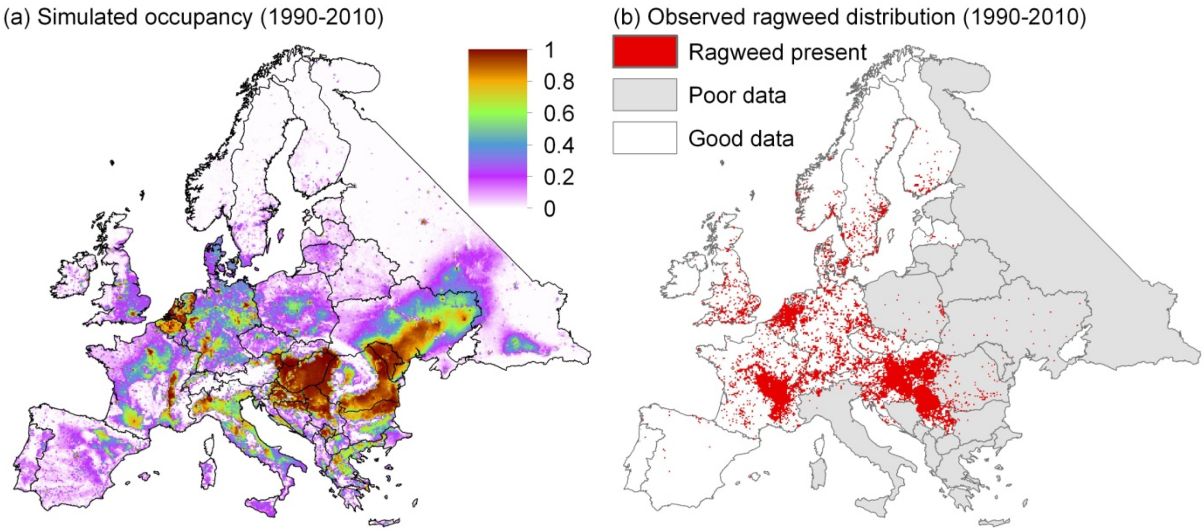


Figure 6.7. (a) Mean occupancy in the calibrated spread model and (b) the distribution of ragweed at a 10 km scale as obtained in Task 3.



4.6 Simulated spread up to 2080 under climate and land use change scenarios

The model was used to simulate the ongoing spread of ragweed up to 2080 under four scenarios of climate and land use change. Spatially downscaled projected decadal climate data from the IPCC4 application of the HADCM3 climate model (http://www.metoffice.gov.uk/research/modelling-systems/unified-model/climate-models/hadcm3) were obtained from CIAT data portal (http://www.ccafs-climate.org/). Equivalent downscaled land use scenarios for crop and urban cover were obtained from the authors of the EU-ALARM project (Rounsevell *et al.* 2005; Rounsevell *et al.* 2006; Settele *et al.* 2012; Spangenberg *et al.* 2012). The four scenarios were:

- **No change**. Simulations run with the current climate and land use data as a control to compare change scenarios to the ongoing spread of ragweed.
- **SRES A1b climate and BMBU land use** (Business as Might Be Usual). This scenario is one of rapid economic growth and globalisation. The land use scenario involves little urbanisation outside of existing cities. Agriculture is encouraged in optimal locations, but a minimum level of activity is maintained in traditional agricultural landscapes.
- **SRES A2a climate and GRAS land use** (GRowth Applied Strategy). This scenario has the greatest warming. It also describes rapid economic growth but in a more divided world than A1b. The land use scenario includes urban sprawl and abandonment of agriculture in the least profitable areas.

- **SRES B2 climate and SEDG land use** (Sustainable European Development Goal). This is a more environmentally-friendly scenario where there is a lower focus on economic growth and the least warming of the change scenarios. The land use scenario includes little urbanisation and an extensification of agriculture.

The ALARM land use data could not be used directly in the ragweed spread model because it covered a more limited extent and is based on a slightly different baseline land cover map. Therefore, we created harmonised land use change maps using a simple algorithm. In countries covered by the ALARM land use scenarios we used the proportion change in crop and urban cover in each grid cell to modify the baseline land cover map. This maintained the within-country spatial pattern of land use change predicted by ALARM. In countries not covered by ALARM, we multiplied crop and urban cover by the median change in each in a geographically and politically roughly analogous country. For this, the UK was used to predict Ireland, Denmark was used to predict for the Faroe Islands, Hungary was used to predict Albania, Bosnia, Bulgaria, Croatia, Kosovo, Macedonia, Moldova, Montenegro, Romania, Serbia and Turkey and Poland was used to predict Belarus, Russia and Ukraine. Example crop cover maps are shown in Fig. 6.8.

All scenario data were obtained for decadal periods centred on 2020, 2050 and 2080. For use in the model, climate and land use variables were interpolated linearly from the state in 2000 to ensure a smooth transition in the underlying drivers of ragweed spread. We did not have any scenarios for planting seed imports, so ran the model assuming that current import volumes between countries are maintained.

Model simulations suggested that in the absence of any climate or land use change ragweed would continue to spread up to 2080 but that spread within the EU was limited compared to its expansion into Russia (Figs. 6.9, 6.10a). Under all three climate change scenarios, the area invaded by ragweed initially increased but then declined after about 2040, with the invasion being most widespread under scenario B2 (Fig. 6.9). As is seen in Fig. 6.10, ragweed's distribution shifts north under the climate change scenarios, with a strong expansion into Germany, northern France, Czech Republic, Poland, Lithuania, eastern Ukraine and Belarus. By contrast, the areas currently invaded by ragweed are predicted to decrease in infestation. Comparing Fig. 6.5 with Fig. 6.11, it can be seen that the model expects these regions to become less climatically suitable for ragweed, primarily because of excessive heat. This is the main factor behind the model's prediction of a range contraction in the current hotspots. As noted above, the data on which we calibrated the high-temperature reduction in ragweed climatic suitability was very limited, and so this prediction of the model should be treated with caution. However, the northward range prediction is likely to be much more robust.

Figure 6.8. Current crop cover and that projected in 2050 according to the climate and land use change scenarios.

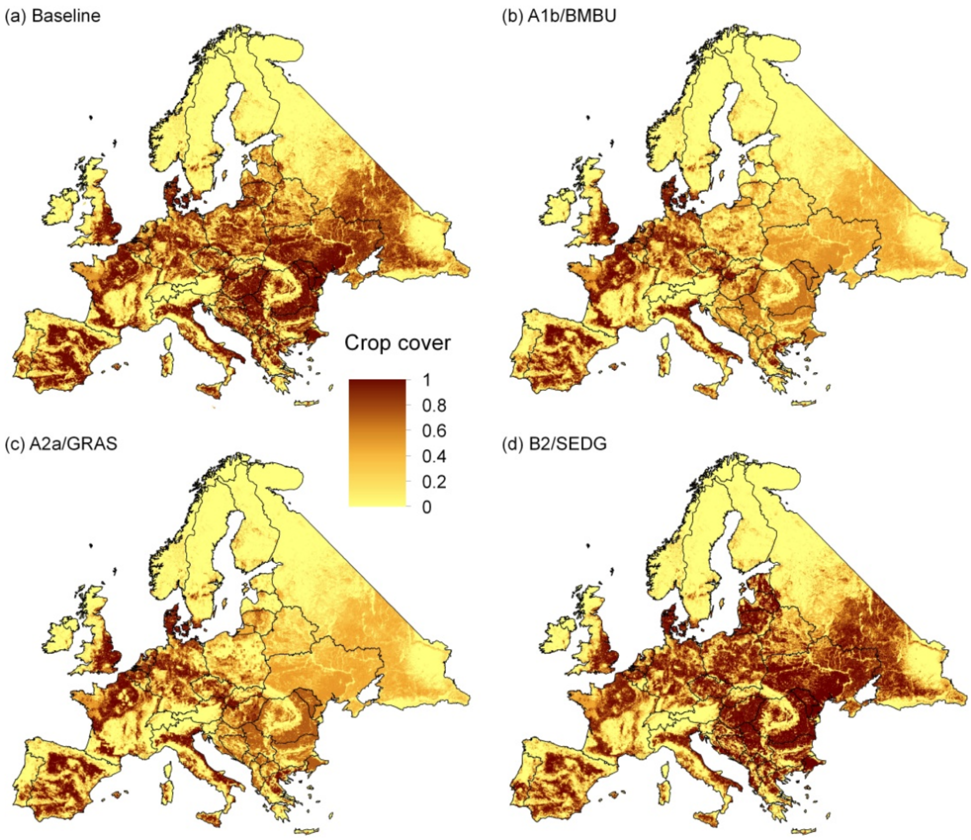


Figure 6.9. Number of 5x5 km grid cells invaded by ragweed under four climate and land use change scenarios, as simulated by the spread model.

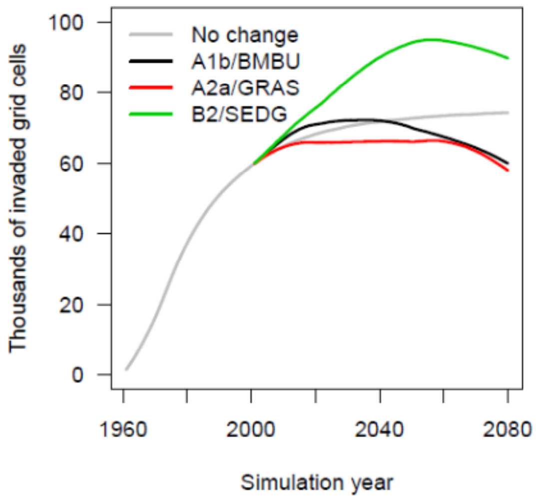


Figure 6.10. Distributions of ragweed in 2050 under four climate and land use change scenarios, as simulated by the spread model.

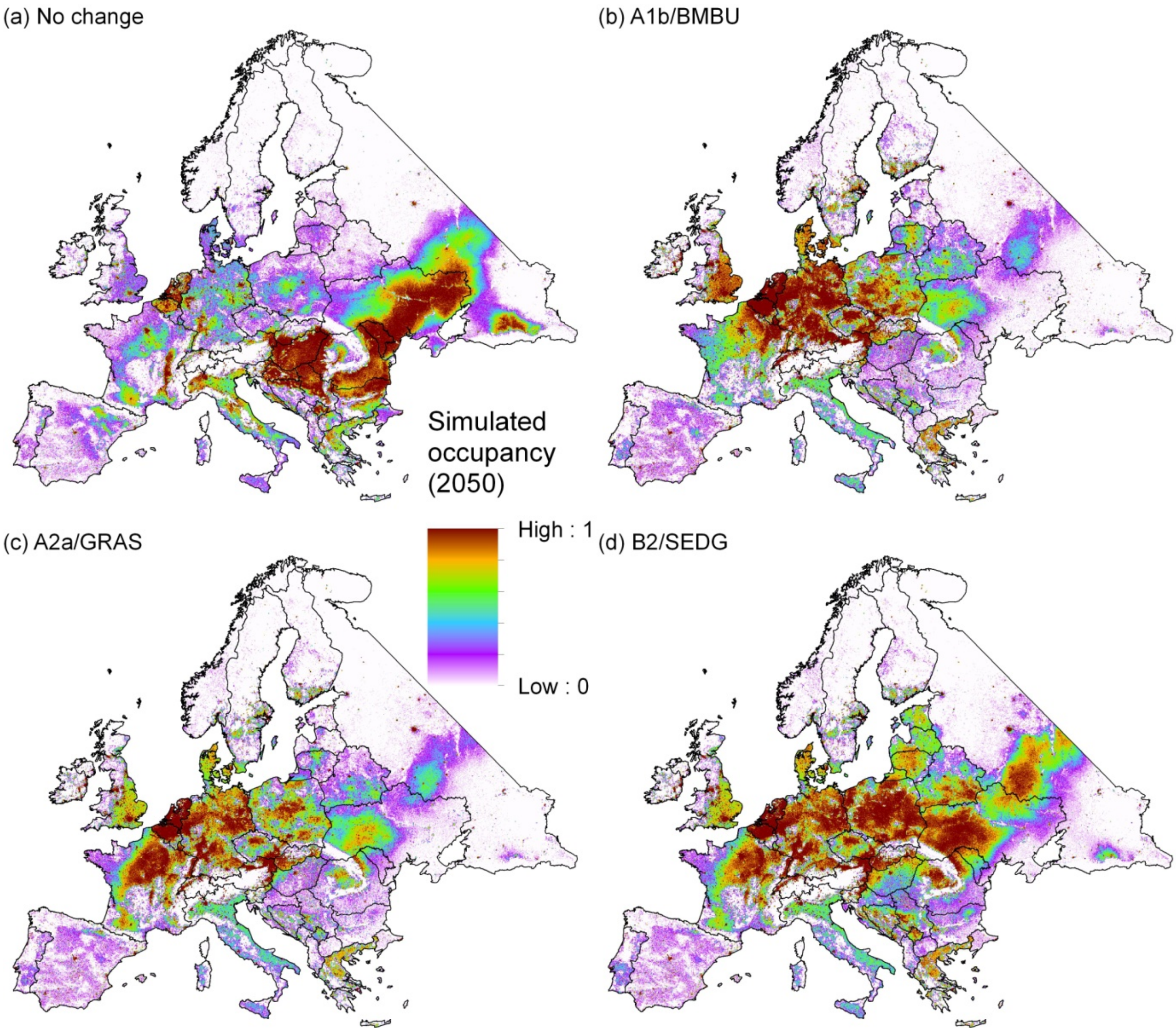
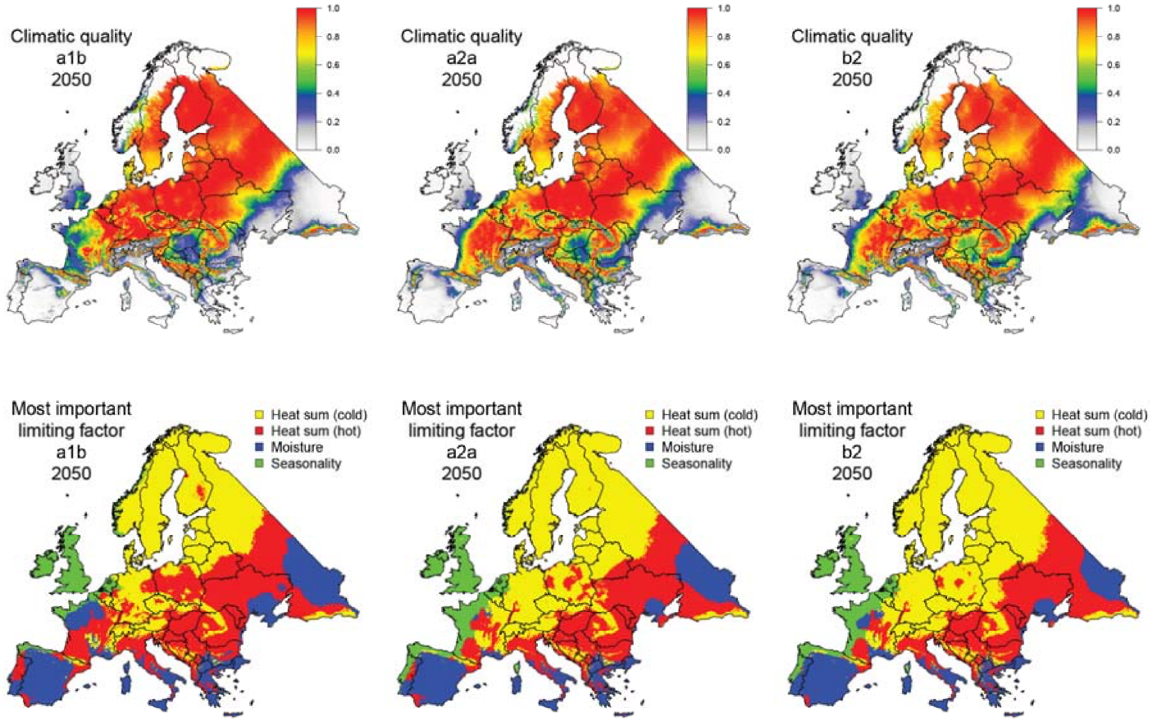


Figure 6.11. Maps of climatic quality and most important limiting climatic factors in 2050 for each of the three climate change scenarios.



5 Ragweed impacts model

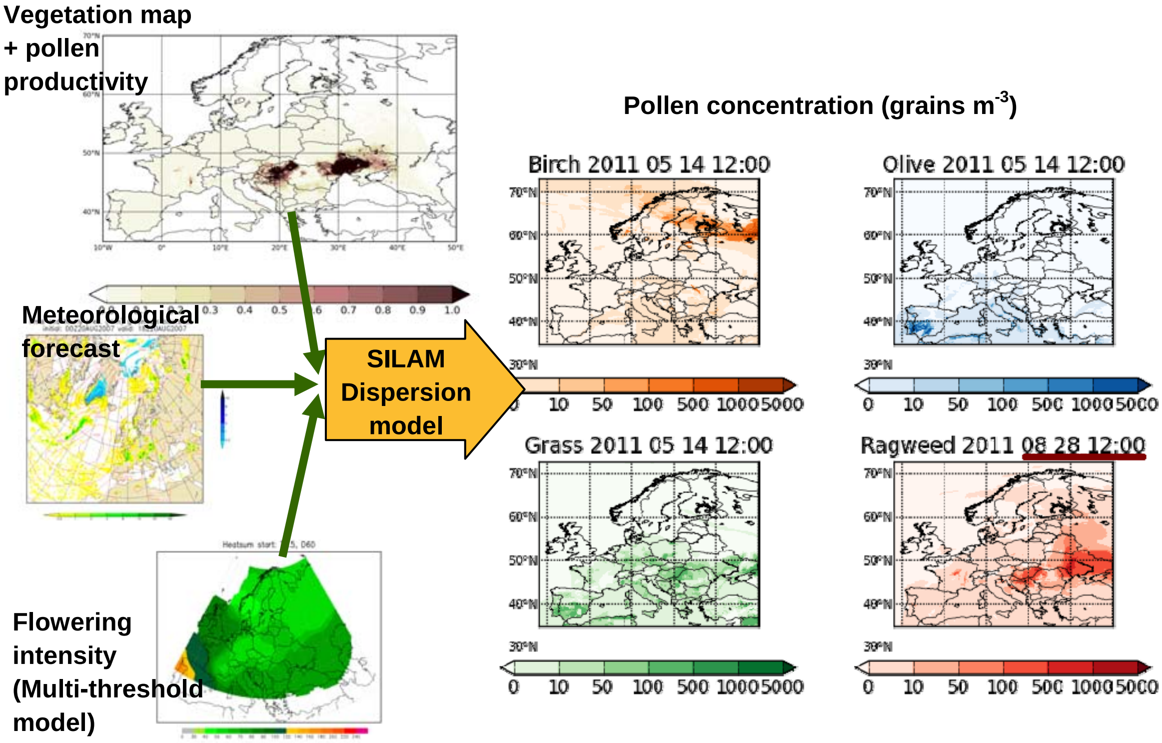
The model of ragweed impacts distinguishes between direct impacts of the plants, and indirect impacts of its pollen, including long-range atmospheric transport (Efstathiou *et al.* 2011).

5.1 Impact of ragweed pollen

5.1.1 Development of the pollen dispersion model

The system developed for ragweed pollen dispersion modelling is based on the System for Integrated modeLling of Atmospheric coMposition (SILAM, http://silam.fmi.fi; Sofiev *et al.* 2008; Sofiev *et al.* 2012). SILAM is a chemical transport model, presently used in research and operational applications related to air quality and, in particular, its allergenic content. SILAM covers the whole atmospheric lifecycle of pollen, starting from its production with an embedded phenological model, release into the air, transport with air masses, and removal from the atmosphere. The model output consists of hourly maps of pollen air concentrations over Europe (Fig. 6.12). Since 2005, SILAM has been used for assessment and forecasting of birch, grass and olive pollen distribution over Europe (Sofiev *et al.* 2006a; Sofiev *et al.* 2006b; Siljamo *et al.* 2008a; Siljamo *et al.* 2008b; Sofiev *et al.* 2008; Veriankaitė *et al.* 2010; Siljamo *et al.* 2012; Sofiev *et al.* 2012).

Figure 6.12. Overview of the SILAM system for ragweed and other pollen dispersion modelling.



The ragweed-related developments of SILAM were concentrated on the new formulations for the pollen source term, which would describe the production of ragweed pollen and its release into the atmosphere for subsequent transport and deposition. The ragweed source term consists of two main components: the ragweed habitat map, which is developed in the ecological spread model and provided to SILAM as an input map, and the phenological model that calculates the flowering time, intensity and amount of the released pollen.

The input map of ragweed habitat originates from the ragweed spread model described in the previous sections of this report chapter, which takes into account the climate suitability, seed import from infected areas, local dispersal in space and time and land use favourable for the plant. The total amount of pollen emitted is assumed to be proportional to ΘQH, where Θ is the simulated probability ragweed occupancy, Q is the climatic quality and H is the proportion cover of invadable habitat.

The flowering time and intensity are described by a normal distribution with prescribed peak time and standard deviation. This parameterization is combined with a multi-threshold dynamic release model (Table 6.4). Meteorology-dependent model used for pollen release from inflorescences has been described in details by Sofiev et al. (2012). According to this model, the pollen release is conditioned to several criteria, which all have to be satisfied for emission to start. In the case of ragweed, the main driver is the calendar day threshold, which allows for the flowering to start when the day length gets sufficiently short. The start of the flowering can also be delayed until an accumulated-bioday threshold is reached, accounting for delays in development due to cold temperatures or inappropriate day lengths (Deen *et al.* 1998a; Deen *et al.* 2001). The season can end prematurely if the soil humidity or minimum night time temperature drop below certain thresholds, representing a termination of the flowering season by frost (Ziska *et al.* 2011) or drought.

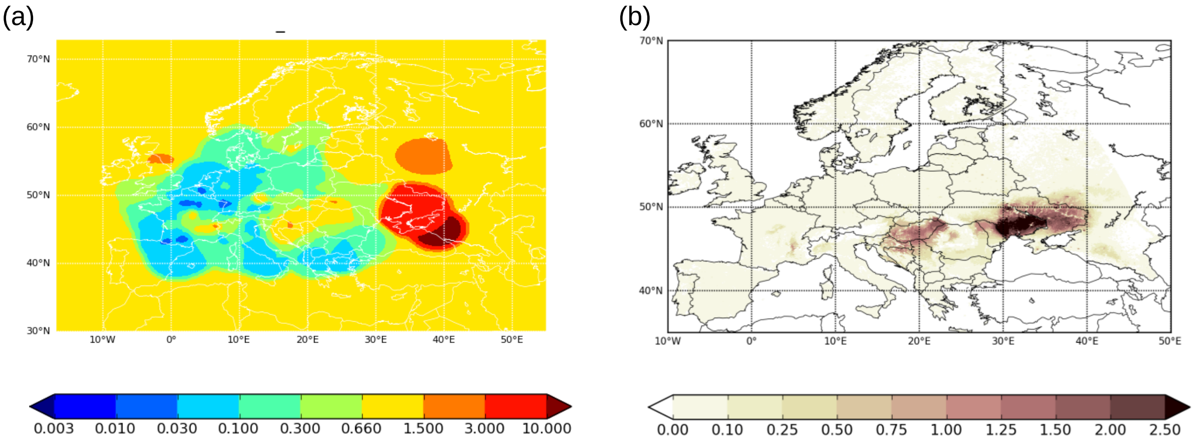
Table 6.4. Parameters of the SILAM model, as applied to ragweed pollen dispersion.

Parameter group	SILAM parameter	Value
Flowering intensity (Normal distribution)	Season peak (day of year)	242.5
	Standard deviation	10 days
	Maximum pollen production	$2x10^7$ grains m^{-2}
Flowering start thresholds	Day of year	205
	Bioday	25
Flowering end thresholds	Day of year	280
	Low temperature	7.5 °C
	Soil moisture	0.1 m^3 m^{-3}
Bioday accumulation	Minimum temperature	0.9 °C
	Maximum temperature	40 °C
	Optimal temperature	31.7 °C
	Maximum optimal day length	14.5 hrs
	Minimum daily average temperature for accumulation to start	7.5 °C
	Minimum hourly temperature for accumulation to start	0 °C
	Accumulation start day	79
	Uncertainty of heat sum threshold	10%
Pollen release	Low humidity threshold (full emission up to it)	50%
	High humidity threshold (no emission above it)	90%
	Precipitation threshold (no emission above it)	0.5 mm hr^{-1}
	Wind speed saturation level (emission grows up to this speed)	5 m s^{-1}
	Wind speed maximum impact (scales emission growth)	1.5 m s^{-1}
	Injection height	50 m
Pollen properties	Pollen diameter	18 µm
	Pollen density	800 kg m^{-3}

To calibrate the parameters and evaluate the model's accuracy, the observational data of European Aeroallergenic Network (EAN, https://ean.polleninfo.eu/Ean) was used. The EAN Pollen Database gathers information from more than 600 pollen counting stations all over Europe, providing the best possible data on actual ragweed pollen concentrations. Model computations were made for years 2006-2010 with meteorological information from European Centre for Medium-Range Weather Forecasts (ECMWF) operational forecasts. During this calibration, it was noted that the input habitat map, being a very good proxy of the present ragweed distribution, still misses several regional peculiarities. Therefore, a correction was computed using the comparison of the SILAM seasonal totals with the EAN observations. This mean correction was used as a scaling factor to the emission map (Fig. 6.13). After that, the computations were repeated with the corrected emissions. As can be seen, raw model emissions were underestimating actual pollen emission in Ukraine and southern Russia, and overestimating it in western Europe.

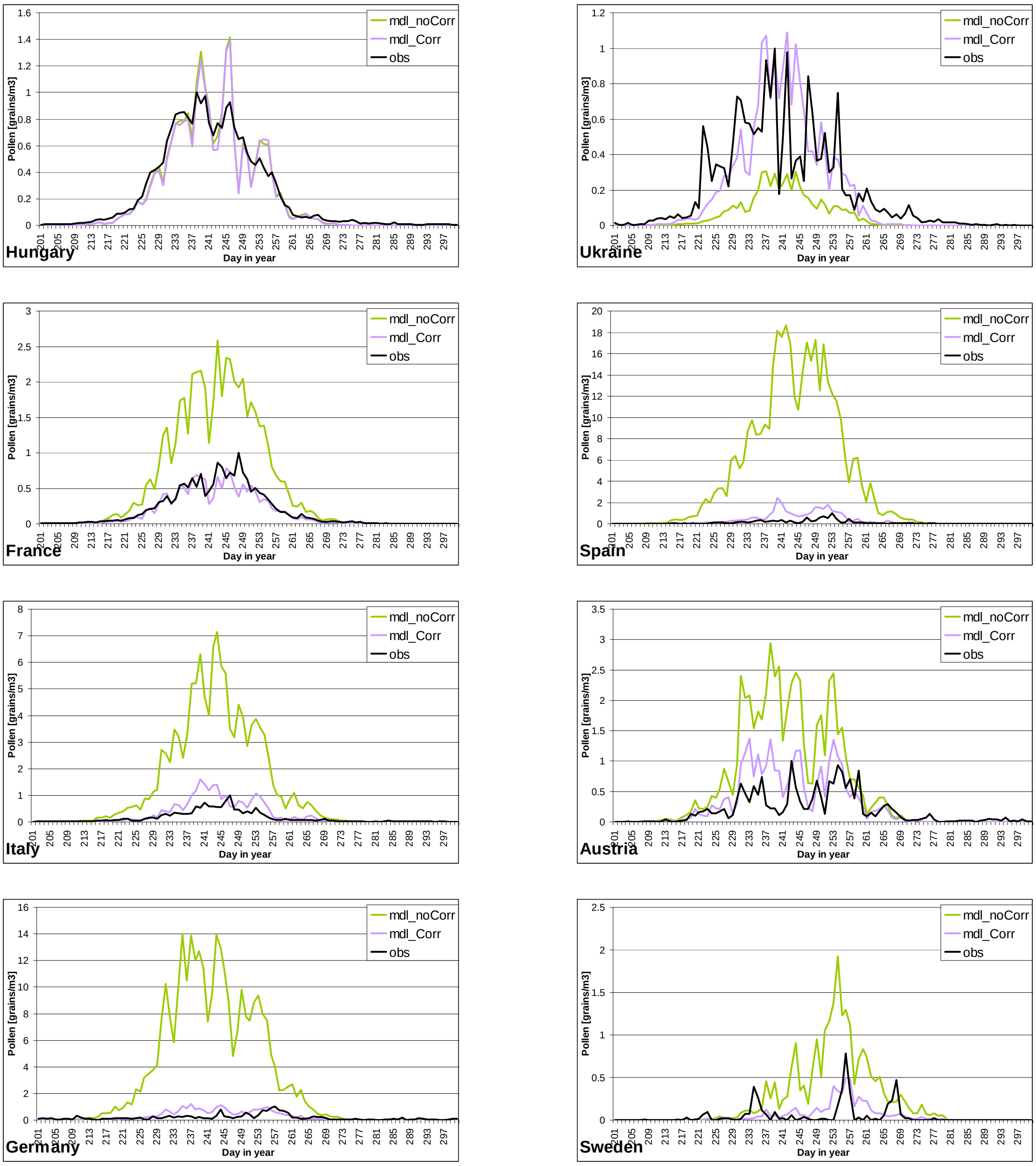
It should be pointed out that the correction map was computed from the comparison of seasonal totals and averaged over five years, thus addressing the long-term bias in the model concentrations, which most likely originate from emission uncertainties. This correction does not affect the phenological seasonal developments or pollen release models, which were parameterized using the daily EAN pollen counts.

Figure 6.13. (a) Ragweed emission correction map, showing the factor by which the ecological-model predicted ragweed emissions required multiplication by in order to produce the correct pollen totals in the European Aeroallergen Network pollen monitoring database. (b) Map of the corrected relative pollen emissions.



The data analysis shows that the model reproduces the pollen season propagation fairly well both in main source regions and further away (Fig. 6.14). The beginning of flowering is well described by the calendar day dependent model, whereas the bioday threshold can influence the flowering timing only in the northern areas. A combination of fixed flowering duration with the minimum night-time temperature limit seems to provide satisfactory results for the timing of the end of the season.

Figure 6.14. Modelled and observed pollen season propagation (average 2006-2010, concentrations normalized to maximum pollen count) for a range of European countries. Observed pollen grain concentrations (obs) are contrasted with SILAM model estimates for uncorrected (noCorr) and corrected (Corr) pollen emissions.



The spatial pattern of total pollen amount is quite well captured even without using the correction map (spatial correlation coefficient across EAN stations is 0.66) and is further improved with the use of the correction (spatial correlation rises to 0.85 if correction is applied). Computing the total emitted pollen amounts as a function of local meteorology (heat sum and soil moisture during the growth period) could further improve the models ability to capture the year-to-year variability of pollen loads, which is now under-predicted.

SILAM's ability to predict the dynamic range of hourly concentrations could not be verified due to daily temporal resolution of EAN. For daily range representation, SILAM output was averaged to daily level and then all the exceedances of selected thresholds were counted for model results both with and without the correction map (Fig. 6.15). In the main source regions (Hungary, Ukraine) the model is under-predicting the number of days with low pollen concentrations (<20) but at least with the correction map the number of high-concentration days are quite accurately predicted. Further away from the main sources the model is over-predicting over the bulk of the range, though the use of the correction map improves the prediction substantially. Corrected and uncorrected maps of pollen threshold exceedances for the current day distribution of ragweed are shown in Fig. 6.16.

5.1.2 Estimation of pollen impacts

Pollen threshold exceedances for a range of thresholds were converted into human exposure using gridded population density data from the Global Rural-Urban Mapping Project (http://sedac.ciesin.columbia.edu/gpw/). By multiplying the number of hours above the threshold by the human population size, it was possible to estimate human exposure in terms of 'person hours' above the threshold. This showed that the largest human exposure to ragweed pollen was in Ukraine, with large populations also affected in other south eastern countries (Fig. 6.17). Italy, France and the UK were also identified as having large population exposure to very low concentrations of ragweed pollen, although as described above, these may result from over-prediction of the lowest pollen concentrations.

Figure 6.15. Modelled and observed distributions of daily pollen concentration exceedances for selected European countries. Model outputs are averaged over the years 2006-2010 and values are normalized to observed days above 1 grain m^{-3}. Observed exceedances (obs) are contrasted with SILAM model estimates for uncorrected (noCorr) and corrected (Corr) pollen emissions.

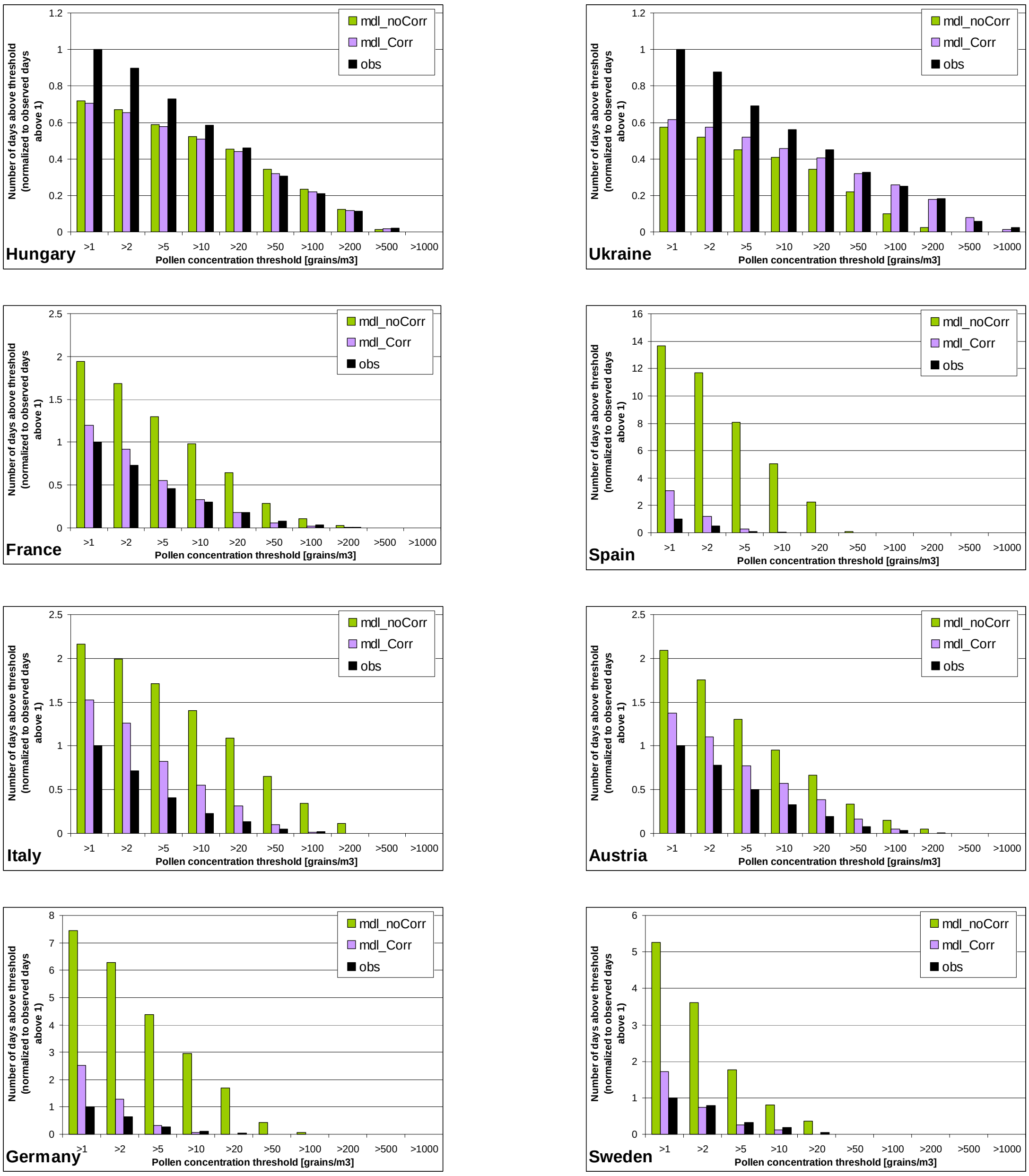


Figure 6.16. Maps of current day (1990-2010 average) ragweed pollen concentration exceedances for 1, 10 and 50 grains m^{-3} thresholds, as outputted by the SILAM model with uncorrected (left) and corrected (right) pollen emissions. Shading shows the number of hours above each threshold.

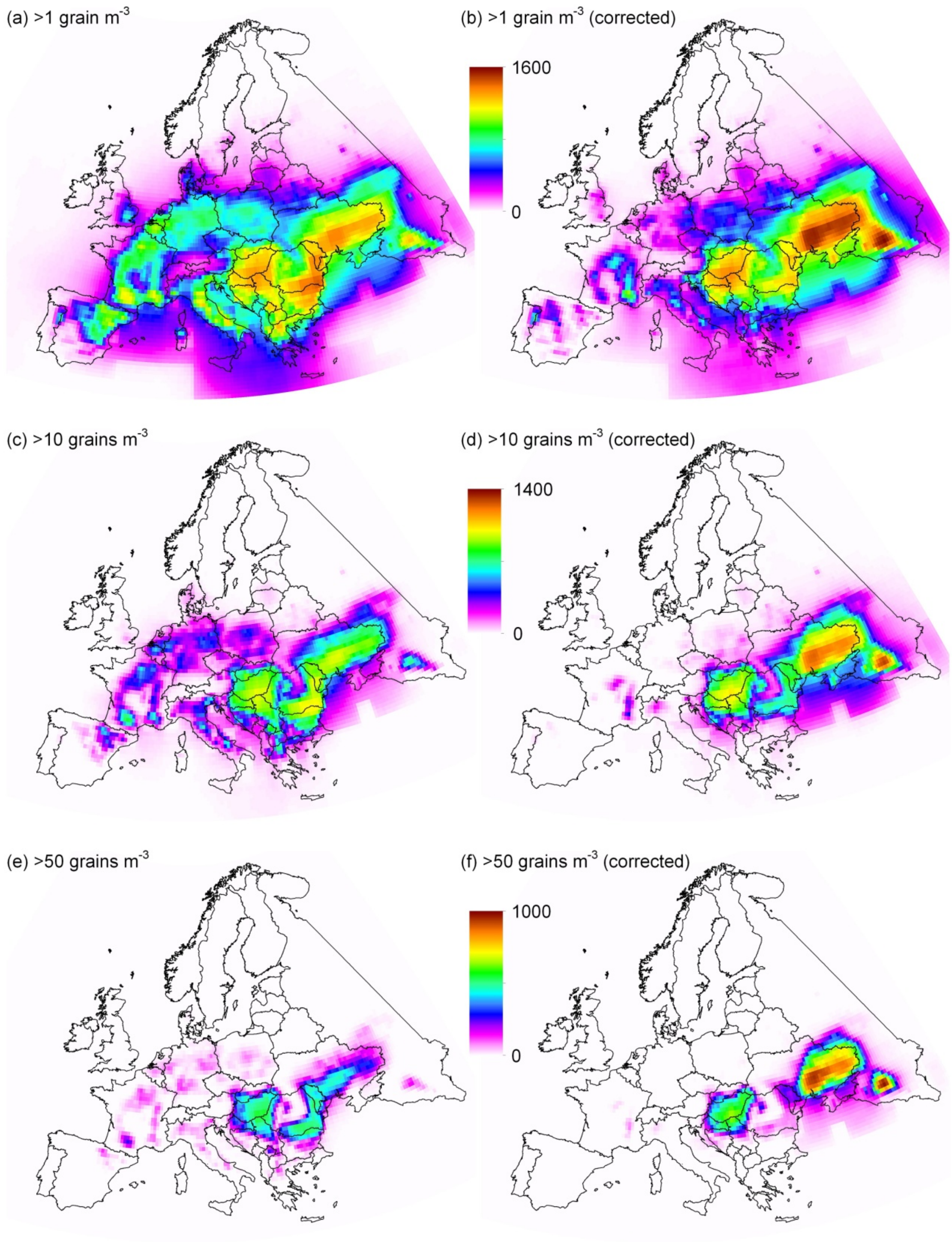
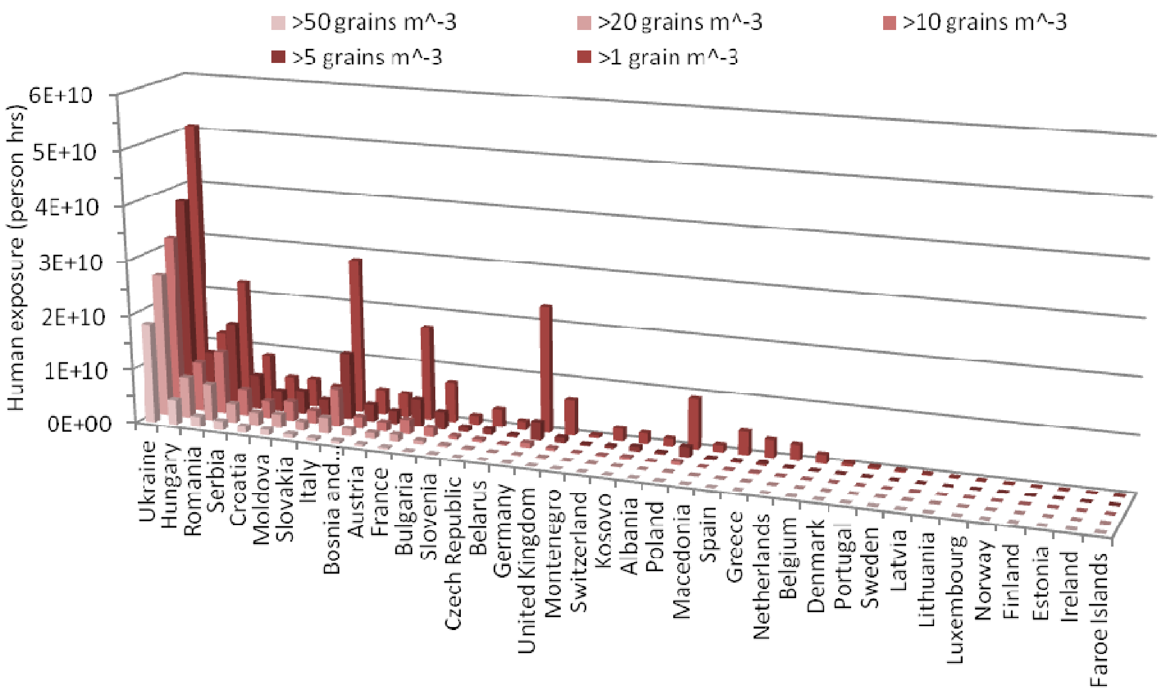


Figure 6.17. Human exposure to ragweed pollen for the current day, in terms of person hours above five different threshold concentrations, computed for each country.



5.1.3 Model outputs for climate and land use change scenarios

As described above, model calibration for the current day was done using meteorological fields from the ECMWF model. For simulations under climate change, we used outputs of the global climate model ECHAM-5 (Roeckner & Meteorologie 2003), which was created by modifying global forecasts from ECMWF. Nevertheless, meteorological fields generated by climate models such as ECHAM-5 evidently differ substantially from those produced by the operational forecasting systems with high spatial resolution and heavy use of data assimilation, such as ECMWF. Therefore, a separate evaluation has been performed for the ECHAM-driven simulations.

The current-climate pollen load was computed as driven by ECHAM-5 meteorological fields both with and without the correction map and compared to EAN pollen counts from last 30 years. The fractional biases of the model predictions are shown in Fig. 6.18. Generally the results agree very well with the ECMWF meteorology driven computations, but a slight underestimation shows up with ECHAM-5 meteorology also for the main source areas. The reason for that is the enhanced mixing in ECHAM-5 data compared with ECMWF. In summer conditions the daytime boundary layer height computed from ECHAM-5 data can exceed that of ECMWF by a factor of approximately two.

SILAM outputs were generated for three climate change scenarios, using the ragweed habitat and distribution maps predicted for each future year by the spread model. Unfortunately, ECHAM-5 does not run SRES scenario B2, which was used in the spread model. Therefore, we used the ECHAM-5 runs of the very similar B1 scenario and call the amalgamated outputs a hybrid B scenario. Although current-day model runs included a correction factor in the total pollen emissions, as the correction cannot be projected to the future the future-climate computations were made without the correction map. The model predicted that the ragweed pollen clouds would shift north with climate and land use change (Fig. 6.19), reflecting the northward shift in the species distribution and habitat quality (Figs. 6.10 and 6.11). Although this meant there was only modest changes to the overall population exposure in Europe (assuming no change in population size or distribution) this masked significant regional changes as illustrated by decreased exposure in Hungary and increased exposure in Germany (Fig. 6.20).

Figure 6.18. Fractional bias of the current climate computations with ECHAM-5 meteorological data with and without the pollen emission correction map, presented for a range of European countries.

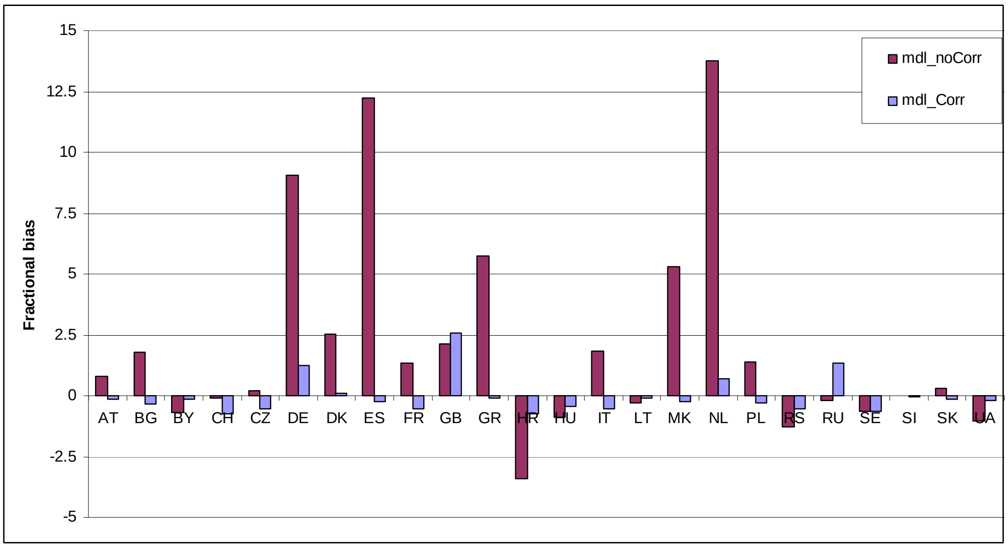


Figure 6.19. Ragweed pollen concentration exceedances for 1 and 50 grains m^{-3} thresholds predicted for the year 2050, under three climate and land use change scenarios. Maps show the number of hours above each threshold. Simulations for the future are made without correction to the pollen emissions.

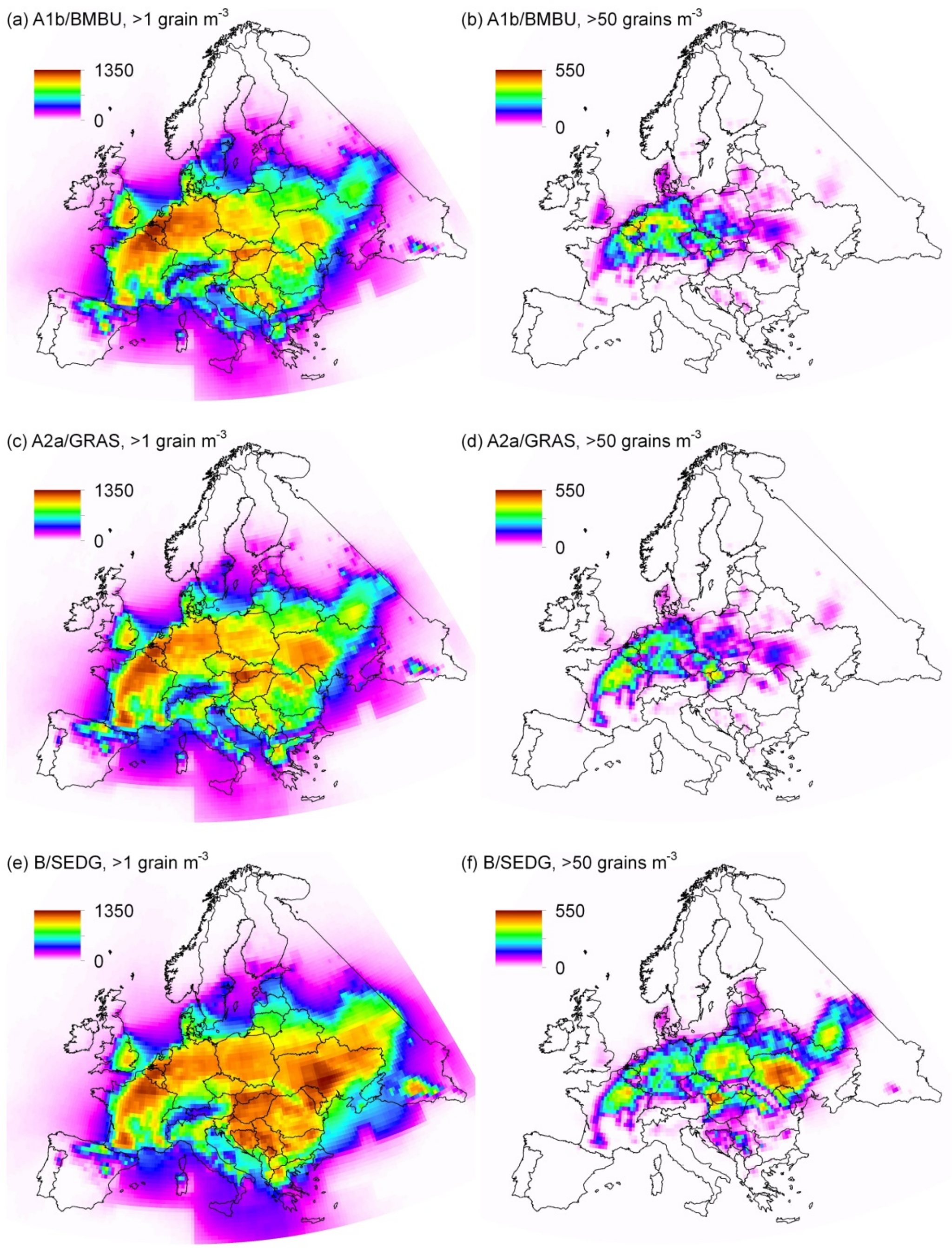
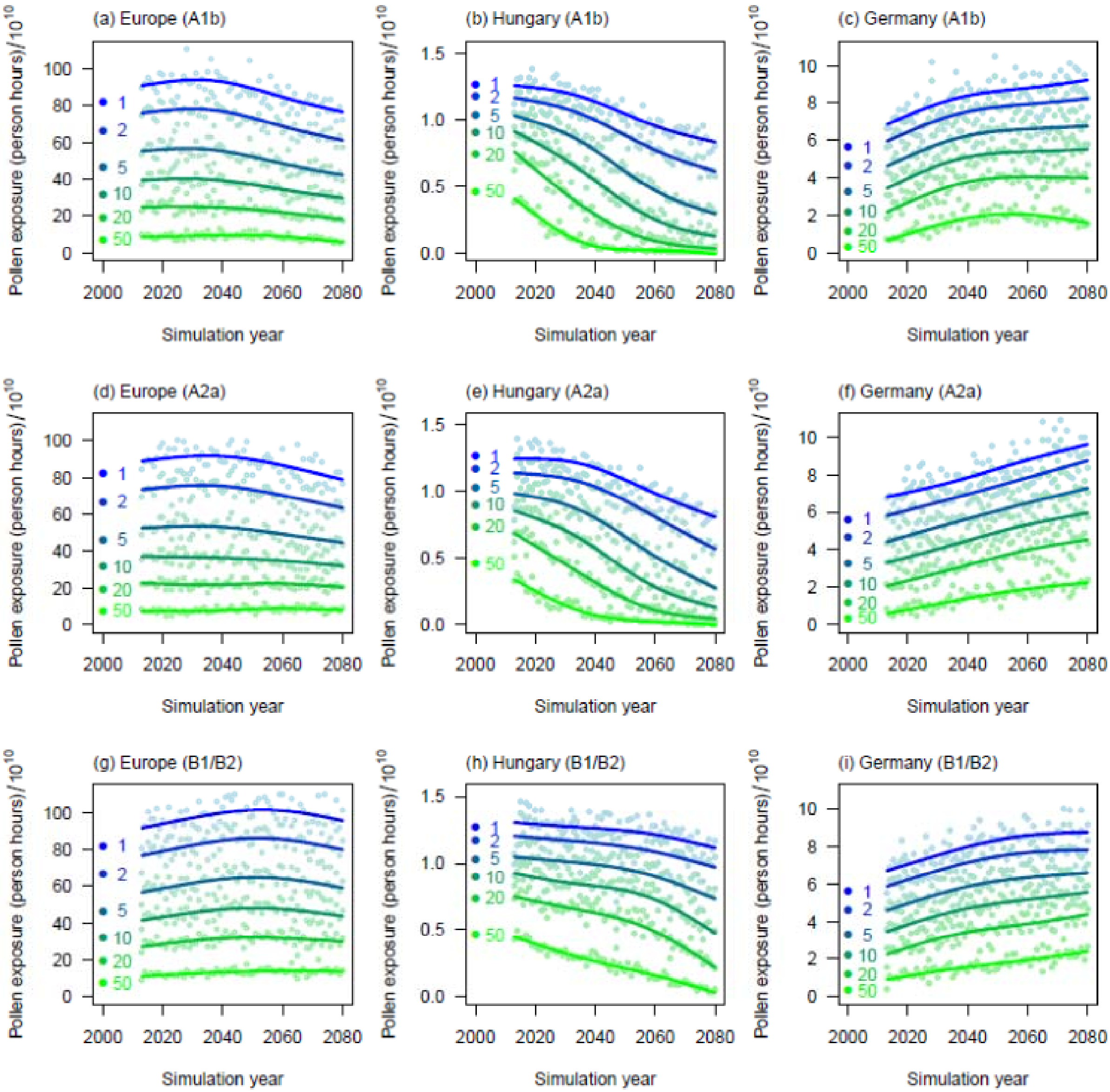


Figure 6.20. Future trajectories of human pollen exposure for six pollen concentration thresholds (line and point colour and labels, grains m^{-3}) under three climate change scenarios (rows) for the whole of Europe (left), Hungary (centre) and Germany (right). Open points show the model outputs for individual years and lines are smotthing spline fits. The filled points show the 1990-2010 average exposures. All results are for SILAM runs with uncorrected pollen emissions and exposure is estimated with the current human population density map, as gridded future population scenarios were not available to us.



5.2 Local impact of ragweed plants on agriculture

The main direct impact of ragweed plants is on agriculture (see Task 4). We initially computed an index of the relative ragweed impact on crop production for each grid cell as $\Theta Q H_c$, where Θ is the simulated probability ragweed occupancy, Q is the climatic quality and H_c is the proportion cover of cropland. However, the modelling of pollen impacts suggested that pollen emission was not directly proportional to this index, but was instead strongly concentrated in the most climatically suitable regions for ragweed (see Fig. 6.13). Since pollen production will be affected by ragweed population size, biomass and plant condition (Fumanal *et al.*, 2007), it seems likely that ragweed's impacts on crops will be strongly correlated with the pollen emission.

Therefore, we developed a new ragweed crop impact index as $\frac{e^{aQ}-1}{e^{a}-1}\Theta H_c$, where a is a parameter whose increasing values concentrate impacts towards higher quality areas. The value of a was estimated at 15.99 by fitting the impact index to the normalised corrected pollen emission (see Fig. 6.13b) within the 'good data' region (see Fig 6.7b), where we expect the spread model to make the most accurate prediction of occupancy. The index was fitted by least squares, with the resulting model showing a good fit (R^2 = 0.763). The high value of a meant that the index suggested that ragweed has virtually no impact on crops where $Q < 0.6$.

As can be seen in Fig. 6.21, the model predicts large impacts in the Rhône Valley (south east France), Pannonian region (Hungary, Serbia and surrounding lowlands), Kosovo, the Bulgaria/Romania border, Moldova, and southern Ukraine. Outside of this region, impacts are generally low even where levels of invasion of high (e.g. Netherlands).

Relative impacts to crops at a national scale, accounting for the between-country variation in crop areas, can be estimated as $\sum_i \frac{e^{aQ_i}-1}{e^{a}-1}\Theta_i H_{c,i} \Big/ \sum_i H_{c,i}$ where i indexes all the grid cells in the country. As can be seen from Fig. 6.22, the worst affected countries are predicted to be in southeast Europe, with little impact outside of this region.

When the model is simulated with the climate change scenarios, it can be seen that over the coming decades ragweed's crop impacts are projected to fall considerably under all the climate change scenarios (Fig. 6.23), despite little change in the total number of grid cells invaded (Fig. 6.9). This reflects the expected loss of suitable climate in the currently heavily invaded areas and loss of cropland in eastern Europe during the scenarios (Fig. 6.24). Impacts are then projected to stabilise or increase, as ragweed shifts its distribution north to colonise newly suitable regions. This is particularly so for scenario B2, where more cropland in Eastern Europe is retained and the severity of the warming is not as pronounced as in the two A scenarios. The model suggests that climate change will cause ragweed to have large impacts on crops in Germany, Netherlands, Belgium, northern France, Czech Republic, Poland, eastern Ukraine and southern Belarus (Fig. 6.24), where there is currently little impact (Fig. 6.21).

Figure 6.21. Map of direct impacts of ragweed to crops, for the simulated current day distribution.

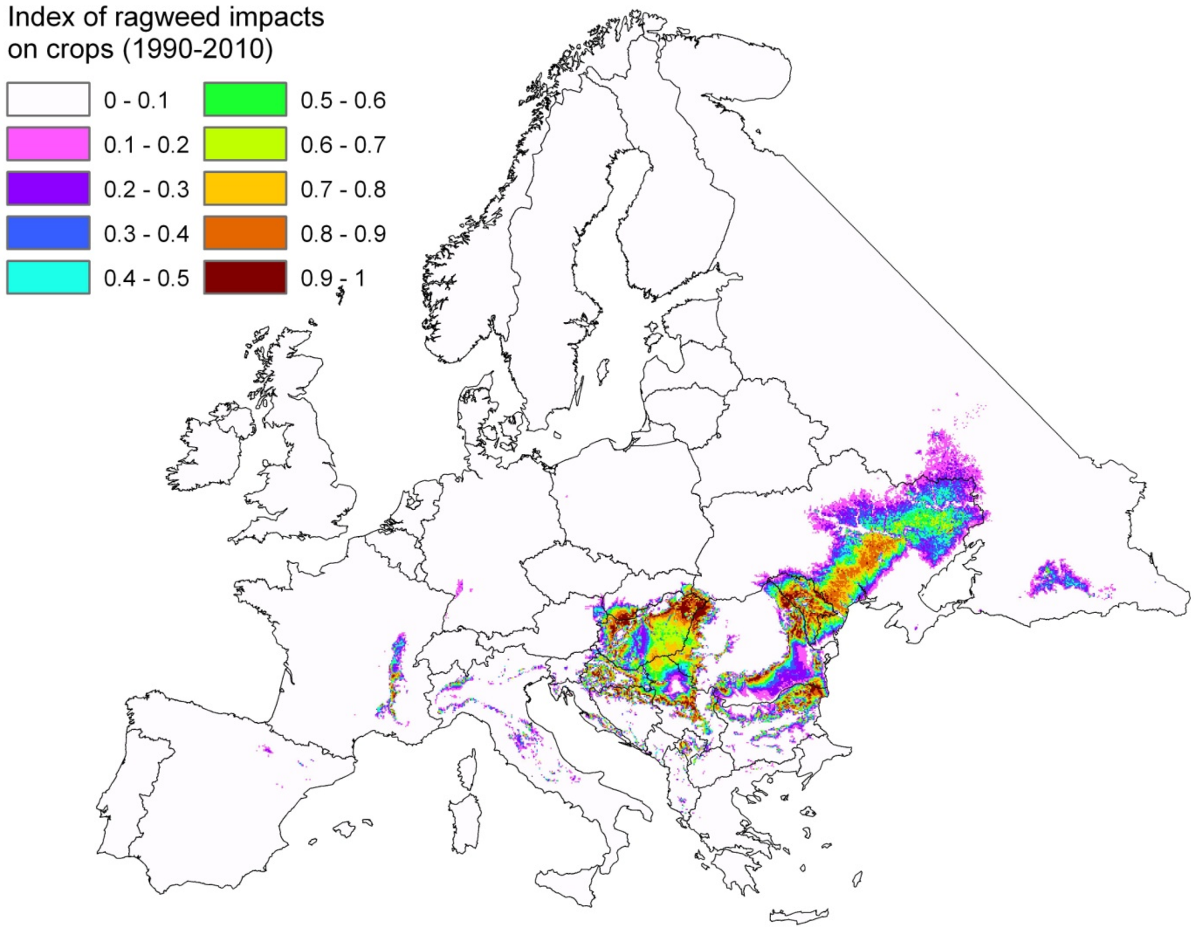


Figure 6.22. National crop impact index for all the modelled countries, except Russia and Turkey which were not fully included in the modelled region.

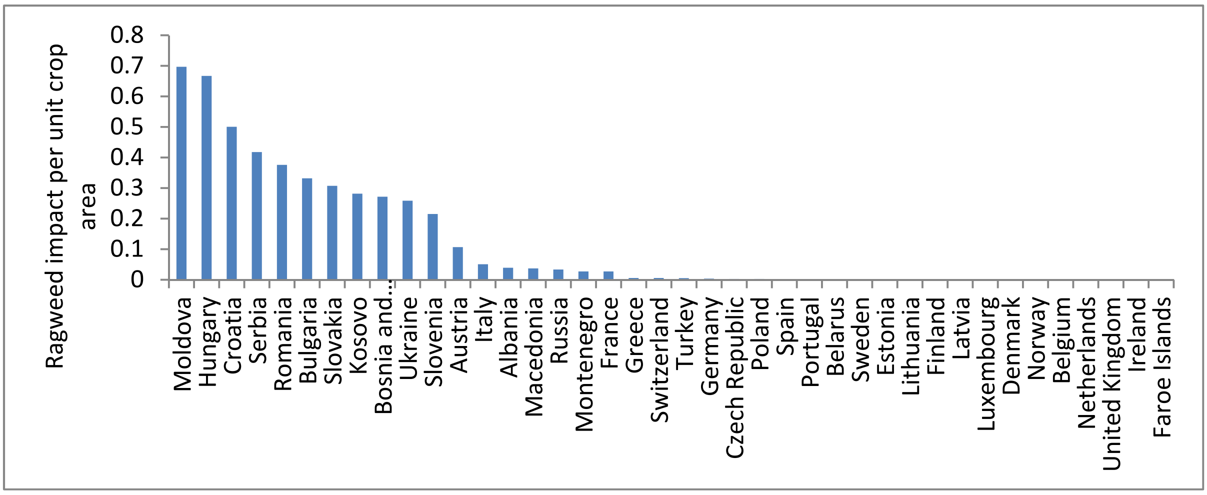


Figure 6.23. Crop impact index for the whole modelled region during simulations of the model with climate change scenarios.

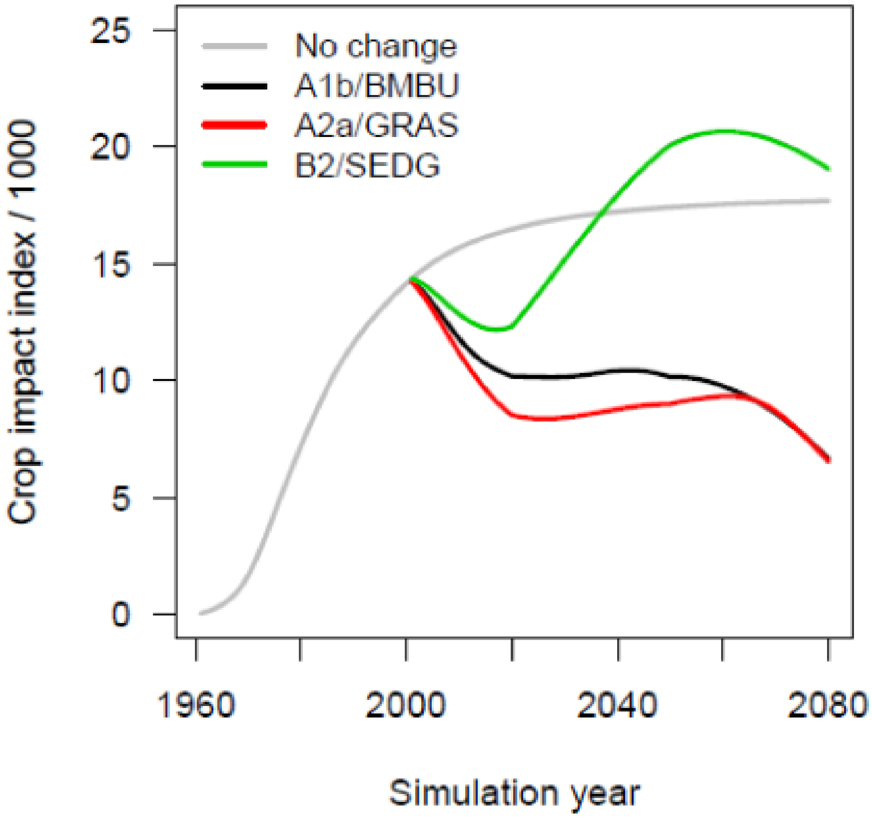
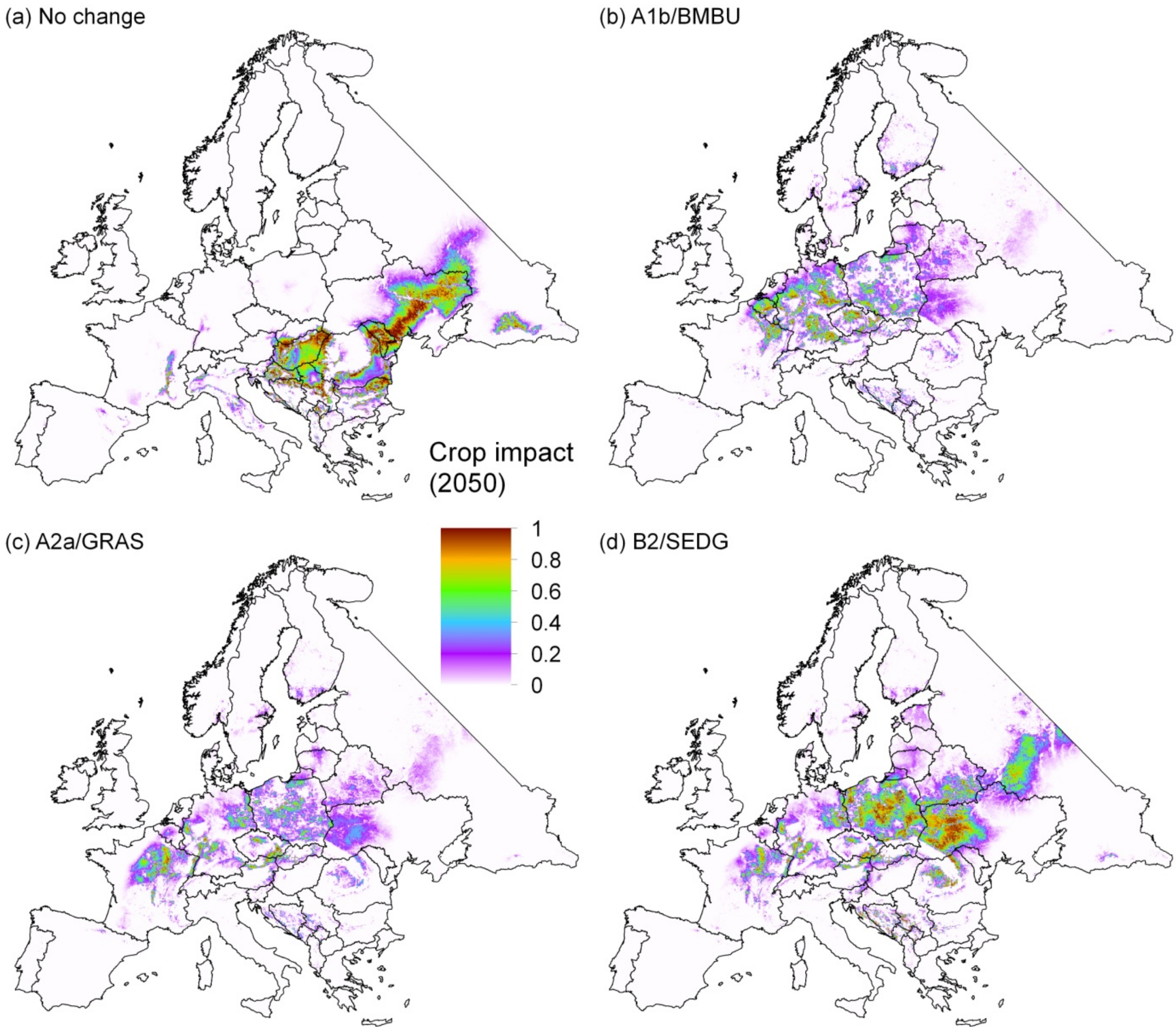


Figure 6.24. Maps of the predicted crop impact index in the year 2050, for model simulations under four scenarios of climate and land use change.



6 Modelling control of ragweed spread

The model was used to investigate the effectiveness of measures (see Task 7,9) for mitigating the risk of ragweed's spread over the next 20 years. Control models were simulated with the climate and land use change scenarios as above, and with control action across the whole model region starting in the year 2013 and persisting until 2032. Two types of control measure were considered:

1. Increased biosecurity, where contamination of imported seeds was reduced to zero.

2. Eradication of ragweed from portions of the infested grid cells, implemented by reducing the area available for ragweed invasion.

The first part of the simulated eradication strategy was the eradication effort, or total area in which ragweed is searched for and destroyed. This was expressed as a percentage of the total crops and urban land area in the cover map for the year 2000.

A second part of the eradication strategy is the way in which control effort is distributed among the grid cells. We assumed that equal effort would be required to carry out eradication in an invaded cell as would be needed to search for and fail to find ragweed in an uninvaded cell. Given that there will always be uncertainty in the knowledge of ragweed's distribution, a real control strategy will necessarily include visits to areas not actually invaded. However, it should be possible to use knowledge of the species' climatic and habitat requirements to target control action to the places most likely to be invaded. Therefore, four alternative strategies for distributing the eradication effort were modelled:

1. **Even** – every 5x5 km grid cell has its invadable area reduced by X%, X being the overall eradication proportion. This is a very basic strategy that applies the control effort in a largely untargeted way.

2. **Past** – eradication uses information on climatic quality and habitat in the recent past (year 2000) to prioritise eradication in the most invadable grid cells. Grid cells are ranked based on *QH*, i.e. the product of climatic quality and cover of crop and urban habitat, and visited intensively in rank order until the desired total area with eradication is achieved. We assume that 100% eradication in any 5x5 km grid cell is impossible, and so limit the eradication in each grid cell to a 95% reduction in its invadable area. This strategy tries to target control more intelligently, but failure to account for climate and land use change means it uses out-of-date information on where ragweed is likely to invade.

3. **Dynamic** – similar to Past, but it uses annually updated habitat and climate maps to target eradication to the most invadable grid cells in the present year. This strategy aims to keep track of the invasion during climate and land use change.

4. **Future** – similar to Past, but it uses the predicted climatic quality and habitat cover in 2032 to prioritise eradication to the areas predicted to be most invadable in the future. This strategy tries to pre-empt the course of the invasion.

The model was run for each combination of climate and land use change scenario, biosecurity scenario, control strategy and eradication efforts of 0, 5, 10, 25, 50 and 75% of the total invadable area.

6.1 Direct ragweed impacts

The model outputs showed that the targeted strategies, based on climatic quality and land use, were more effective than the 'even' strategy for reducing both the area invaded (Fig. 6.25) and the impact to crops (Fig. 6.26). When climate or land use change occur in the model, then control strategies based on dynamically updated or future-predicted climatic quality and habitat cover are more effective than a strategy based on past knowledge.

Control efforts had a greater impact on the crop impact indices than on the number of invaded grid cells (Figs. 6.25 and 6.26). This was because we assumed complete eradication from an entire 5x5 km grid cell was very difficult, but the control effort eliminated ragweed from a large part of the cropland and so reduced the impact.

Biosecurity increased the effectiveness of all strategies, but was more important for limiting spread than impact. This was because the areas where ragweed had the greatest impact hold self-sustaining ragweed populations, which were not very dependent on seed imports. Therefore, biosecurity prevented new introductions in peripheral areas where impacts were low, but had a lower effect on impacts within the established invasion hotspots.

Assuming control effort on 5% of the European crop area, targeted by the most effective 'dynamic' or 'future' strategies, the model predicts proportional reductions of 3-14% for ragweed occupancy and 24-30% for the crop impact index, depending on the climate change scenario. If rigorous biosecurity is implemented in the model, these are predicted to increase to reductions of 36-58% for occupancy and 32-48% for crop impacts.

Figure 6.25. Numbers of grid cells invaded by ragweed after 20 years of simulated control with varying effort and strategy and with and without improved biosecurity to prevent seed import contamination. Panels show model results under the four climate and land use change scenarios.

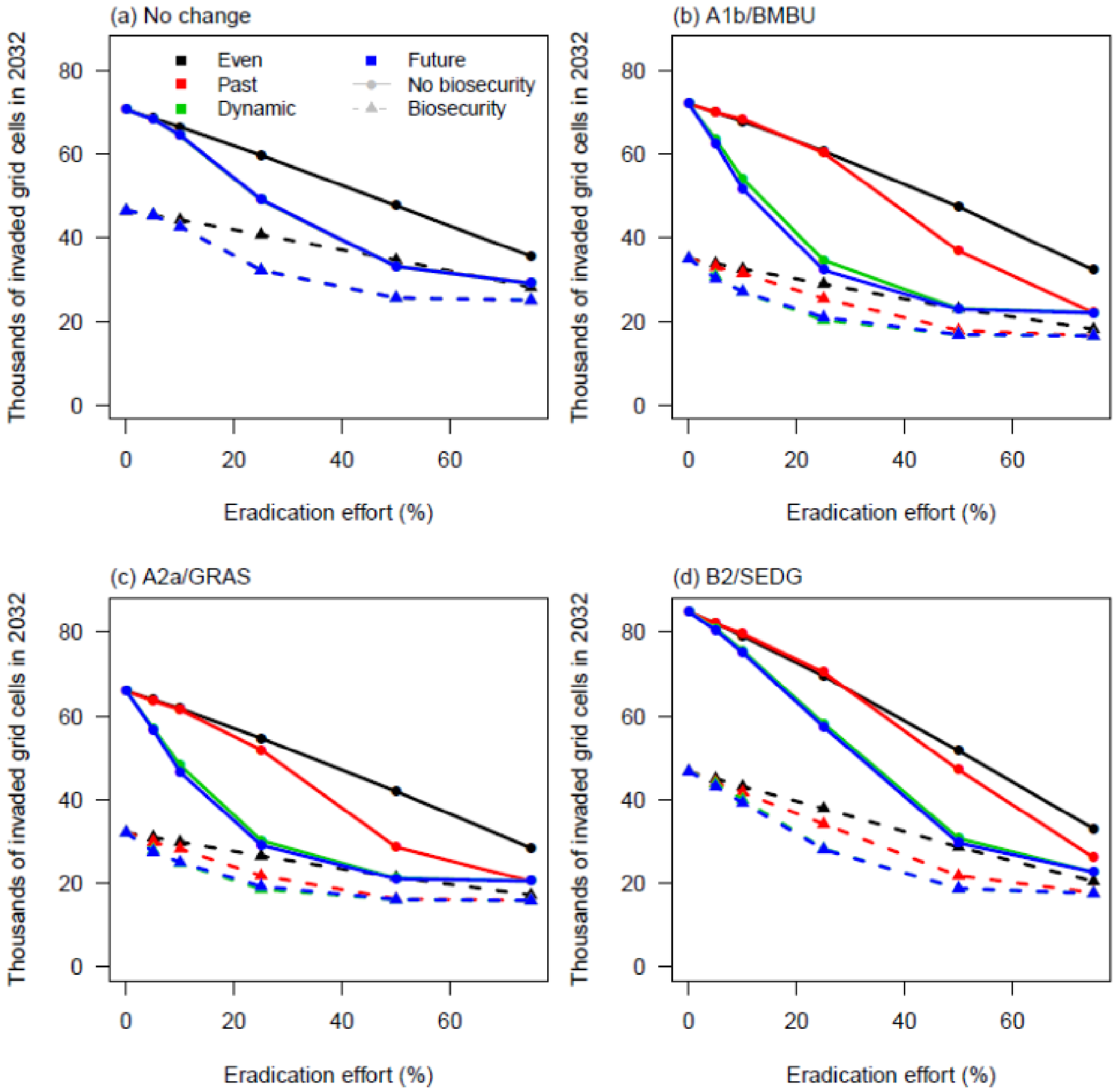
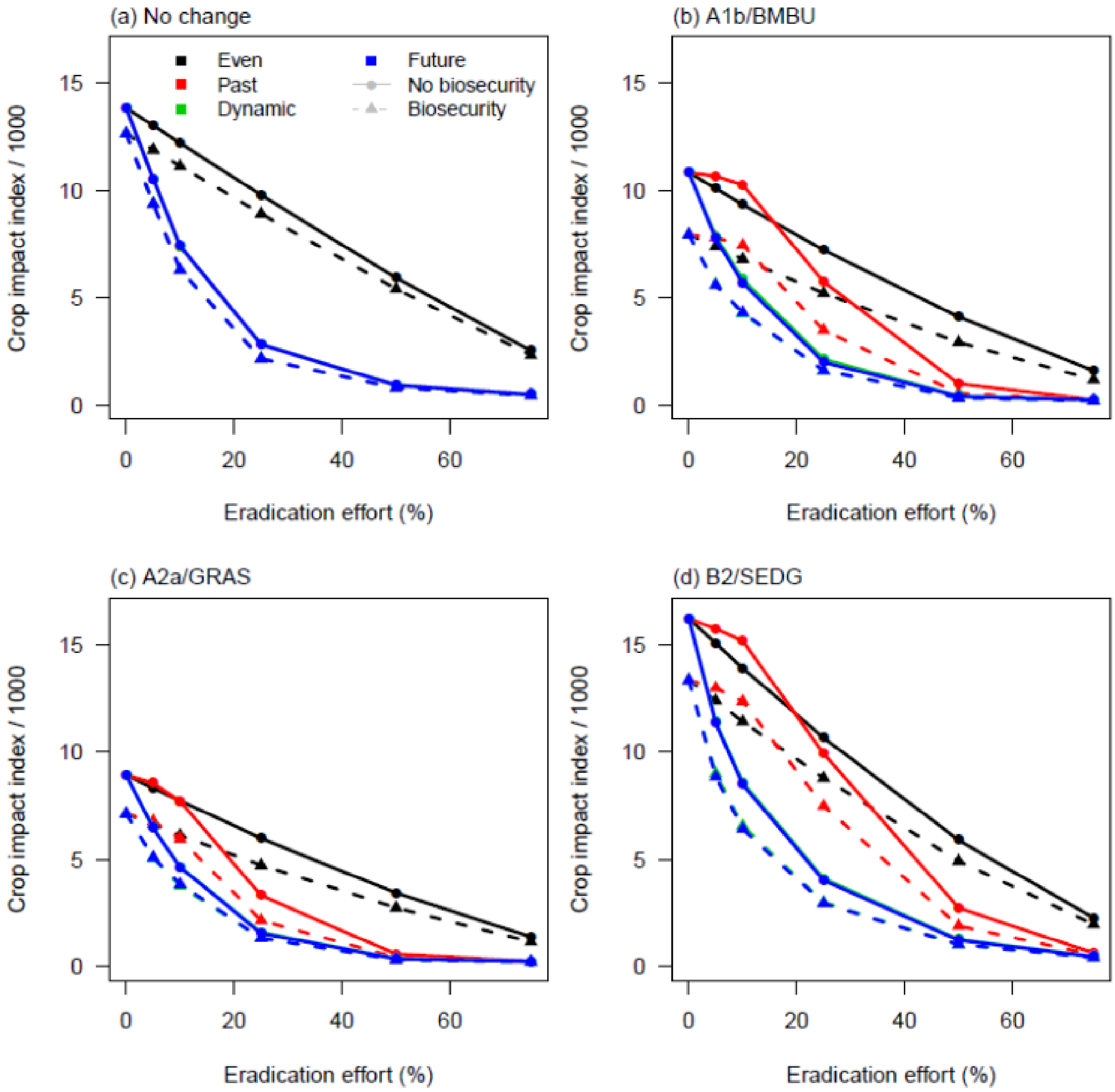


Figure 6.26. Equivalent of Fig. 6.25 but showing the crop impact index instead of invaded area.



6.2 Pollen impacts

In the time available, it was not possible to estimate effects of control on pollen exposure by running SILAM for the control scenarios. In any case, SILAM model runs would have been of limited use for estimating control impacts because of the inability to apply the spatial emission correction to the future distributions. Therefore, we made an approximation to the pollen exposure maps by a spatial buffering of the crop impact index (Figs. 6.21 and 6.24) using focal averaging. In focal averaging, the values of each grid cell are replaced by the average value of the grid cells in the surrounding neighbourhood. In this way the averaging makes a crude approximation to the diffusion of pollen away from emission sources, which we believe to be mainly coincident with crop impacts.

We found that focal averaging with circular radius of 30 grid cells (150 km) resulted in a very strong correlation to the number of hours with ragweed pollen above 5 grains m^{-3} (r = 0.968), this being a pollen concentration at which sensitive patients often become affected (see Task 4). The focal averaging output was strongly related to this exceedance according to the sigmoidal model $e = 2343 f^{1.191} / \left(f^{1.191} + 0.535^{1.191}\right)$, where e is the exceedance, f is the focal average crop impact index and the coefficients are fitted by least squares estimation (R^2 = 0.942) (Fig. 6.27). Pollen exposure according to the focal model was under-estimated in Ukraine and southern Russia, which is most likely because the spread model underestimated the extent of the invasion there. There was also an underestimation in little-invaded countries that suffer occasional long-range transport events (e.g. Poland), but the impact of these events is likely to be quite low anyway.

Using the focal averaging estimates of pollen exposure, the simulated control effort had a similar effect on pollen exposure (Fig. 6.28) as was previously calculated for the crop impact index (Fig. 6.26). Assuming control effort on 5% of the European crop area, targeted by the most effective 'dynamic' or 'future' strategies, the model predicts proportional reductions in this level of pollen exposure of 25-39% if biosecurity measures are not implemented and 28-60% if contamination of imported seed is eliminated.

Figure 6.27. (a) Current day estimate of average hours per year with ragweed pollen greater than 5 grains m^{-3}. This map is produced from SILAM outputs made with spatially corrected pollen emissions. (b) An approximation to the current day exceedance, made by focal averaging of the crop impact index.

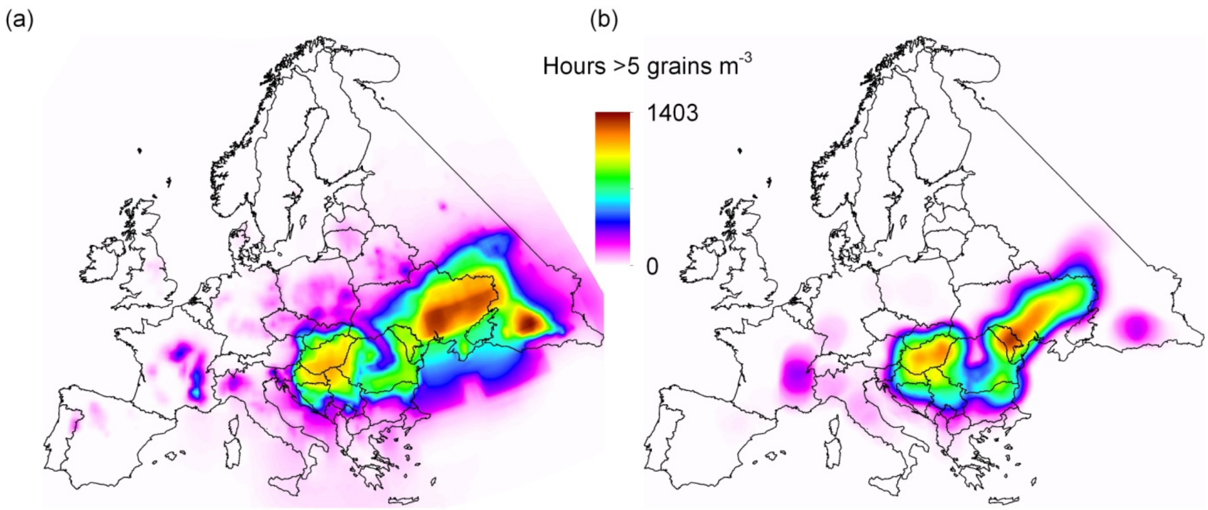
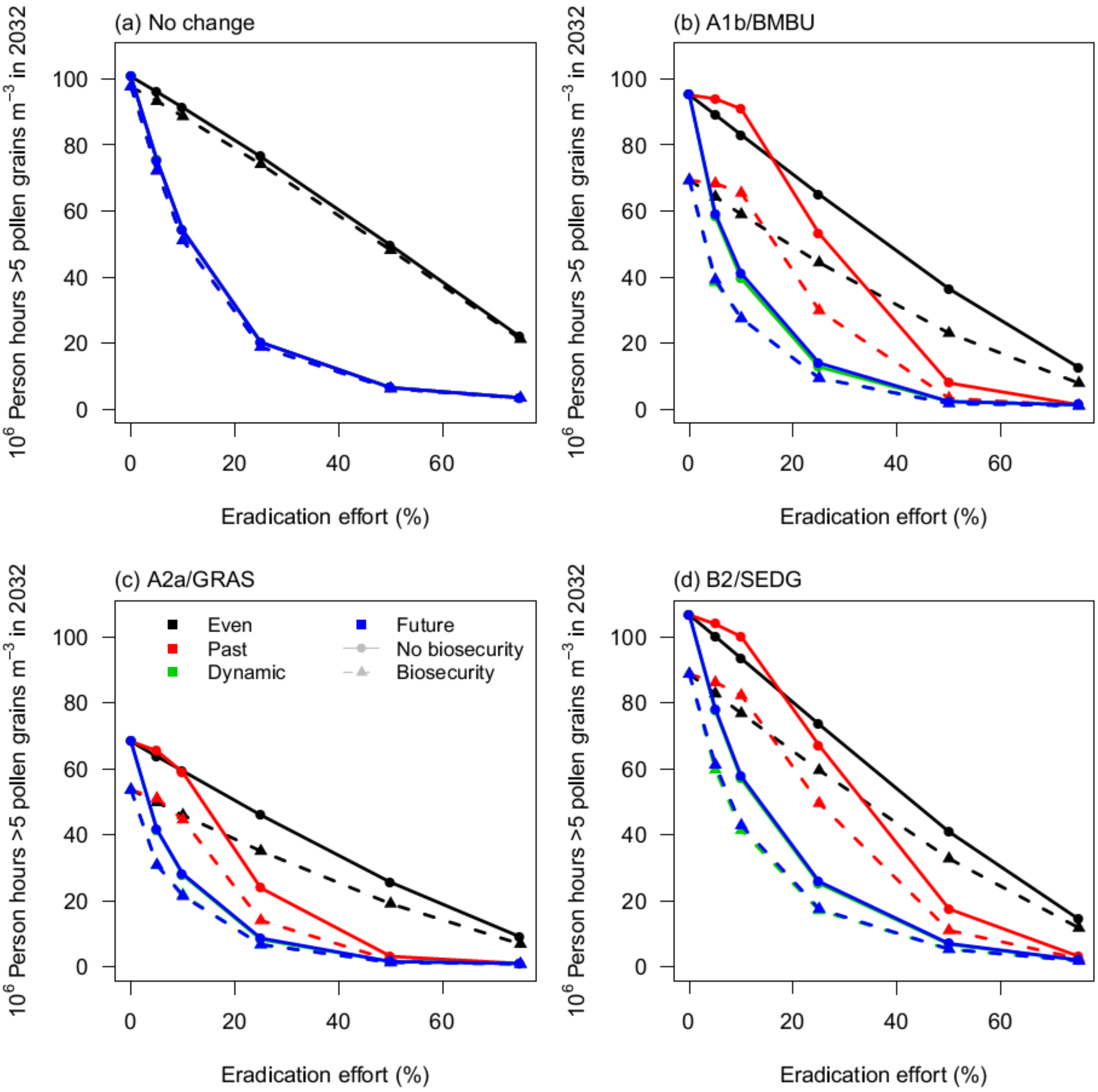


Figure 6.28. Equivalent of Fig. 6.25 but showing the focal averaging estimate of pollen exposure, expressed as the person hours exposed to >5 ragweed pollen grains m^{-3}.



7 Discussion

7.1 Phenology model

The use of mechanistic phenology modelling in predicting species distributions is very rare in plant ecology (Chuine & Beaubien 2001; Morin *et al.* 2007) and to our knowledge this is the first application of such a technique for an invasive plant. Our modelling of ragweed phenology allowed us to predict the northern and high-elevation range margin from the region where thermal and photoperiod constraints permitted ragweed to complete its lifecycle before being killed by frost. The modelling made a very good prediction of the native North American range limit and captured nearly all European records. Where European ragweed records occurred beyond the predicted range limit, the literature emphasised their ephemeral nature and inability to set seed (Dahl *et al.* 1999; Saar *et al.* 2000; Déchamp *et al.* 2009) in agreement with the model prediction. Therefore these records most likely represent transient introductions as seed contaminants. In the northern part of the predicted range successful production of seed is highlighted in the literature, but references also suggest casual populations persisting for only a few years or failing to spread (Rich 1994; Dahl *et al.* 1999; Saar *et al.* 2000; Brandes & Nitzche 2006; Déchamp *et al.* 2009; Sauliene *et al.* 2011). This suggests that the application of the model to predict where reproduction typically occurs was valid, but that ragweed is not able to spread by its own means to the full extent of its reproductive range. Colonisation of northern areas must therefore be aided by humans.

Nevertheless, the phenology model produces a mechanistic link between the climate and ragweed's potential range. Extrapolation of mechanistic models into novel conditions, such as warmer climates, should be more reliable than extrapolation of correlative statistical species distribution models (Dormann *et al.* 2012). The phenology model is based upon mechanistic growth responses to temperature and survival responses to frost. This provides a clear prediction that warmer summer temperatures and later autumn frosts will permit ragweed reproduction over a wider area than is currently observed.

7.2 Spread model

The spread model refined the conclusions of the phenology modelling, by showing how populations in the northern part of the predicted range have high extinction rates and so are casual. Even though these populations can produce seed, low temperatures or in some cases insufficiently continental climates promote extinction in the model (Figs. 6.5, 6.6). In the southern part of the predicted range, drought was suggested as a major factor limiting the invasion (Fig. 6.5). Drought has a disproportionately high effect on ragweed germination and seedling establishment (Shrestha *et al.* 1999) and this early mortality may mean that records of ragweed seed introductions from droughted areas are rare. The model was coded to output the distribution of wherever ragweed germinated in each year, and so would not differentiate between locations where ragweed dies as very young plants because of drought and those where it grows to adulthood but fails to reproduce properly because it is too cold. It is much less likely that the species would be recorded as present for the former scenario than the latter. This may be a factor explaining a lack of records of the species from Spain and Portugal, where seed import rates should cause many introductions to occur (Figs. 6.4, 6.7).

Extension of the model to explicitly represent the different demographic factors affecting extinction risk (seed survival and viability, adult growth and survival, fecundity, population size) would therefore probably increase the model's ability to represent the observed distribution pattern but would require better data on ragweed demography than are currently available. However, the current model performs well in predicting very low extinction risk in the known 'hotspots' of invasion (southern France, Pannonian Plain, northern Italy, Bulgaria, Romania, Moldova, Ukraine and southern Russia). In these regions ragweed establishes persistent and spreading populations in the model (Fig. 6.7).

Modelled ragweed spread was based on three dispersal mechanisms – neighbourhood spread, introduction as a seed contaminant with imports from the native range and within Europe, and dispersal through time in the seed bank. For simplicity, neighbourhood spread was modelled with a simple dispersal kernel model where seeds are broadcast randomly around the source grid cell. In reality, most landscape-scale local spread is probably achieved through human-aided movements (e.g. with agricultural machinery or transported soil; Tasks 1 and 2). Since humans do not move randomly a more sophisticated dispersal model may have been more appropriate.

Chapman et al. (2007) developed a model where dispersers originating in a particular location are competed for by the potential sites in which they can immigrate to. The strength of competition depended upon distance from the propagule source and features of the target locations facilitating transport of the propagule. This kind of model has the potential to capture aspects of human dispersal vectors. For example, application of this model to ragweed spread could be used to bias dispersal between grid cells with lots of cropland, reflecting a disproportionate movement of agricultural machines between neighbouring farmland rather than into non-farmed or very distant areas.

Although this would be much more computationally demanding than the current dispersal model, the major advantage could be a more rapid simulated spread and higher occupancy and pollen emission in Ukraine and southern Russia. In these areas the cropland is very fragmented and so the simple model may have under-estimated spread. Although we lack good distribution data for this region, the SILAM pollen emission corrections suggested that ragweed should be more frequent in these areas than was predicted by the model (Fig. 6.17). Therefore, we would suggest that the accuracy of the modelling would be enhanced by future implementation of a more complex model of neighbourhood seed dispersal. In particular, this would reduce the need for a pollen emission correction in the SILAM modelling of pollen dispersion. As a result pollen exposure for future climatic conditions could be predicted with a higher degree of confidence.

The seed contaminant model was also very simple, in assuming an even distribution of imported seed. A better spatial resolution in the information on where imported seed is used and sourced from could be used to generate a more accurate model of ragweed introduction. This may be especially important for the larger countries. Other potential refinements to the model that would have increased data and/or computational requirements include the use of annually varying meteorological weather data rather than long-term average climate data and refinement of the habitat layer to include different crop types, agricultural practices and invadable micro-habitats (e.g. road verges and riverbanks).

However, despite its simplicity, the spread model gave a good correspondence to the known distribution of ragweed in the EU (Fig. 6.7).

7.3 Modelling ragweed impacts

We modelled crop impacts and pollen emission as being severe only where the climate is highly suitable and there is invasion of lots of disturbed habitat. An interesting feature of the model that could only be revealed through our mechanistic and dynamic approach was that ragweed's impacts are partly decoupled from its distribution. This occurred for two reasons. First, between-country variation in seed imports meant that the species is widely distributed in countries that are largely unsuitable for ragweed but import lots of seed, such as Netherlands or Belgium. In these countries, the distribution overstates the very low impact of the casual introductions.

Second, atmospheric transport of pollen emitted from the invasion hotspots can expose human populations to ragweed allergies in areas where ragweed is not common. In the main this occurs in regions adjacent to and downwind of the invasion hotspots, such as northern Slovakia or Poland; this finding is supported by the empirical evidence for long distance ragweed pollen travel reported in Task 4 (Section 2.3). In these countries, the distribution understates the impact of the pollen cloud.

Application of standard species distribution modelling would not reveal these important features of the invasion and could lead to misleading predictions about where ragweed can invade or impact. This justifies the ongoing development of ever more accurate ragweed models, and suggests that simply monitoring the distribution of ragweed will be insufficient to assess its impacts.

7.4 Predicted effects of climate and land use change on ragweed spread and impacts

When simulated with climate and land use change the model predicts two major changes in ragweed's distribution and impacts. First, the species colonises north-western European countries by 2050, approximately up to the southern coast of the Baltic Sea (Fig. 6.10). In these countries, direct impacts to crops and pollen-mediated impacts on people are projected to increase by our modelling. Second, ragweed becomes less widespread in the current invasion hotspots, causing impacts to decrease. This is more tentative than the first conclusion, since the reason for the range contraction is excessive summer heat and there was little distribution data on which to calibrate the response to high temperatures. With better survey data from areas such as northern Italy and the Romanian/Bulgarian border we could be more confident about how the distribution will respond to higher temperatures.

Nevertheless, there is some evidence to suppose that very high temperatures are detrimental to ragweed. In Europe, without this effect we would expect to see a more widespread invasion of Northern Italy and Romania than are apparently observed (Déchamp *et al.* 2009). In the USA, atmospheric pollen maps show that the highest concentrations are in the north east of the country (Girsh 1982). Applying the climatic quality model to the USA confirms that the north east is a high quality region, while the south east is of low quality because of high heat (details not shown).

Ragweed is commonly recorded in the south eastern USA (Fig. 6.3b) and so the low pollen production there is in agreement with the heat-limitation expected by the climatic quality model.

7.5 Modelling control of the ragweed invasion

We used the spread model to investigate the effects of increased biosecurity (reduced imported seed contamination) and ragweed eradication efforts on the spread and direct impacts of the species to crops. The main results of this were to suggest that targeted eradication on as little as 5% of Europe's currently invadable area could reduce ragweed's direct impacts to crops by up to 50% and exposure to dangerous pollen concentrations (>5 grains m^{-3}) by up to 60%. In order to achieve these benefits, the control strategy should target the areas predicted to become suitable for invasion over the next 20 years, rather than a strategy that uses information on the areas highly suited to ragweed invasion now. In other words, given ongoing climate and land use change we recommend that control should try to pre-empt or track the course of the invasion, rather than use static information that will quickly become outdated. The model suggested that eradication was most effective when combined with improved biosecurity to reduce colonisation through the international seed trade, though this had a greater effect on ragweed's distribution than its impact.

A limitation of these predictions is that the computational intensiveness of the SILAM model meant we had to make an approximation to the pollen cloud for control simulations. Further work developing the emission term for the SILAM model is also necessary for accurately predicting the effectiveness of ragweed control programmes.

7.6 Conclusion

In Task 6 we believe we have made considerable progress in understanding the recent European invasion by ragweed and in predicting how it may progress in the future. Future spread will depend on the climate and land use change we experience and whether or not any control action is attempted. We have developed three mechanistic models for predicting the phenology, spread and atmospheric pollen concentrations of ragweed that have allowed us to estimate indices for its impacts on agriculture and public health. The models suggest that ragweed will spread north with a warmer climate, bringing severe impacts to areas not presently suffering to a high degree. However, the modelling also suggests that targeted eradication and enhanced biosecurity should be effective in mitigating the harm caused by this highly invasive plant.

7.7 Acknowledgements

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Tasks 7, 9: Current practices to prevent the further introduction and spread of ragweed, to reduce or mitigate its harmful effects and for its eradication

1 Introduction

Due to its impacts on agriculture and human health many countries have consequently set up measures to prevent the further introduction and spread of ragweed, to reduce existing populations or completely eradicate it where possible. These measures include funding of research, creating legal instruments, applying various mechanical and chemical measures, public awareness campaigns, monitoring programmes etc.

Despite these measures, it does not appear that the spread of *A. artemisiifolia* in Europe has been stopped or even slowed down significantly with the exception of some local or regional successes (Starfinger in Bohren *et al*. 2011). This is probably due to the fact that the conditions and drivers that favour the spread of *A. artemisiifolia* comprise the wide tolerance of the species to a range of climatic and environmental conditions, phenotypic plasticity that enables the species to respond to a variety of environments and novel selection pressures, and anthropogenic factors that create disturbed habitat suitable for this annual, ruderal plant. The greatest limiting factor on the spread of *A. artemisiifolia* seems to be climate (Task 1,2; Task 6; the species cannot establish naturalized populations in climates too cold for flowering and successful fruiting. Other than this the densely populated countries of Europe, with mobile and expanding populations reliant on greater infrastructure and a large food supply, provide ideal conditions for this opportunistic species with a high capacity to adapt. The species is tolerant of such factors as mowing, elevated salinity, waterlogging, drought, herbicides, periods of low disturbance and elevated light levels and CO_2 concentrations with an increased biomass.

This report presents overview of the current practices in Member States and in other affected European countries (e.g. Switzerland and Croatia) to prevent the further introduction and spread of *A. artemisiifolia*, to reduce or mitigate its harmful effects, and to finally eradicate it if possible. As explained below, all these measures are considered together as actions to control ragweed. The report addresses Tasks 7 and 9 together as, in practice, measures to control ragweed cannot be disentangled. See section 4 for a further explanation.

2 Data gathering

A data gathering exercise was carried out compiling and comparing existing systems designed to prevent the further introduction and spread of *A. artemisiifolia*, to reduce and mitigate its harmful effects once the invasion has occurred, as well as the existing measures and current practices used to eradicate *A. artemisiifolia*.

The study was focused on the selected EU27 Member States with the addition of other known highly affected European countries: Austria, Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, France, Germany, Hungary, Italy, Latvia, Moldova, Poland, Romania, Serbia, Switzerland, Ukraine.

In parallel with the work of the national experts (see General Methodology) a complementary search for information was undertaken through personal contacts, examination of relevant published and grey literature, reports, websites and other available sources using internet search engines, mainly Google and Google books, using various search terms such as: *Ambrosia artemisiifolia*; + measure, + control, + prevention, + eradication, + policy, + regulation, + spread, + monitoring and awareness raising; focusing on more general background information and regional approaches and countries for which there are no associated national experts (e.g. Luxembourg, the Netherlands, Slovakia, Portugal, Russia), and countries outside of Europe.

Table 7.1. Structure of the Excel-data sheet for gathering information

Section	***Required information***	***Clarification***
General information	Country/region	Provide geographical area where the measure is applied
	Contact person if available	Possible contact to a person who could provide more information
	Prescribed by law/regulation	e.g. compulsory or not; provide also the name of the law/regulation if applicable, incl. regulating level (national, regional, local)
	Implementing body	Name the body responsible for the implementation of the measure or coordination in implementation
	Purpose of the measure	Select between the 3 offered options: prevent introduction; prevent further spread; reduce or mitigate harmful effects
The measures	Measure taken	Title/name of the measure implemented (ensure all measures are listed)
	Description of the measures/method	Ensure all measures described in specific terms
	Level of approach	Geographical/administrative area within which measures apply (e.g. municipality, county, national)
	Specific location of application	Indicate where (ecosystems/habitats etc.) measures are applied in practice
	Sectors it applies to	Which sector applies the measures (e.g. agriculture, building , industry, citizens, etc.)
Observed impact of measures (short term)	Impact on common ragweed	Describe the expected effectiveness of the measures
	Negative/positive impacts on other species	Describe any possible impact the measure may have on other species
	Negative/positive impact on habitats	Describe any possible impact the measure may have on habitats where it is applied
	Environmental impacts	Describe any possible impact the measure may have on the environmental quality (e.g. air, ground or surface water quality)
	Other impacts/risks/benefits related to the measure taken	Describe any other possible impact/risk/benefit the measure may have on society (e.g. human health when using pesticides, costs to society, access to land, damage to crops)

Section	***Required information***	***Clarification***
Stakeholder/ public involvement	Stakeholder involvement	If not covered above in relation to sectors give brief indication of involvement of stakeholders in planning/execution of measures
	General public involvement	e.g. publicity campaigns, voluntary action, research etc.
Evaluation of measures (incl. potential long term impacts)	Applicability for other invasive species	If possible name the species to which the measures also could apply
	Durability	Describe the durability of the measures
	Selectivity	Describe the selectivity of the measure especially in terms of affecting the native species
	Replication potential	Is it possible to apply the measure in other countries/region/habitats
	Effectiveness of the measure	Describe the effectiveness of the measure
	Results quantifiable and how	Describe possible quantification of results and effectiveness of the measure
	Costs per unit	Provide estimated costs per unit if possible
	Human resources required	Provide more details on the human resources required to implement the measure
	Level of knowledge/capacity building required	Describe the knowledge required for implementing the measure and possible capacity building requirements
	Potential for long term involvement of stakeholders/public	Describe the potential for further public/stakeholder implementation of the measures without dedicated programme
	Key factors for success of the measure	Describe the key factors critical for the success of the measures
	Limitations	Describe the possible limitation of the measures
Conclusions	Key issues	What are the key issues related to the measure in general
	Benefits	What are the benefits of applying this measure
	Conditions for success	Describe the pre-conditions for success of the measure
	Limitations	Describe the possible limitations of the measure
	Barriers and bottlenecks	Describe any possible barriers and bottlenecks for implementation of the measure
	Cost effectiveness	A comparison of the costs per unit and effectiveness of different options. This can be qualitative, if the effectiveness can be quantified (i.e. unit cost/unit effectiveness) or qualitative.
	Other comments	Any other comments/conclusions you find relevant
Sources/ references	Relevant references	Provide a full list of references relevant for this measure (including web references), including evidence on effectiveness
	Relevant experts	Provide a full list of relevant experts with contact details if available

To assist the national experts in their search for data, a questionnaire was supplied outlining the details of the data they should retrieve (Table 7.1). This was done in order to provide the structure in the data gathering process and aid in the comparison of data sets at a later date.

3 Context for the evaluation of the measures for control of ragweed

All of these measures should be evaluated having in mind the most important mechanisms, vectors and drivers of spread. The mechanisms (the processes and pathways involved) and the vectors (the carriers) are inextricably linked and are for the most-part human-mediated (see Tasks 1, 2).

As reported in Tasks 1 and 2, the literature on *A. artemisiifolia* and the personal observations made about the spread of the species by the national experts indicated six large-scale systems that integrate numerous mechanisms of spread. Ranked in terms of their relative importance, these are: 1) farming and food production – the agro-industry, 2) the road transport system, 3) the construction industry, 4) the rail transport system, 5) waterways, and 6) natural dispersal by animals. We considered it useful to rank these large-scale systems in addition to ranking individual mechanisms. An approach to control and eradication would be to make individual industries aware of their roles and potential roles in the spread ragweed.

The Task 1, 2 report clearly shows that there are individual mechanisms (or vectors) of spread that are more responsible for geographic or population expansion than others. Table 1.3 of the Task 1, 2 report lists these mechanisms, which are ranked in order of importance (1, highest) with a break-down of their possible routes into the wider environment (road, rail etc.), the habitats/systems they invade, and the drivers and conditions facilitating that spread.

Considering the fact that the *A. artemisiifolia* spreads only by seeds and that for the most part the long-distance seed dispersal is human-assisted, a thorough knowledge of existing measures and best practices to prevent further seed movement and combat the species will be a key issue in achieving a Europe-wide control of the species and getting closer to eradication. The results of this exercise will form the basis to help authorities in:

- The elaboration of regulations related to the main introduction pathways as identified above;
- The development of guidelines on the best control practices;
- The implementation of awareness campaigns to inform and mobilise the general public to participate in the actions for control.

A. artemisiifolia has an enormous potential to multiply since one plant can produce over 2,500 seeds per year on average (see Task 1, 2). Flowers are wind pollinated and able to produce viable seeds by self-fertilization, meaning that even one isolated plant is capable of starting a new population. In addition, the persistent *A. artemisiifolia* seed bank makes eradication of the species difficult. In this context, the prevention and reduction of spread into new areas becomes a key issue and underlines the need for the development of an early warning system as the main tool to rapidly detect its introduction into new areas (see Task 8). When prevention has failed and *A. artemisiifolia* plants have invaded new areas, the most effective strategy will be to eradicate them as soon as possible and preferably before the start of the flowering season. Awareness campaigns to involve stakeholders and the general public are crucial at this stage, as is the establishment of a follow-up control and monitoring system in subsequent years to ensure that the eradication has been successful. Another element to consider is pre-empting factors that might become important in future control, e.g. evolution of herbicide tolerance (Patzoldt et al 2001).

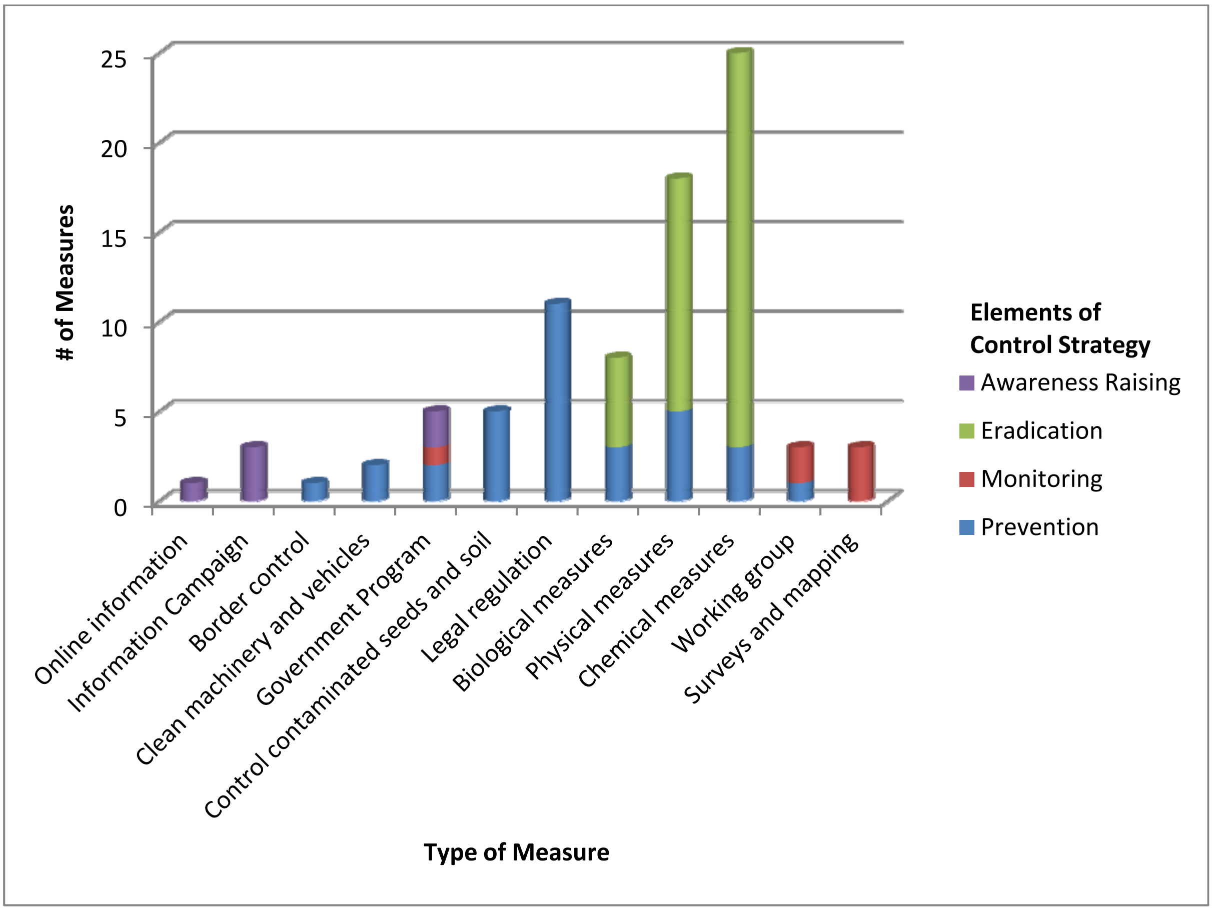
4 Classification of the measures

Initially it was proposed to gather the information on the measures to prevent the further introduction and spread of *A. artemisiifolia* and to reduce or mitigate its harmful effects (Task 7) and the current practices for eradication (Task 9) separately. However, during the data collection process it became apprent that it is difficult and artificial to make a clear distinction between the two sets of measures. While going through the process of gathering and assessing the data it turned out that much of the literature does not make a clear distinction between these aims.

This comes from the fact that there are no specifically developed definitions of eradication, control, etc. We concluded that control mighth be seen as an overall approach to reduce the numbers or distribution of a species, or to eradicate it, in an invaded area. Eradication commonly refers to completely removing the species from the territory and could be seen as just one subset of actions in the overall continuum of management and strategy for control. After the realisation that it is no longer possible to eradicate the species (e.g. because it has become widespread), efforts are then dedicated to preventing its further introduction and spread (where the species isn't eradicated but is reduced in distribution and abundance), and the mitigation of harmful effects, awareness raising, and monitoring. *A. artemisiifolia* is now so widespread in Europe that it is likely that entire eradication is no longer practical or economically feasible; however, it is still feasible to prevent or reduce its spread into new areas (Buttenschøn *et al*. 2009). This conclusion can also be seen in the reports from the national experts, as a number of them report that there are no measures for eradication being taken in their respective countries, but they describe all of the measures undertaken as efforts for controlling spread (e.g. Italy, France and Ukraine). A focus on controlling further spread is increasingly important given the likely expansion of ragweed northwards in Europe under climate change (see Task 6).

The overlap in terminologies was most obvious in surveying the biological, chemical and physical measures, which were sometimes classified as prevention and sometimes as eradication (Figure 7.1).

Figure 7.1 Elements of a Control Strategy and types of measures for controlling ragweed. The chart shows the number of times each type of measure was reported by the national experts.



For more clarity all the measures shown in Figure 7.1 and the subsequent figures of this section are briefly described in Table 7.2. More detailed information on all the measures is available in Annex 7.

The collected information also shows large differences among the countries in the way they respond to the problem of *A. artemisiifolia* invasion and to what extent they implement the various elements of a control strategy (Figure 7.2). Reports from as many as seven countries (Belgium, Czech Republic, Denmark, Romania, Latvia, Moldova and Poland) showed that there were no control actions being implemented. However, Belgium has in the meantime begun a volunteer observation based early warning and rapid response system for Invasive Alien Species (IAS), which includes *A. artemisiifolia* (http://waarnemingen.be/invasive_alert_view.php). The aim of this approach is to streamline the process of observation and reporting to land managers and relevant authorities for intervention in relation to IAS.

The measures applied in various European countries in their efforts to control *A. artemisiifolia* invasion are described in more detail below. These measures are grouped in terms of the components which together comprise a possible strategy for control (Figure 7.3): **Prevention**;

Eradication, **Awareness raising**; and **Monitoring** (e.g. Mack *et al.*, 2000). To put together a potentially successful control strategy, all of the four components have to be in place, while the awareness raising component is crucial for the success of all the other actions.

Table 7.2. Description of measures for controlling ragweed summarised from the national expert reports.

Measure	***Description***
Biological measures	Cultivation of competing vegetation, control by other animals, crop rotation, sowing of competing vegetation.
Border control	Inspecting imported material, particularly agricultural products, and sending contaminated imports back to origin.
Chemical measures	Applying herbicides
Clean machinery and vehicles	Machinery and vehicles are washed after working in a ragweed contaminated area.
Control contaminated seeds and soil	Seed control includes special machinery to sort ragweed seeds from other seeds and limiting the sale of infested birdseeds. Soil control includes quarantining contaminated soil, integrating it in deeper soil layers, covering it with uncontaminated soil, and labelling it.
Government Program - Awareness raising	Programs run by Government agencies that provide information to stakeholders. These involve input from specialists from different sectors, such as agriculture, health, and nature. Some programs also require each person finding ragweed to remove the plants/clusters.
Government Program - Monitoring	Government mandates require city districts to be searched for ragweed and the results compiled in a data bank. Some programs include researching measures to prevent the spread of ragweed.
Information Campaign	Disseminates information to the general public or special interest groups via flyers, magazines, newspapers, meetings and reports in media about avoiding the spread of ragweed. Some campaigns are seasonal, others occur every couple of years.
Legal regulation	Country/region/city regulations which can include requirements to remove plants, report sightings, and employ measures to control and eradicate plants. Some impose penalties.
Online information	Websites describe the problems associated with ragweed as well as how to recognize and remove the plant. Some websites have the capability for people to report sightings online.
Physical measures	Mowing, hoeing, clipping, uprooting plants, weeding, mulching, burning, ploughing, and discing.
Surveys and mapping	Identification, reporting, and mapping of ragweed occurrences. Completed by various stakeholders, such as citizens and government agencies.
Working group	Involves various stakeholders developing plans to control and eradicate ragweed. Stakeholders include representatives from governmental agencies, health services, plant protection, agriculture, nature protection, highway construction and maintenance, and the community. Not required by Government regulation.

Figure 7.2 The number and types of measures applied against ragweed in different European countries. Only countries for which any measures were reported are included (see text for others).

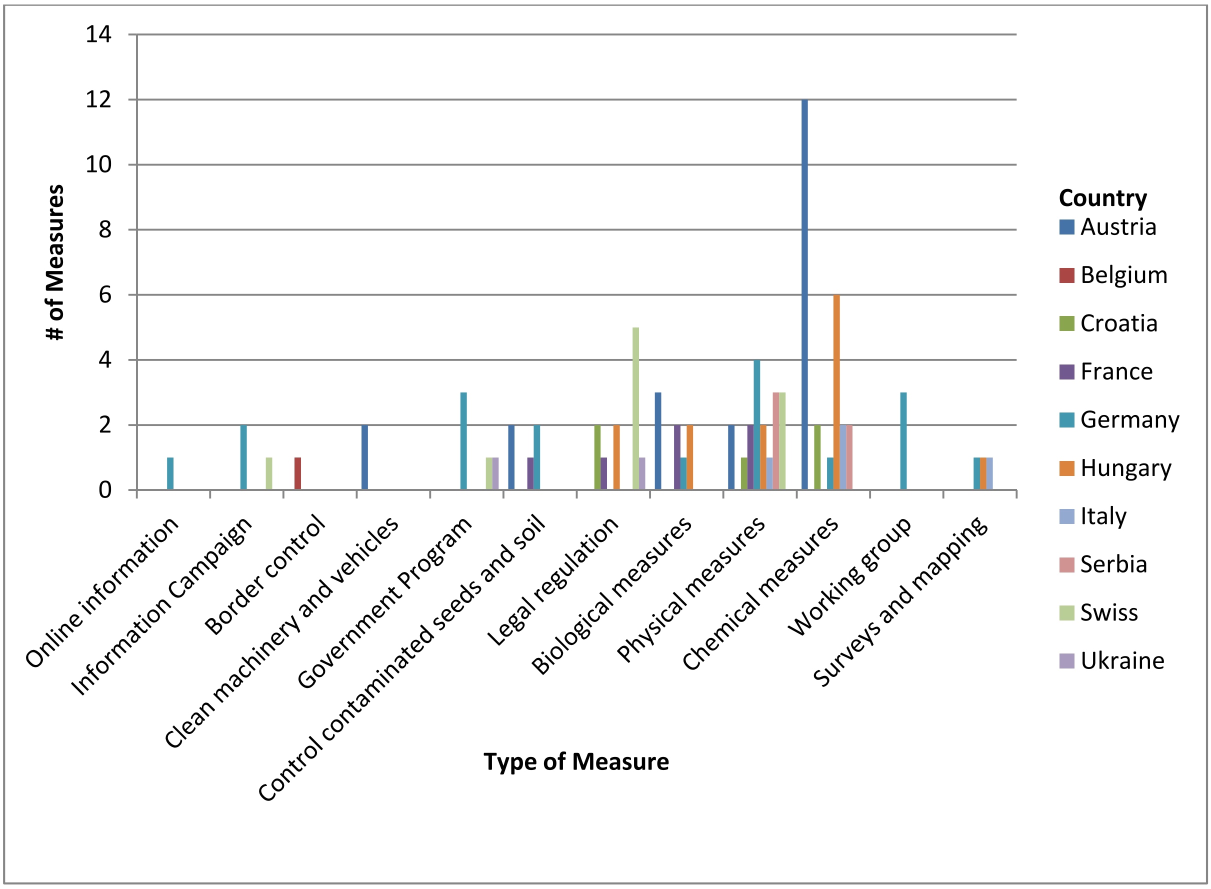
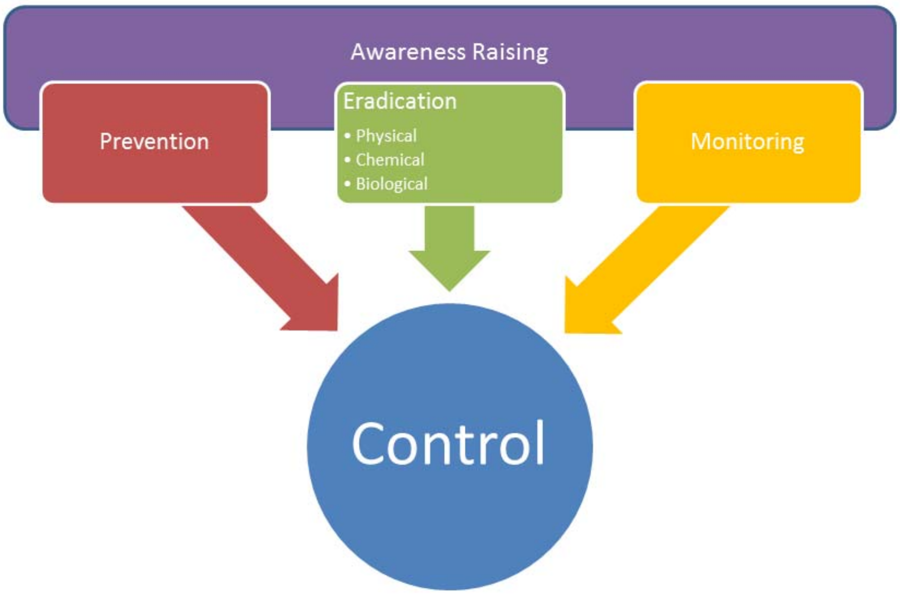


Figure 7.3 *A. artemisiifolia* control strategy. The figure shows that the control strategy can be made up of four different elements. The range of measures for Prevention, Eradication and/or Monitoring in a control strategy is optional, but Awareness Raising is always part of a control strategy.



4.1 Awareness raising

A good awareness raising campaign is essential for a successful control strategy and is an inseparable from the other three components (Mack *et al.*, 2000; Genovesi, 2005). An awareness raising campaign is rarely reported as a separate measure but almost always in combination with the other measures. This is important because the general public and targeted stakeholders must realize and understand the threat *A. artemisiifolia* poses, how to identify it, and how to remove it in order to take steps to successfully reduce the ragweed population in a community. Very good awareness raising campaigns are active in Gemany: the countrywide Action Program Ragweed, Bavarian Action Program Ragweed, and a General information campaign in Hesse. Also Switzerland has countrywide awareness raising campaigns in place.

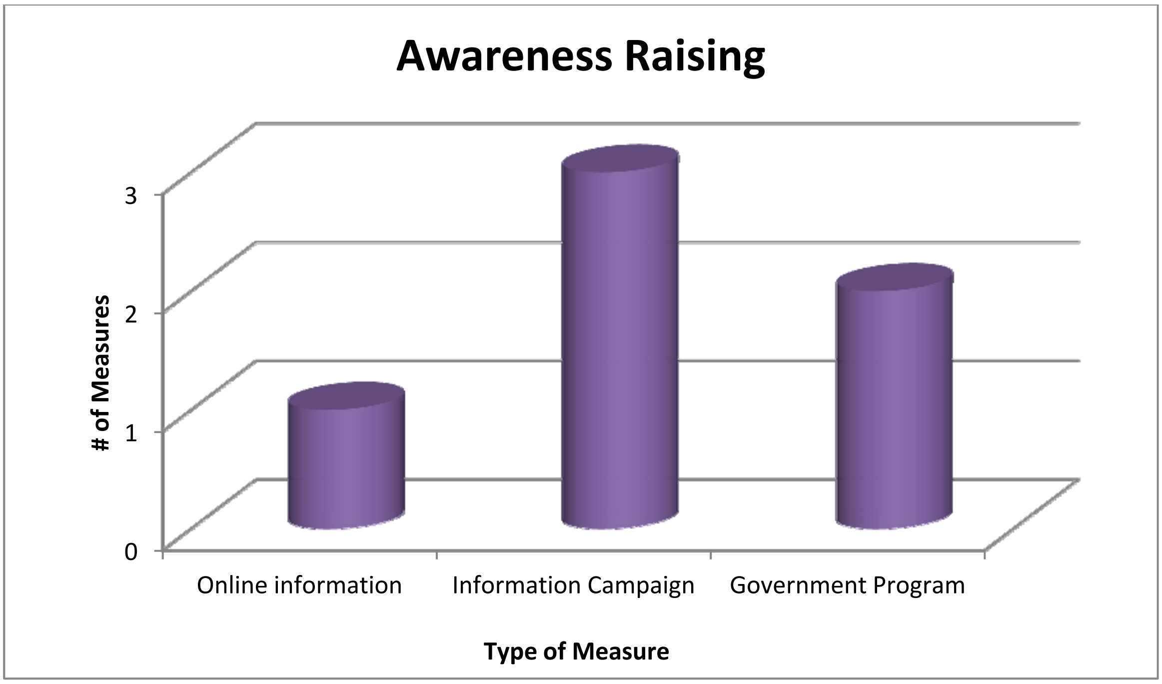
The results from the national expert's questionnaires show that the current awareness raising measures can generally be divided into three categories (Figure 7.4): making information available online, government programmes, and informational campaigns. These categories include measures pertaining to training, workshops, media campaigns, leaflets, and websites. The majority of these measures are implemented by governments or special interest groups; however, they can be adapted by a variety of other stakeholders.

Most countries surveyed already have detailed websites that are either maintained by a governmental agency or an independent group that describe the problem, outline how to recognizing the plant and provide guidance on how to deal it. These websites are listed below:

- Austria: http://www.noe.gv.at/Gesundheit/Gesundheitsvorsorge-Forschung/Umweltmedizin-und-Umwelthygiene/GS2_Gesundheitsvorsorge_Ragweed.html
- Croatia, Osijek, Eastern Croatia: https://ambrozijaosijek.crowdmap.com/
- France, Rhône-Alpes Region: http://www.ambroisie.info/
- Germany, Berling: http://ambrosia.met.fu-berlin.de/ambrosia/index.php
- Germany, Brandenburg: http://www.mugv.brandenburg.de/cms/detail.php/bb1.c.189328.de
- Gremany, Württemburg: http://www.lubw.baden-wuerttemberg.de/servlet/is/26311/
- Italy, Capralba municipality: http://www.comune.capralba.gov.it/servizi/emergenze/ambrosia.aspx
- Switzerland: http://www.ambrosia.ch/

Several of them have the capability for users to report *A. artemisiifolia* sightings online. Many countries also utilize targeted information campaigns, such as Switzerland: 2006 National Ambrosia Working Group Campaign or the Hesse Region of Germany: broadbase information campaign. This is advantageous because the targeted group will be provided information only relevant to their duties and responsibilities; thus, increasing the likelihood of implementation of additional control measures. Unfortunately, knowledge deficits exist among groups of people who are especially relevant for the introduction and spread of *A. artemisiifolia*, such as the construction industry and road maintenance crews. This lack of knowledge originates from the fact that general awareness raising campaigns are often unsuccessful in sufficiently reaching these specific professional groups.

Figure 7.4 Most frequently reported categories of awareness raising measures. The chart shows the number of times each type of measure was reported by the national experts.

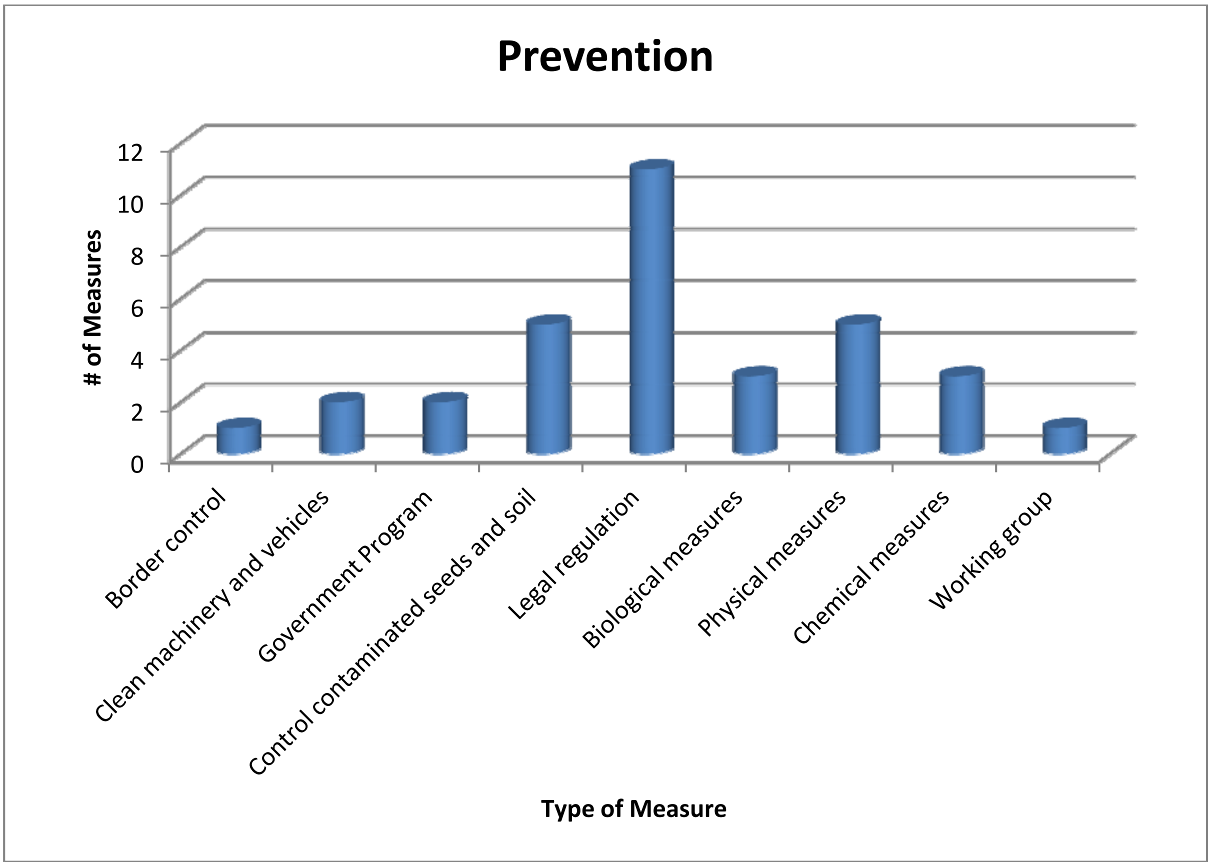


4.2 Prevention

Preventative measures are being undertaken in Austria, Bulgaria, Croatia, France, Germany, Italy, Hungary, Serbia, Switzerland and Ukraine, as well as at the EU level. They aim to prevent the introduction of *A. artemisiifolia* into the areas where it is not yet present. However, for the purpose of this report, within the overall framework for the Control Strategy, under prevention we also included the measures for containment – preventing the spread of a species before it becomes established in a certain area. Once an invasive species has become established it often proves to be very hard, if not impossible, to eradicate it from the area (Wadsworth *et al.*, 2000; Travis *et al.* 2011). Prevention is generally the most cost-effective approach to controlling invasive plant species (Buttenschøn et al. 2009) and should always be part of a control strategy (see Task 5, section 8). The most commonly used preventative measures include legal regulation (Figure 7.5), the control and destruction of contaminated seeds and soil, biological measures such as crop rotation and encouragement of competitive vegetation, chemical measures such as spraying of herbicides and physical measures such as repeated mowing, ploughing that buries the seeds 10 cm deep to prevent it from germinating (Guillemin *et al*. in Buttenschøn et al. 2009), or pulling of *A. artemisiifolia*.

The national expert questionnaires show that the majority of the preventative measures are enforced by law. These laws usually entail other concrete measures for prevention. These include quarantine regulations to prevent the transportation of contaminated seed and soil. Other regulations include requirements to report sightings, remove the plant and set limits for the allowable quantity in animal feed. For example, in the Bavaria region of Germany each person finding *A. artemisiifolia* is expected to weed single plants/clusters, up to 100 plants. However, some municipalities do not want to implement laws because they are impossible to apply due to the large amount of plants, and they are difficult to enforce to due lack of resources and fines which are too low.

Figure 7.5 Most frequently reported categories of implemented measures for prevention. The chart shows the number of times each type of measure was reported by the national experts.



Several national experts stressed the importance of controlling contaminated soil and seeds – for example the single instance of ragweed invasion of a protected habitat in Germany was due to illegal dumping of contaminated soil (see Task 4, section 4.2). In particular, at construction sites they suggested that contaminated soil should not leave the premises. Instead it should be integrated in deeper soil layers at the site or covered with uncontaminated soil. Where soil is transported to other locations, it should be labelled, and the recipient should be informed about necessary control measures. On agricultural lands, no soil tilling should be carried out, if at all possible, and the use of vehicles on the land should be avoided in order to avoid spreading. Additionally, cleaning both construction and farming machinery and vehicles was found to be an effective way to limit the spread of contaminated seed and soil. Prevention of the import of contaminated animal feed has been in force in Switzerland since 2005 (the Ordinance on Animal Feed) and it is being shown to be very successful (see section 8.1). The Ordinance requires that the content of *A. artemisiifolia* seed in animal feed - in particular bird-seed mixtures - should not be over 0.2 g ha^{-1} (ca. 10 seeds kg^{-1}). As of January 1st 2012 equivalent regulation has been applied for the whole EU. The Commission Regulation No 574/2011 from 16 June 2011, amending Annex I of the Directive 2002/32/EC on undesirable substances in animal feed, proscribes that the seeds from *Ambrosia spp*. should not be present in the feed materials and compound feed containing unground grains and seeds in the quantity higner than 50 ppm (mg kg^{-1}). Exceptions to this are millet (grains of *Panicum miliaceum* L.) and sorghum (grains of *Sorghum bicolor* (L) Moench s.l.) which are not directly fed to animals, where the maximum allowed quantity of *Ambrosia* spp seeds may not exceed 200 ppm (mg kg^{-1}) (European Commission, 2011).

4.3 Monitoring

Continuous monitoring is needed for any control strategy to be effective (Mack *et al.*, 2000). Monitoring is an important element of any control strategy because it makes it possible to draw conclusions about the development of the infestation and it also provides evidence for the success (or failure) of the combination of abatement measures utilized. Monitoring can be organized formally and executed by members of the public (volunteers) or professionals. The expert questionnaires show that in Europe there are both professionally organized monitoring programmes and programmes using members of the public. These monitoring programmes are either organised as a part of Government Programmes, Surveys and Monitoring Programmes led by different groups or organisations, or various Working Groups (Figure 7.6). In countries like Belgium, Croatia, Czech Republic, Denmark, France, Italy, Hungary, Latvia, Poland, Switzerland and Ukraine, there is a legal obligation for certain landowners and members of the public to conduct monitoring activities, as a part of wider control activities (Annex 2). These countries put their faith in legislation which clearly states what members of the public should do when they discover *A. artemisiifolia* on their land. In Switzerland, for example, *A. artemisiifolia* is a quarantine organism and therefore all plants have to be removed and the sites have to be registered. To achieve that the municipality employees, gardeners and farmers were given short courses and they are instructed to watch out for *A. artemisiifolia* “by the way”. Another interesting fact was that the costs of the measures taken have been significantly lower than expected at the beginning (Popow in Bohren *et al.,* 2011). In other countries, such as Germany for example, institutions or concerned volunteers have started working groups that undertake surveys for the presence of *A. artemisiifolia*. In the framework of the “Berlin Action Programme against Ambrosia” the employment services in Berlin have tried to involve long-term unemployed people into the job market by engaging them in the search and the removal of *A. artemisiifolia* in the city. In nine city districts approximately 20 people, the so-called ”Ambrosia Scouts“, search their respective district systematically, report and, wherever possible, remove any plants found in their districts. The basic idea of the ”Berlin Action Programme against Ambrosia“ is to combine and coordinate the potential resource of everyone in the city willing to contribute to the fight against *A. artemisiifolia* (Dümmel & Kannabei, 2011).

The most popular methods for monitoring *A. artemisiifolia* are surveys and mapping, working groups, and Government programmes. Surveys and mapping include multi-year site visits of the known *A. artemisiifolia* infestations and documentation of the development of the infestation. Most often, two site visits —before and after abatement measures— are completed to allow an evaluation of the abatement success. It is important to determine the exact demarcation (location) of *A. artemisiifolia* finds, to authenticate records (avoidance of misidentifications), and to report to the registration and abatement offices. Working groups and Government programmes involve the city, community, and state-wide associations of counties. Representatives are from environment-related health services, workers protection, plant protection, agriculture, nature protection, consumer protection, law and order, and highway construction and maintenance.

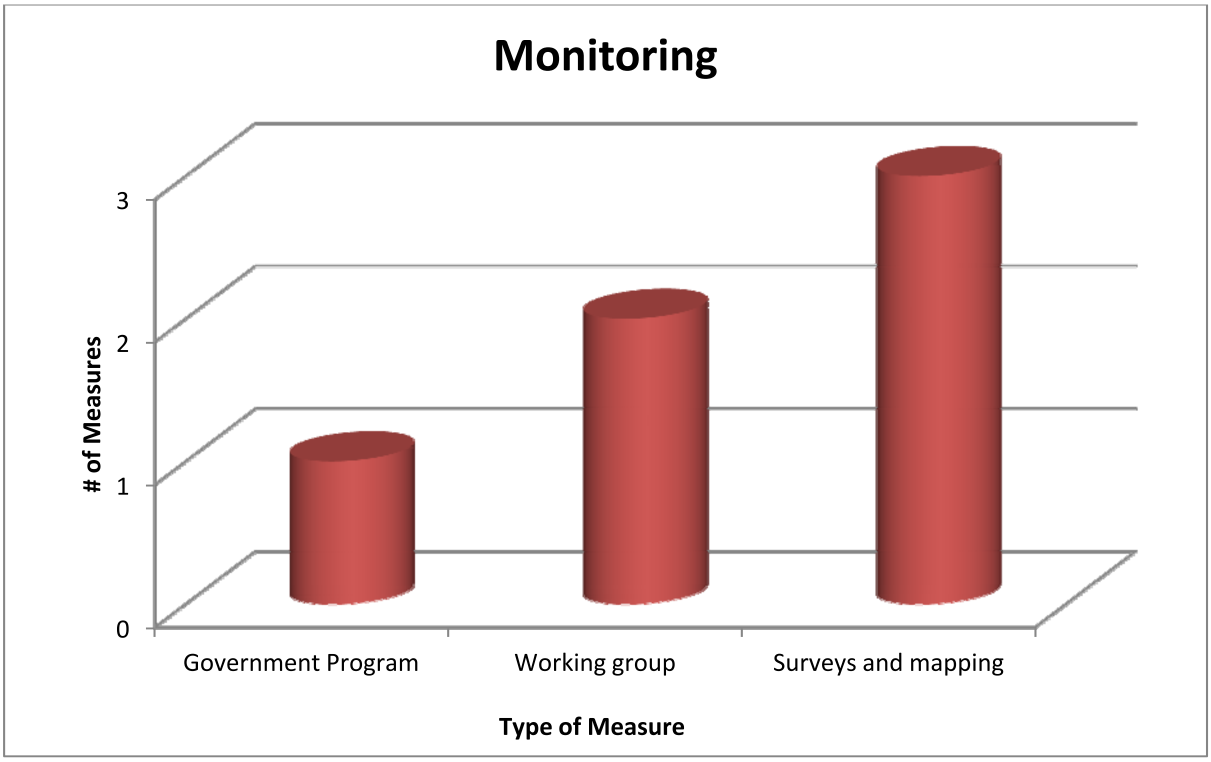
In Hungary a monitoring system for *A. artemisiifolia* which is based on the remote sensing has been developed and made operational by The Hungarian Institute of Geodesy, Cartography and Remote Sensing (FÖMI). A country-wide risk map is based on the analysis of satellite imagery validated by a 10% ground-truthing sample. This information feeds into the "Central Ragweed Server and Information System" which is one of the main pillars of the ragweed control programme in Hungary (Csornai *et al*. 2009, 2010, Nádor *et al*. 2011).

In general, the experts suggest that a legal requirement for monitoring is the most successful approach, which for the large part can be explained by the fact that legal measures are generally part of a larger control strategy combining all the different control measures. Additionally, there must be dedicated funding and resources to ensure successful implementation.

Social media, such as Facebook, Twitter, and recently very faster growing every-day usage of smartphones with a variety of applications, so called apps, have become the latest tools to link scientists with the public, empowering people to act on their behalf and actively participate in monitoring species and reporting the presence of invasive species such as *A. artemisiifolia*. As an example, by using the Ambrosia Scout (http://alphablind.com/portfoliomenu/ambrosia-scout/), people can actively participate in the fight against the *A. artemisiifolia* in Germany. With the smartphone app, available for both iPhone and Android smartphones, it is possible to report locations of *A. artemisiifolia*. The data are stored in a central database at the Free University of Berlin, in the so-called Ambrosia Atlas. This information then helps the competent authorities to detect, monitor and eliminate the plant when it occurs.

Following these new trends the European Environment Agency (EEA) has initiated citizen science activities by introducing Eye on Earth (EoE) (http://naturewatch.eyeonearth.org/) — an exploratory web-based IT platform for user-friendly, two-way sharing of environmental data and other environmental information with the general public and the scientific community. Current applications are Airwatch and Waterwatch, but there is also the intention to develop other environmental watch activities including invasive alien species watch (IASwatch) under the Naturewatch as a pilot project (Uludeg &Bruun in Bohren *et al.* 2011).

Figure 7.6 Most frequently reported types of monitoring programmes for *A. artemisiifolia*. The chart shows the number of times each type of measure was reported by the national experts.



4.4 Eradication

Eradication covers measures that aim to reduce population numbers and with the final goal to remove *A. artemisiifolia* completely from a certain location where possible. As indicated above, this can also be a type of preventative measure, illustrating that the borders between these two different categories of measures are not clear cut. There are three forms of eradication: biological, physical and chemical.

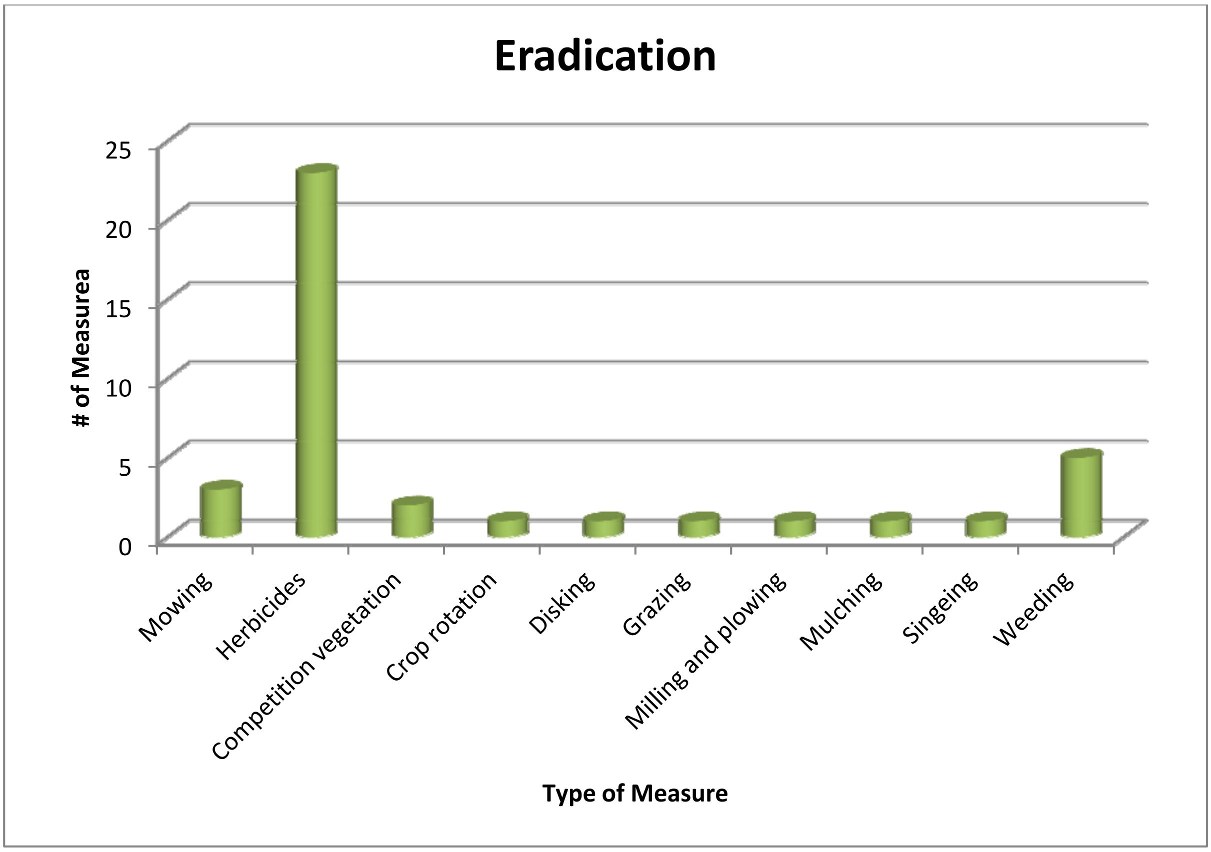
Biological eradication is being undertaken in Germany (Bavaria) and Hungary. It can involve introducing or enhancing natural controls of an alien invasive species in the form of specific parasites, predators and pathogens or the introduction of other plant species that outcompete *A. artemisiifolia*. Experiments undertaken in the glasshouse conditions showed that simultaneously sown competing vegetation appeared to be very effective in reducing the density of *A. artemisiifolia* and therefore prevented a high seed production. There are currently experiments running involving sowing of competitive plant species on the newly constructed roadsides (Milakovic & Karrer in Bohren et al., 2011). There are examples from other parts of the world (e.g. Australia, see section 6 below) where plant-eating insects have been introduced and showed to be successful in controlling

A. artemisiifolia. Several such attempts have been made in Europe and Russia, but none of them appear to be effective (Reznik, 2009). Currently there are no effective biological control agents available in Europe (EPPO, 2009; Gerber *et al*. 2011).

Physical eradication is being undertaken in Austria, Croatia, Germany, Hungary, Serbai and Switzerland. It includes mechanical forms to remove physically the plant from a certain location. This can include mowing, mulching, burning (i.e with a weed burner) or pulling. These measures are work-intensive and therefore costly. Therefore, the willingness to pay for it is very limited because the stakeholders do not have the budget and the personnel to perform such work on a larger scale. Mowing, if it is completed in right season and correctly, can be very effective and reduce the harmful effects of *A. artemisiifolia*. The national experts are in agreement that multiple cutting sessions are required, one before the *A. artemisiifolia* start flowering and a second time in September. For a greater efficiency mowing should be combined with chemical measures. The optimal time for mulching (covering the ground and seedlings with mulch; e.g. hay, grass, wood chips etc.) is shortly before the start of seed ripening, about the beginning of September. Since the optimal time of mulching conflicts with preventing health impacts from pollen movement, measures using this method have mostly been carried out earlier. This allows regeneration of *A. artemisiifolia* and thus reduces the effectiveness of the measure. As an alternative to mulching, a black plastic cover can be used to reduce light and raise the soil temperature to kill small plants and prevent the germination of seeds (e.g. on construction sites) In one reported case, burning proved to be an effective measure when combined with weeding and mowing. This involved short-term heating of the plants to a temperature of 50 to 70 degrees Celsius. With this method, larger *A. artemisiifolia* stock can be combated prior to flowering without the use of herbicides. Another eradication method that could be considered as physical is grazing by animals. The Austrian national expert reports preliminary results of a study conducted in Austria which indicated that sheep will eat *A. artemisiifolia* readily with no negative effects. On infested dry river beds in the Ramières Nature Reserve in France, sheep grazing trials on infested river beds indicate that this control method may be well suited to keep ragweed at bay (http://ramieres.val.drome.reserves-naturelles.org/ambroisie2007.html).

Chemical eradication is being undertaken in Austria, (Eastern) Croatia, Germany (Bavaria), Hungary and Serbia (Belgrade). It covers all forms of removal that involve chemical measures. This is almost solely limited to the spraying of herbicides. This method is very effective and most commonly used (Figure 7.7) but special attention must be paid to the period of intervention and the equipment used. Since the *A. artemisiifolia* plants have a long germination period, a combination of leaf and soil active compounds is often utilized to achieve a lasting control during the growing season. National experts stressed that adhering to the proper application procedures is essential to ensure success. Downsides to this measure include increased production costs for farmers, toxic harmful effects to human health and an increased risk of developing glyphosate resistant *A. artemisiifolia* varieties. Furthermore, ragweed is developing herbicide tolerance in its native range, and there are some indications in Europe – see section 6.5 in Task 4. There are numerous herbicides available on the market under various commercial names in different countries. However, most of them are based on one of the following chemicals as the active ingredient: glyphosate, mesotrione, clopyralid, MCPP, and florasulam.

Figure 7.7 Most frequently reported implemented measures for eradication. The chart shows the number of times each type of measure was reported by the national experts.



5 Best bet control strategies

It is clear from the information gathered that it is almost impossible to provide a fully objective assessment of the single most effective and successful measure among the variety that are being applied against *A. artemisiifolia* across Europe. Countries are showing a certain level of success when implementing a systematic control strategy consisting of several measures. These measures comprise the four previously defined components: awareness raising, monitoring, prevention, and eradication. Since all of these components are interlinked and complement each other, the measures undertaken have the best effect when used in combination.

An example of such approach could be the “State Programme to Locate and Eliminate the Common ragweed - *Ambrosia artemisiifolia* in Ukraine by 2017” (reported by the national expert for Ukraine) which is aiming to ensure a balanced and comprehensive set of measures to combat ragweed in the coming years, including the simultaneous use of mechanical, chemical and biological techniques. The

Programme is designed to identify the key regions where *A. artemisiifolia* should be controlled and possibly eradicated by 2017. The main tasks of the programme include: to raise public awareness about *A. artemisiifolia* colonising abandoned land; conduct measures to eliminate *A. artemisiifolia* in fallow and arable fields, beside tracks, hedgerows, roadsides and railways, abandoned fields; control *A. artemisiifolia* through simultaneous application of chemical, agrotechnical, mechanical and other methods; conduct seminars and workshops with local authorities and entities engaged in farm production, import, export, transport, processing, storage, sale and use; disseminate information; improve responsibility for the implementation of measures by increasing penalties.

Based on the information in the questionnaires filled in by the national experts, some of the measures are used in combination more often than others and their success depends on several factors. Table 7.3 gives an overview of the most commonly used measures together with the measures with which they are most often combined, as well as their success factors. The fact that needs to be stressed is that awareness measures, as a direct or indirect activity, contribute to the success of all the other measures and the control strategies as such.

Table 7.3 Most frequently used combinations of measures and the pre-conditions for their success

These measures	**are used in combination with…**	**and their success depends upon…**
Clean machinery and vehicles	Information campaign	Availability of workers
	Legal regulations	Funding
		Operators willingness to complete
Competing vegetation	Mowing	Compensation payments
	Weeding	Follow-up checks
		Proper maintenance
Control contaminated seeds and soil	Clean machinery and vehicles	EU wide measures
	Information campaign	Funding
	Legal regulations	Public involvement
	Surveillance activities	
Controlled fallows	Herbicides	Early detection
	Legal regulations	Funding
	Mowing	Multi-agency coordination
	Surveys and mapping	
Crop rotation	Herbicides	Timing and frequency
	Mowing	
Disking	Herbicides	Funding
		Timing and frequency
Government Programme	Information campaign	EU wide measures
	Compensation payments	Evaluation
	Legal regulations	Timing and frequency

These measures	are used in combination with…	and their success depends upon…
	Penalties for violations	Training
	Surveillance activities	
Herbicide	Mowing	Funding
	Information campaign	Multi-year measures
	Surveillance activities	Proper application
	Crop rotation	Public involvement
		Timing and frequency
		Training
		Weather conditions
Information campaign	Legal regulations	Multi-agency coordination
	Multidisciplinary workshops	Early detection
	Surveys and mapping	
Law/Regulation	Crop rotation	Multi-agency coordination
	Herbicides	Public involvement
	Information campaign	Report sightings
	Mowing	Timing and frequency
	Surveys and mapping	
	Penalties for violations	
	Weeding	
Manual tearing	Information campaign	Funding
	Legal regulation	Political support
		Proper application
		Public involvement
		Training
Milling and ploughing	Surveillance activities	Repetition
		Timing and frequency
Mowing	Information campaign	Availability of workers
	Herbicides	Funding
	Legal regulations	Proper application
	Online information	Public involvement
	Sowing	Timing and frequency
	Working group	Trained staff
		Weather conditions
Mulching	Herbicides	Multi-year measures
	Mowing	Timing and frequency
Online information	Legal regulations	Multi-agency coordination
	Surveys and mapping	

These measures	are used in combination with…	and their success depends upon…
Burning	Mowing	Governmental agency support
	Weeding	
Surveillance activities	Information campaign	Consistency
	Legal regulations	Evaluation
		Report sightings
		Training
Surveys and mapping	Legal regulations	EU wide measures
	Penalties for violations	Planning
		Timing and frequency
Weeding	Information campaign	Available labour force
	Herbicides	Funding
	Mowing	Multi-year measures
	Mulching	Timing and frequency
	Surveillance activities	Political support
	Working group	Public involvement
Working group	Information campaign	Community resources
	Surveillance activities	Multi-agency coordination
		Multi-year measures
		Public involvement

Based on the issues mentioned above, considering the fact that the *A. artemisiifolia* spreads only by seeds, the best practices to prevent the further spread should be aimed at the prevention of the production of fertile seeds and their spreading in the environment.

Having in mind that *A. artemisiifolia* can build a large seed bank in a couple of years , which remains viable for more than 35 years (Task 1, 2), the sooner after its introduction the control measures are initiated, the higher the chances of eradication and the lower the costs of control will be (Buttenschøn et al. 2009).

As suggested by the *A. artemisiifolia* control process above (Figure 7.2): **prevention** has to be the first step in combating *A. artemisiifolia*, with the aim at preventing its occurrence in the first place. If *A. artemisiifolia* is present, **eradication** should preferably occur before the flowering season starts by applying a number of measures described above and according to the local conditions. Once initiated, the eradication should be consequent and continuous – without missing a single year. In order to detect the appearance of *A. artemisiifolia* in time and react promptly, it is necessary to have a good **monitoring** system in place. Monitoring is also important as a follow-up to the eradication measures to confirm the success of the measures or trigger a repeated eradication action. Because the seed bank is long-lived, monitoring should continue for several years.

A well-targeted intensive **awareness raising** campaign is a key to success of all of the above mentioned actions. It will lead to both an increase the number of people that can contribute to tackling the issue (e.g. citizens, volunteers, farmers, landowners), often at low or no further costs, as well as building their capacity. An example from Germany showed that the proportion of new *A. artemisiifolia* stands detected by private persons decreased from 60 % to 20 %, due to a decreased media interest (Alberternst & Nawrath, 2011).

According to the available data from the literature, and from the reports of national experts, there are five broad categories of habitat types which are the most sensitive to the invasion and spread of *A. artemisiifolia* so these are also the areas where the most of the efforts for control should and are being applied. These broad habitat types are:

1) Agricultural fields
2) Building sites
3) Roadsides
4) Gardens and parks
5) Natural habitats

It is important to note that there are individual industries (sectors) that are closely linked to these broad habitat categories and that have a significant number of people working in the field every day. These sectors should be made aware of their potential roles in the spread of the *A. artemisiifolia*, but also, no less important, their role and responsibilities in the process of controlling it. This makes it easier to design information campaigns for specific groups of stakeholders. These parties (farmers, garden owners, the construction sector, the transport sector etc.) are in an ideal position to do the monitoring, both in the sense of early warning and post-eradication success assessment, without a large additional work load for them and with relatively small investment by the Government– mainly for the awareness raising, capacity building and coordination. Similar approach has already successfully been used in Eastern Switzerland (Popow in Bohren *et al.,* 2011). Such an approach could reduce the costs significantly and also provide much better coverage. Using scientists to do the monitoring would be much more expensive and probably not the best approach in relation to implementation (see Task 5).

5.1 Overview of the approaches applied in different sensitive habitat types

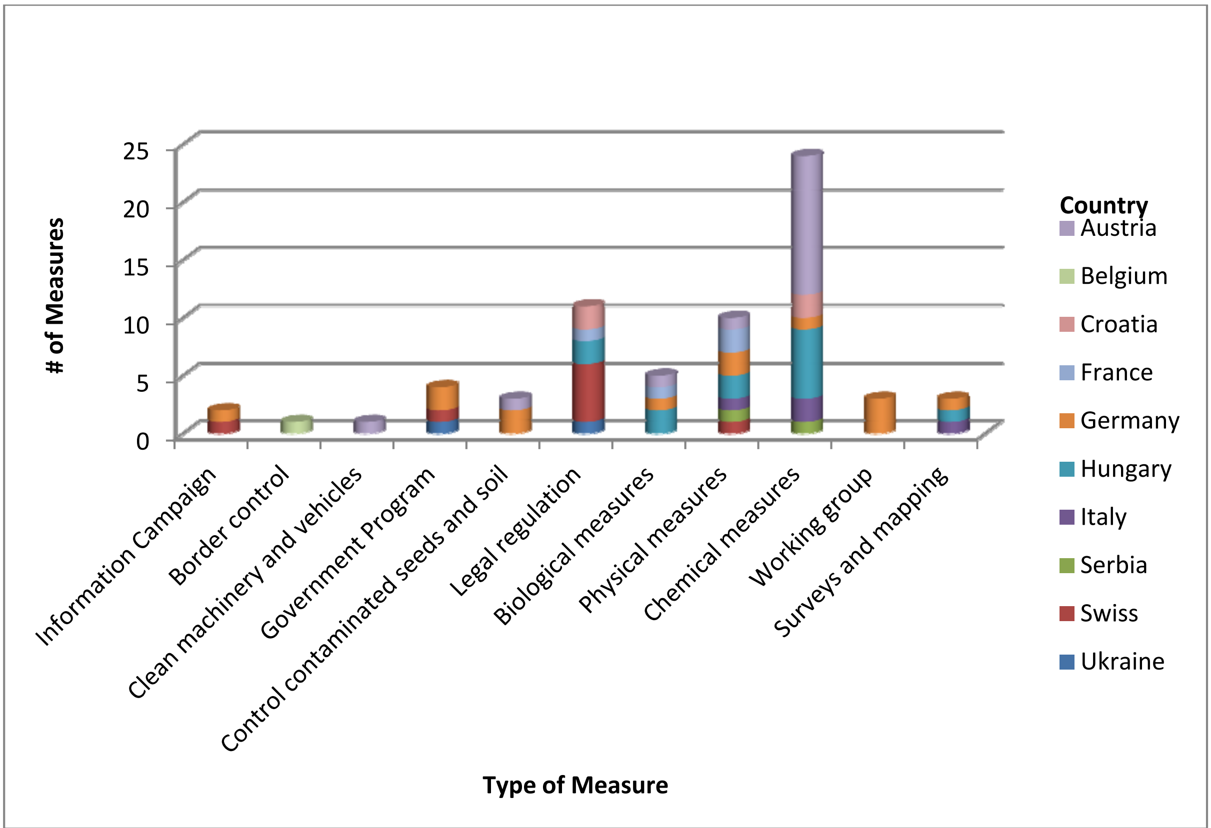
5.1.1 Agricultural fields

In Europe, *A. artemisiifolia* is mainly reported as a weed of spring-sown crops, causing significant yield losses, especially in sunflower, maize, potatoes, oilseed rape, sugar beet, soya bean and cereal crops (Task 4, section 6). Agriculture is the field where the economic impact is, due to the yield loss, direct and most obvious (Task 5). Therefore, in most of the countries, the majority of control measures are focused on this sector.

General recommendation for control in agricultural fields is to apply the herbicides with good efficacy on *A. artemisiifolia* according to their recommended dosage. Sequential treatments may improve herbicide activity; however, widespread herbicide resistance (see section 6.5 in Task 4) and the ban or dose reduction of efficient herbicides would greatly limit successful short-term management in crop fields (Buttenschøn *et al*. 2009; Gerber *et al*. 2011). Chemical measures should be combined with the crop rotation as crops with high density can reduce the growth of *A. artemisiifolia*.

Figure 7.8 shows that the chemical measures are indeed applied most frequently in agriculture across Europe, most frequently in combination with mechanical measures and to a lesser extent with crop rotation (Biological measures). The figure also indicates that application of most of these measures is backed up by national laws and regulations.

Figure 7.8 The number and type of measures applied in different countries to control *A. artemisiifolia* in agricultural fields.

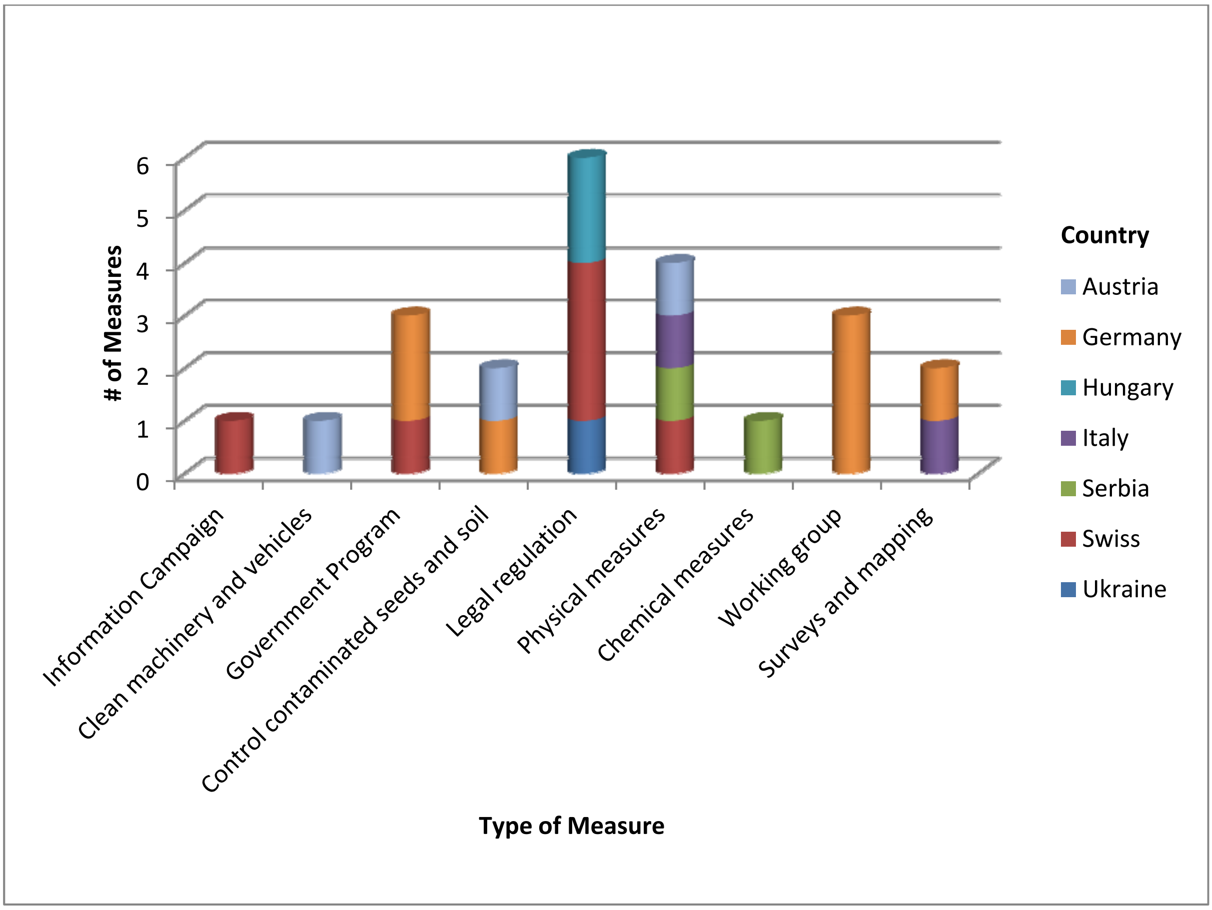


5.1.2 Building sites

Disturbed soil in building sites is a good habitat for *A. artemisiifolia*. To make the situation worse the transportation of soil and gravel between neighbouring countries is a common practice in parts of Europe (see Task 1). One possible solution for reducing growth and seed production of *A.*

artemisiifolia in such conditions is to sowi a high density cover crop. However, in practice little is being done in the field. This is illustrated in the Figure 7.9 which shows that there are legal regulations in place; but actual implementation of measures is reported less frequently.

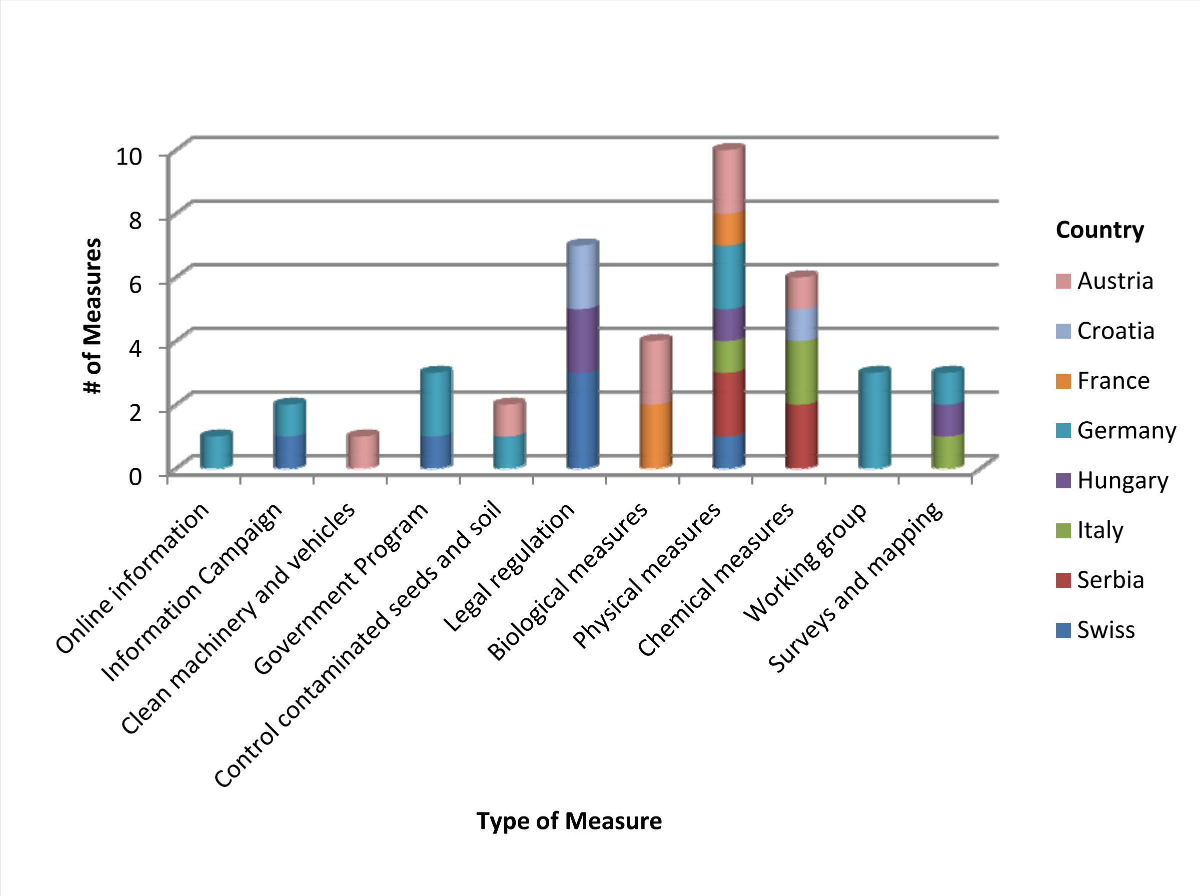
Figure 7.9 The number and type of measures applied in different countries to control *A. artemisiifolia* on building sites.



5.1.3 Roadsides

Roads verges are another habitat susceptible to *A. artemisiifolia* (Task 1, 2). Plant cover along road sides must often be cut in early summer for the traffic security reasons. In case *A. artemisiifolia* is abundant, infested zones should be treated additionally with an herbicide for achieving best control of re-growing plants. This is also linked to the fact that the second cut ususally cannot affect the horizontal side sprouts which grow along the soil surface (Buttenschøn *et al*. 2009). In the case of repetitive mowing as the control strategy, the timing and frequency of mowing should be based on observation of target plant rather than calendar dates (Karrer & Milakovic 2011). Figure 7.10 shows that mechanical measures (mowing) are being applied in most of the countries and are often combined with the chemical measures.

Figure 7.10 The number and type of measures applied in different countries to control *A. artemisiifolia* on roadsides

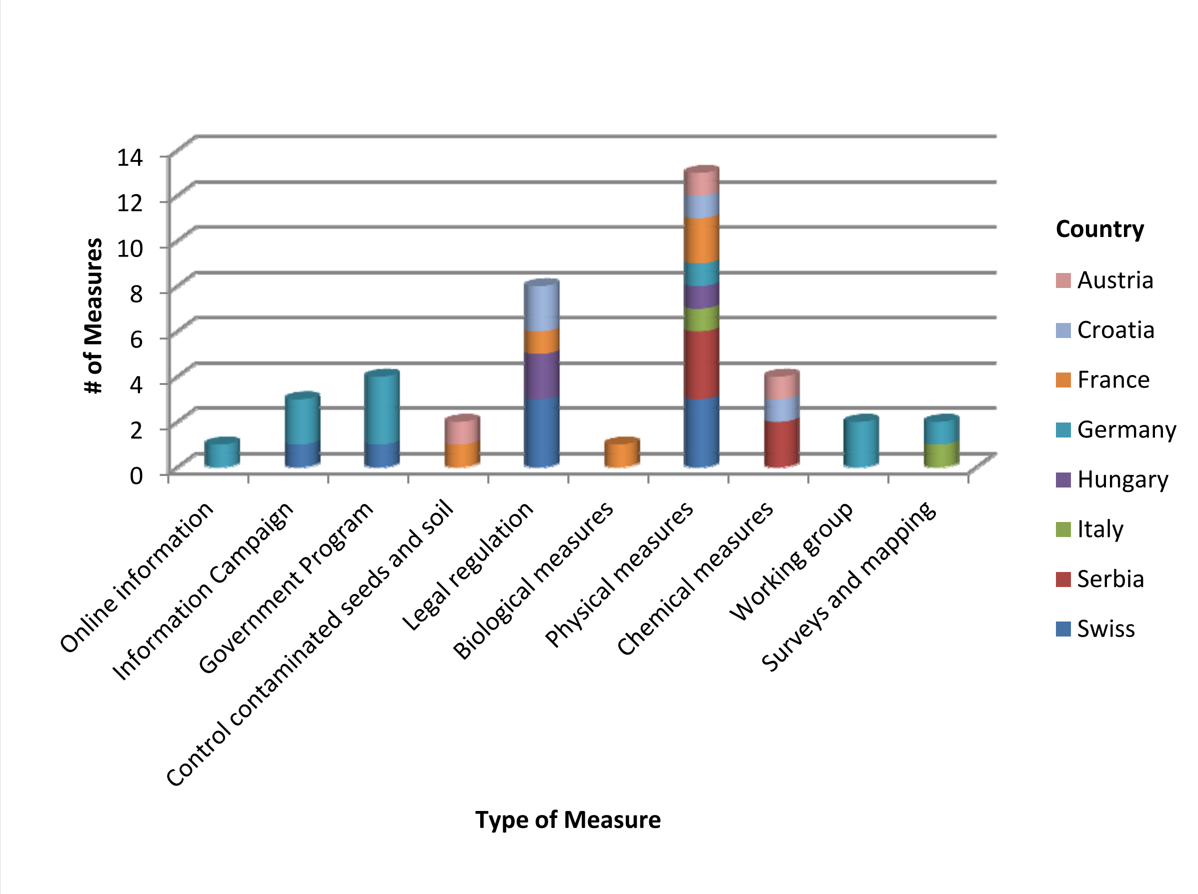


5.1.4 Gardens and Parks

Private gardens are often infested by *A. artemisiifolia* seeds present in the mixtures bird seeds (Task 1, 2). Therefore the regulations on the presence of *A. artemisiifolia* in seeds mixtures is becoming more strict (e.g. in Switzerland, described in section 6.1 in more detail).

Also as suggested for the other habitats, a dense cover by plants effectively slows down infestation by *A. artemisiifolia*. Single plant stands should be uprooted and destroyed completely before flowering to avoid both pollen production and the production of seeds. (Buttenschøn *et al*. 2009). Figure 7.11 shows that physical measures are the most frequently applied for removing the *A. artemisiifolia* from gardens and parks.

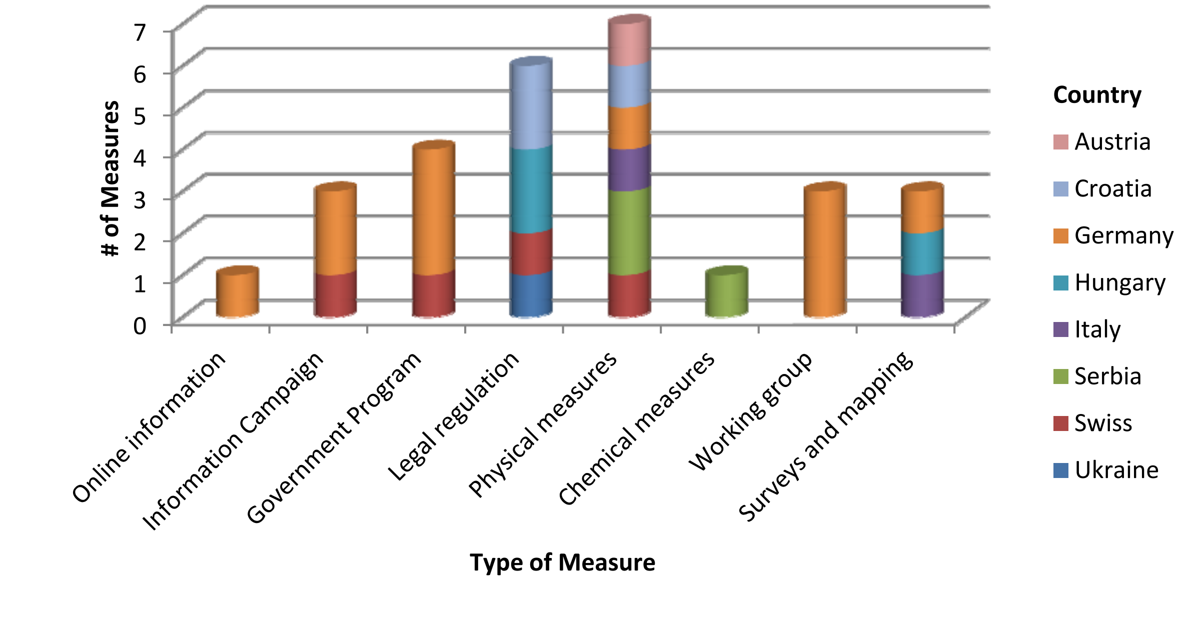
Figure 7.11 The number and type of measures applied in different countries to control *A. artemisiifolia* in gardens and parks



5.1.5 Natural habitats

Natural habitats that are at risk the most are those naturally disturbed (e.g. floodplain ecosystems by floods) or with excessive anthropogenic disturbance, such as overgrazed grasslands (Task 4, section 4). In such places ragweed might be controlled by immediately establishing a dense population of endemic plants in the cases of advanced infestation. Single plant stands in the areas where the infestation is beginning, should be uprooted and completely destroyed (Buttenschøn *et al*. 2009). Chemical measures used in natural habitats are not acceptable in many countries, although it has been reported from Serbia (Figure 7.12). The most frequently reported measures are indeed physical measures.

Figure 7.12 The number and type of measures applied in different countries to control *A. artemisiifolia* in natural habitats



6 Examples of success in control strategies

6.1 European examples

GERMANY:

National Programme – The Bavarian Action Programme Ragweed showed tremendous success during the period 2006-2008. This requires that each person finding *A. artemisiifolia* is expected to weed single plants/clusters. Reports of more than 100 plants are handled by the local county agencies. Over 101 large (>=100 plants) *A. artemisiifolia* occurrences were examined in Bavaria, mostly in Oberbayern, Mittelfranken, and Niederbayern. The number of individual plants decreased the following year and the decrease was deemed sufficiently large for 14 sites. The success of the eradication measures has been only partial or remains in the initial phase regarding complete eradication of *A. artemisiifolia* on a specific site in the year of the eradication measures, permanent eradication of the plant through collection or complete sealing of the seed bank, prevention of further spread, and prevention of further introduction. This programme relies on public education and participation. In some cases, it is more effective if county and city agencies carry out the measures if the occurrence of *A. artemisiifolia* extends to property belong to several owners.

However, the fact remains that ”the prevention of spread of *A. artemisiifolia* in Bavaria as well as in most other parts of Germany is only possible in an early phase of the species´ spread when the populations and the seed bank are still small. Thus intensification and optimisation of control measures are very important to avoid the development of extensive ragweed populations” (Alberternst & Nawrath, 2011).

Weeding – In a nature protection area in Lower Bavaria the stock of *A. artemisiifolia* had increased to about 10,000 plants in the early 2000s and covered 200-300 m^2 of the area adjacent to the dune that had been uncontaminated until then. In that location, *A. artemisiifolia* was eradicated by weeding. Once plants are pulled out, they cannot regenerate themselves through the root stock. Through the entire year 2004, *A. artemisiifolia* plants were pulled out and reduced the stock by 25 per cent in 2005. The same procedure was repeated in 2005 with the result that the *A. artemisiifolia* infestation “has apparently been successfully fought against.” In order to find all plants on a plot, sufficient time should be allowed for a careful search of the area. The most successful searches follow a particular strategy (division of the area into sub-plots or along rows). Under ideal conditions, the search is carried out by several persons who look for plants from different perspectives. For safety purposes, all *A. artemisiifolia* plants that are weeded from July on should be placed in plastic bags and placed in waste containers for materials to be incinerated. They should not be placed in bins for compostable materials or on compost heaps. A condition for the effectiveness of this method is that almost all plants are found and it is implemented as a multi-year, focused measure. An interruption of the measures can lead to a restocking of the seed bank, which will set back the process by years.

SERBIA:

Chemical and Mechanical Measures – Ruderal sites outside settlements were treated by glyphosate at a rate of 1.2 kg per ha to 2.4 kg per ha. Mechanical measures included cultivating in the germination phase, maintenance of crops without weeds, as well as mowing of non-arable land. Before systematic application of the measures (2001), Novi Sad had the highest concentration of pollen grains/day amounting to 3247 m^{-3} air. In 2003 the concentration amount was 653 pollen grains m^{-3} air and in 2004 the concentration of pollen was 185 pollen grains m^{-3}. In 2006 the concentration was 583 pollen grains m^{-3}, in 2007 it was 468 pollen grains m^{-3}, in 2008 it was 191 pollen grains m^{-3}, while in 2009 the concentration was 783 m^{-3}.

HUNGARY:

In 2005 the Hungarian Institute of Geodesy, Cartography and Remote Sensing (FÖMI) elaborated a monitoring and control programme for *A. artemisiifolia* in Hungary – Ragweed Risk Map – based mainly on remote sensing technology. The remote sensing (RS) based assessment is now being applied to the whole arable land area. It is considered that the combination of four high tech components (RS+GPS+GIS+WEB) has led to the better and more efficient monitoring and control of *A. artemisiifolia*. The utilization of up-to-date remote sensing and GIS methods along with the GPS technology simplifies and makes more efficient *in situ* measurements and reduces the time needed for administration of control measures.

The most important and indispensable element of this system is ragweed recognition by remote sensing. It is considered to be objective, accurate, reliable, and can be used in different ways by adjusting the spatial-temporal-spectral image data set. The approach can use a range of satellite images. All the subsystems can be tailored and adapted to a wide variety of specific local and regional needs, terrains and environmental conditions, ragweed stand occurrence, etc. Some components or the whole system could be made operational also in other regions of Europe (Csornai *et al*. 2009, 2010, Nádor *et al*. 2011).

SWITZERLAND:

National Regulation –The Ordinance on Animal Feed 2005 forbids the presence of *A. artemisiifolia* seed in animal feed - in particular, bird feed. It requires that the content of *A. artemisiifolia* seed should not be over 0.2 g ha^{-1} (ca. 10 seeds kg^{-1}). After implementation of this regulation the occurrence of *A. artemisiifolia* in domestic gardens declined by more than 90 % between 2006 and 2008. This method relies on the successful coordination between different governmental organizations to ensure the regulations are interpreted and enforced appropriately. Additionally, open communication between governmental groups, interest groups, and the public is critical.

Weeding – This is completed by householders or by each commune. Regular inspections are conducted during maintenance work and reminders are sent to households. In Zurich, garden occurrences dropped significantly over four years (2006 - 397, 2007 - 65, 2008 - 28, 2009 – 12). Occurrences also dropped in public spaces (63, 13, 10, 3), roadsides (52, 14, 9, 2), meadows/grasslands (22, 8, 1, 1), and construction sites (18, 6, 8, 2). This measure must be implemented at early stages of infestation and is dependent on the level of organization and communication with in the community.

Chemical and Mechanical Measures - Trials showed that a single mowing at the beginning of September was sufficient to break the plant lifecycle in some years, while in others it was not. So, a single mowing strategy is inefficient in the long-term. Even two mowings cannot guarantee a total success in disrupting the plants lifecycle; however, it strongly reduces seed production. A first intervention in mid-August followed by a second in end September is recommended. Glyphosate was found to be one of the most efficient herbicides in controlling *A. artemisiifolia*; however, it fails to break the plant lifecycle satisfactorily with one application, especially where populations are dense. In such cases an initial mowing in July to limit pollen production, followed by an application of glyphosate in August is recommended. Promising results were also obtained with glufosinate and various other herbicides containing 2,4 D, bromoxynil, ioxynil, florasulam, fluroxypyr, and mecoprop-P. This study showed that mowing on its own is recommended for road verges, gravel pits, nature reserves, river banks, and other area where herbicides are not allowed. Timing of application is critical to the success of this measure.

ITALY:

Chemical and Mechanical Measures - For treatment before flowering, made at the end of June, glyphosate (360 g/l) has been successfully used in doses of 2.16 $kgha^{-1}$ to control *A. artemisiifolia*. *A. artemisiifolia* has been completely eradicated in the plots ploughed at the end of June . For the treatments carried out in the second half of April, two different strategies can be followed. 1) Application of high doses (5.44 kg ha^{-1}) of dichlobenil (170 g l^{-1}). The result is around 98% success at 172 days after the intervention. 2) Implementation of a double treatment using dichlobenil (170 g l^{-1}) at a dose of 1.36 kg ha^{-1}, repeating the treatment after a maximum of 30 days, always with dichlobenil (170 g l^{-1}) at low doses with glyphosate (360 g/l) at a dose of 2.16 kg/ha. For post-germination treatment (for plants with 2-3 leaves) the best results are achieved with double intervention (the second intervention must be carried out after 30-60 days on the basis of the needs and the extent of the infestation) with dichlobenil (170 g l^{-1}) + glyphosate (360 g l^{-1}) which is already very effective at the lowest dose of dichlobenil (1.36 kg ha^{-1}). In the cases when it is not possible to carry out pre- and post- treatments early enough, the following options can be effective: plough the invaded area at the end of June to eradicate the plant completely and prevent the regrowth and apply glyphosate (360 gl^{-1}) as a dose of 2.16 kg ha^{-1} before flowering.

6.2 Examples outside Europe

AUSTRALIA:

Biological Control – Between 1980 and 1984, three biological control agents from Mexico were introduced into Australia for the biological control of *Parthenium hysterophorus*., a species closely related to the genus *Ambrosia*. They were the leaf-feeding beetle *Zygogramma bicolorata*, the sap-sucking bug *Stobaera concinna* and the tip-galling moth *Epiblema strenuana*. All three insects also attack *A. artemisiifolia*, and in particular, *E. strenuana* is reported to reduce the size, abundance and pollen production of the weed. In 1990, *Zygogramma suturalis* was introduced into Australia from the USA to increase *A. artemisiifolia* control, but the species failed to establish. Presently, *A. artemisiifolia* is considered to be well controlled in south-eastern Queensland and northern New South Wales. From an economic point of view, biological control of *A. artemisiifolia* is regarded as an outstanding success in Australia (Gerber *et al*. 2011).

UNITED STATES:

Chemical and Mechanical Measures – Good control of *A. artemisiifolia* is achieved with applications of glyphosate at 1.4 (equivalent to 0.25% v/v) when weeds are less than 15 cm tall, 2.8 lha^{-1} (equivalent to 0.5% v/v) when weeds are 15 to 30 cm tall, and 3.85 lha^{-1} (equivalent to 1% v/v) when weeds are greater than 30 cm tall. If an additional flush occurs, repeat applications of glyphosate are made, but the maximum annual application rate (19.6 $lha^{-1}yr^{-1}$) must be followed. Addition of dry ammonium sulphate at 1-2% w/v (8.5-17 gl^{-1}) may increase the performance of glyphosate, particularly under hard water and drought conditions. The equivalent of liquid formulation of ammonium sulphate may also be used. Overreliance and repeated use of glyphosate for *A.*

artemisiifolia control can greatly increase selection pressure for traits that allow it to be glyphosate-resistant (Odero *et al*., 2011).

To prevent development of glyphosate-resistant *A. artemisiifolia*, overreliance and repeated use of glyphosate should be minimized; also, tank mixes or sequential treatments of herbicides with different modes of action (for example, 2,4-D and saflufenacil), but which are active on *A. artemisiifolia*, should be used along with glyphosate. Application of 2,4-D at 2.4 to 5.9 lha^{-1} (equivalent to 0.08-0.16% v/v) when *A. artemisiifolia* is young and actively growing provides good control. Tank mixing 2,4-D at 1.4 lha^{-1} with glyphosate at 2.4 lha^{-1} provides better *A. artemisiifolia* control (Odero *et al*., 2011).

Competition Measures – Research and observation both show that *A. artemisiifolia* problems are greater in pastures that fail to maintain competition from a full leaf canopy of grass during late May through late June. Any management that develops and maintains a dense leaf canopy at this time helps reduce problems with *A. artemisiifolia*. This includes increasing grass growth with fertilizer and thickening stands by seeding, but most important of all is to avoid grazing heavily in areas with *A. artemisiifolia* problems. If it is grazed heavily or hay is cut, treating with herbicides such as 2,4-D, Picloram, Aminopyralid or Glyphosate 41 after grazing or cutting gives good control of *A. artemisiifolia* seedlings and small plants. And if *A. artemisiifolia* gets away, shredding in September can reduce seed production (Mues, 2010).

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Task 8: The necessary elements for an European early warning and rapid response system

1 Introduction

This chapter aims to put together a number of elements that are of relevance for establishing a European early warning system for invasive alien species in general and for *A. artemisiifolia* in particular. An early warning and rapid response (EWWR) system is 'a framework designed to respond to biological invasions through a coordinated system of surveillance and monitoring activities; diagnosis of invading species; assessment of risks; circulation of information, including reporting to competent authorities; and identification and enforcement of appropriate responses.' (EEA, 2010).

In this report we refer to EWRR and Early Warning Systems (EWS). These terms are interchangeable, although an EWRR adds an element of response to an EWS.

Given the multitude of EWRR systems that have already been established internationally (mostly for a broader pallet of invasive alien species or wider environmental issues) or nationally (with more narrow focus, e.g. dedicated to *A. artemisiifolia*) we have compiled an overview of these existing EWRR systems in Europe and elsewhere in the world. The basic sources of information for this review are previous overview reports, national experts, and internet searches.

As part of the review process we have also identified the key stakeholders involved in EWRRs for invasive alien species (IAS). Again, the national contact points provided the majority of information for this part. Because there are so many different types of stakeholders involved, we provide a categorisation based on expert judgement. Section 3 provides a review and section 7 spells out possible roles and responsibilities.

An important element in any EWRR is the availability of reliable information sources and databases. A number of such databases exist for Europe and these are described in section 4 on the basis of information on their respective websites and complemented with information from direct contact with people that are centrally involved in these databases. Note that the Task 3 report describes in detail the current knowledge of the distribution of ragweed in Europe.

Closely related to the databases are the monitoring programmes for IAS. These are mostly coordinated at national level with (parts of the) information and data flowing into international databases. Section 5 provides a quick overview of relevant monitoring programmes.

Another essential component of any EWRR is communication, awareness raising and education (see also Task 7, 9), especially to aid responses to observed invasions. An overview on the basis of internet search and personal interviews is provided in section 6. Section 8 provides more detail in the use of modern technology as an aid for communication and monitoring.

Section 9, finally, brings together a number of the elements and proposes an institutional setup for a European EWRR on IAS. This builds on a number of reports that have been produced by European networks and organisations and is complemented by personal communication with people that are directly involved in these networks.

We are grateful for the comments and references received during personal contacts with Sarah Brunel, Wolfgang Rabitsch, Melanie Josefsson, Wiebe Lammers and Etienne Branquart.

2 Review of existing early warning and rapid response systems

Throughout the world many early warning and rapid response systems (EWRR) have been put in place at a national level to help prevent or eradicate invasive alien species, including *A. artemisiifolia*. When developing an approach for Europe it is important to learn from these experiences, to adopt successful approaches, to avoid known pitfalls and to build on existing methods and data flows.

This section provides an overview of national EWRRs in Europe and around the world. The country information for Europe was provided by the national experts, as described in the overall project methodology. We received responses from 14 European countries (Belgium, Croatia, Czech Republic, Denmark, France, Germany, Hungary, Ireland, Italy, Latvia, the Netherlands, Poland, Serbia, Switzerland). Eight countries reported about EWRRs, which are described below. The other six countries have to our knowledge no EWRR for IAS in place. The selection of examples covering all of Europe and those beyond Europe is based on a quick scan using internet searches.

2.1 National early warning systems in Europe

Switzerland

Switzerland has an early warning system in place specifically for *Ambrosia artemisiifolia*. Under their Plant Protection Ordinance of 28 February 2001 *A. artemisiifolia* is listed as a particularly dangerous weed. As a result, it is mandatory to report sightings to the local cantonal authorities, and owners and managers of land that is contaminated with *A. artemisiifolia* are required to remove the plants using the appropriate measures. The sightings are ultimately reported to the Federal Office of the Environment (FOEN). A website has been developed to collect and disseminate information regarding the weed. The website contains relevant contacts for each local canton and several of them have links for online reporting. The website also provides identification tools, health warning information, control measures for different situations, and required actions.

Website: www.ambrosia.ch

Denmark

Denmark has an early warning system in place for a number of invasive species, including *A. artemisiifolia*, which is managed by the Nature Agency, Ministry of Environment. This agency oversees the country's action plan against invasive species. In addition to outlining control and monitoring methods, this plan also lists species that have been introduced or arrived in nearby countries and addresses the possibility that they could spread into Denmark. Their website provides information to organizations, private enterprises, public administrations and the public on invasive species, national legislation, and international cooperation in relation to the species. Additionally, the website allows anyone to report sightings of invasive species. Denmark also participates in the Rapid Alert System for Food and Feed (RASFF), an early warning system between the EU member states, Iceland and Norway that monitors the risk from food, including risk of seeds from invasive species. Reports are made by inspectors from the directorate and agricultural consultants.

Website: www.nst.dk

Hungary

Hungary has an early warning system in place for invasive alien plant species, but this does not include *A. artemisiifolia*, despite the extensive distribution of the species throughout the country. The Hungarian Biodiversity Monitoring System (HBMS) periodically monitors 124 selected plots for 5 invasive plant species (*Ailanthus altissima*, *Amorpha fruticosa*, *Asclepias syriaca*, *Solidago gigantea, S. canadensis*) at the landscape, community and population level since 1998. There are two main laws in Hungary dealing with invasive alien species. These deal mainly with acts around the introduction and removal of alien species in the country. The agricultural administration has long developed measures against pests, diseases and weeds and also has rules and regulations in place to protect against invasive alien species like *A. artemisiifolia*.

Ireland

Ireland currently has an informal Early Warning System for invasive species in place. It does not, at this time, cover *A. artemisiifolia*. Invasive Species Ireland is a joint venture between the Northern Ireland Environment Agency and the Irish National Parks and Wildlife Service. The National Invasive Species Database is hosted at the National Biodiversity Data Centre. Records of potential invasive species can be issued to the database, which will then send out a species alert. This is a key part of the early warning system, which will inform the public and stakeholders, trigger a rapid response and encourage further reporting. A drawback is that the alerts are only issued to a very limited number of people and most will have to actively check the website. Other drawbacks have led to the view that the current system should be further developed into a formal system, although the current system seems to work (only for species that are new to Ireland).

Website: http://invasivespeciesireland.com

France

France does not have an early warning system in place for invasive species; however, legislation gives prefects and mayors the authority to enact specific bylaws concerning *A. artemisiifolia*. As a result many of the infested regions have made it obligatory to prevent the growth and clear the land of ragweed. The southern region of France has several online sources that provide information regarding invasive species in the region as well as methods for control. The Regional Health Agency (ARS) Rhône-Alpes organizes public seminars about *A. artemisiifolia*. The public can report sightings online via www.ambroisie.info or they can call a telephone number, which is managed by the Rhône Department. Recently, the National Institute of Agricultural Research has been placed in charge of the Observatoire de l'ambroisie, which will be responsible for coordinating the removal of the plant.

Websites: www.ars.rhonealpes.sante.fr/Ambroisie.91569.0.html; www.ambroisie.info

Belgium

Belgium does not have a formal structure in place for early warning regarding invasive alien species. However, there is an informal structure in place called the Belgian Forum on Invasive Species (BFIS), which is facilitated by the Belgian Biodiversity Platform. The forum involves scientists interested in biological invasions and encourages information exchange and dissemination in order to support the development of measures dedicated to the prevention and mitigation of the impacts of invasive species. The BFIS updates the reference list of invasive alien species invading ecosystems in Belgium. Information on invasive alien species and their spread is regularly updated within the Harmonia information system, after being assessed through the Invasive Species Environmental Impact Assessment (ISEIA) protocol. The Harmonia system includes *A. artemisiifolia*.

Website: http://ias.biodiversity.be

The Netherlands

In the Netherlands the Food and Consumer Product Safety Authority (NVWA) hosts a Team on Invasive Aliens that has a central role in managing *A. artemisiifolia* in the Netherlands. In particular it plays a central role in setting up and running a national communication campaign targeting citizens, municipalities, land users and arable farmers (www.ambrosiavrij.nu; started in 2010, repeated in 2011 and possibly to be repeated in 2012).

People are encouraged to report observations through existing web portals, such as www.waarneming.nl and 'de Natuurkalender', the phenological reporting network for the Netherlands. Amongst other species, this network covers the different species of *Ambrosia*, including *A. artemisiifolia*. The public is asked to report sightings of the species and are supported in determining which species it actually is. This provides an insight in the spread of the plant. They are also advised as to the eradication of the plants. The reported sightings are being published on a map on the website.

Website: www.ambrosiavrij.nu

Italy

Italy does not have an early warning system for invasive alien species. It also lacks national legislation about the control of *A. artemisiifolia*, due to its regional distribution. In Northern Italy, local and regional governments have issued laws and guidelines regulating the management and control of *A. artemisiifolia*.

2.2 European early warning systems

European and Mediterranean Plant Protection Organization (EPPO)

The EPPO is an intergovernmental organization responsible for cooperation in plant protection in the European and Mediterranean region. Under the umbrella of the International Plant Protection Convention (IPPC), EPPO is the regional plant protection organization (RPPO) for Europe. One of the aims of EPPO is to help its 50 member countries to prevent entry or spread of dangerous pests. The Organization has therefore been given the task of identifying pests which may present a risk, and of making proposals on the phytosanitary measures which can be taken. In recent years, the identification of risk has been formalized and called the Pest Risk Analysis (PRA). Additionally, the EPPO maintains an Alert List, which provides an early warning to member countries to certain pests possibly presenting a risk to them. All pests on the Alert List are selected because they may present a phytosanitary risk for the EPPO region. The Alert List is reviewed critically every year by the Panel on Phytosanitary Measures. As a result, they may be added to the EPPO Action List, which is the list of pests recommended for regulations, or, if the PRA shows the risk to be low, removed from the Alert List.

EPPO, in the framework of the IPPC and the European strategy on invasive alien species under the Bern Convention (Council of Europe, 2004), is developing a cooperative Europe-wide strategy to protect the EPPO region against invasive alien plants. In 2002 an ad hoc Panel on Invasive Alien Species was created and was given the task to identify invasive plant species which may present a risk to the EPPO region, and to propose management options. The number of plants that can be considered as potential pest species is very large and the Panel is elaborating a prioritization process for all known, or potential invasive alien plants in the EPPO region. During this process the Panel is documenting invasive alien plant species on data sheets and when necessary, conducting PRAs following the EPPO Decision support scheme, 'Pest Risk Analysis for quarantine pests'.

As a result, the Panel has established the EPPO List of Invasive Alien Plants which can be considered as a list of priorities. Countries which are endangered by these species are strongly recommended to take measures to prevent their spread. *A. artemisiifolia* is one of the plant species that are listed by the EPPO List and for which both a data sheet and a PRA have been produced. Section 4.1 provides more information on the inventory and database managed by EPPO.

Finally, pathway analyses are regarded by National Plant Protection Organizations as a very efficient way to address the risks posed by invasive alien species.

Countries covered by EPPO: Albania, Algeria, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Israel, Italy, Jordan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxemburg, FYRoMacedonia, Malta, Moldova, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Turkey, Ukraine, United Kingdom, Uzbekistan

Website: www.eppo.int

European Network on Invasive Alien Species (NOBANIS)

The European Network on Invasive Alien Species (NOBANIS) was established as a network among authorities of the region. One of the main goals is to provide tools for implementing the precautionary approach against the unintentional dispersal of invasive alien species. It also establishes regional cooperation to aid countries in eradication and mitigation of these species. Currently, the NOBANIS system only stores data and information about IAS in the participating countries and can provide statistical and geographical information about these species. It includes *A. artemisiifolia.* It has no active early warning system in place at the moment, but during a workshop in June 2010 in Ireland recommendations were formulated on the development of such a system based on the NOBANIS database: Developing an early warning system for invasive alien species based on the NOBANIS database (NOBANIS, 2010).

Being a network of authorities, NOBANIS also establishes regional cooperation to aid countries in eradication, control and mitigation of these species. The fact that NOBANIS focuses on Western- and Northern Europe is considered a drawback by some.

Countries covered by NOBANIS: Austria, Belarus, Belgium, Czech Republic, Denmark, Estonia, Faroe Islands, Finland, Germany, Greenland, Iceland, Ireland, Latvia, Lithuania, Netherlands, Norway, Poland, European part of Russia, Slovakia, Sweden

Website: www.nobanis.org

Rapid Alert System for Food and Feed (RASFF)

The Rapid Alert System for Food and Feed (RASFF) provides authorities with a tool to exchange information about measures taken responding to serious risks detected in relation to food or feed. When an RASFF member has any information about a serious health risk deriving from food, feed or food contact materials, it must immediately notify the European Commission using RASFF. These notifications report on risks that are placed on the market in the notifying country or detained at an EU point of entry at the border with an EU neighbouring country. The notifying country reports on the risks it has identified, the product and its traceability and the measures it has taken. According to the seriousness of the risks identified and the distribution of the product on the market, the notification is classified as alert, information or border rejection notification. In 2011, a total of 3812 original notifications were transmitted through the RASFF, of which 635 were classified as alert, 573 as information for follow-up, 744 as information for attention and 1860 as border rejection notification. These original notifications gave rise to 5345 follow-up notifications.

Countries covered by RASFF: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxemburg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland

Website: http://ec.europa.eu/food/food/rapidalert/index_en.htm

2.3 Early warning systems outside Europe

United States

The United States has a federal system in place for the Early Detection and Rapid Response (EDRR) to Alien Invasive Species. The National Invasive Species Council (NISC) was established in 1999 by Executive Order (EO) 13112 to ensure that Federal programs and activities to prevent and control invasive species are coordinated, effective and efficient. EO13112 does not specify particular species that fall in the category of Alien Species, but states that it means '…with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem'. This therefore can also cover *A. artemisiifolia*, although native to North America. The NISC coordinates the effort of US States and regions to implement their own EDRR systems. Such EDRR's consist of three elements: (1) Early Detection provides initial evidence of an invasive species, (2) Rapid assessment, which may recommend that a response be initiated and (3) Rapid Response efforts to contain, and where possible, eradicate invasive populations.

The National Framework for Early Detection, Rapid Assessment, and Rapid Response to Invasive Species has been developed by the National Biological Information Infrastructure (NBII) as a prototype for different governments to use in the development and implementation of an EDRR. It consists of six components each describing an activity associated with addressing the invasive species issue and provides access to resources.

Specifically aimed at invasive plant species, the Federal Interagency Committee for the Management of Noxious and Exotic Weeds (FICMNEW) has the task of coordinating, through the respective Secretaries, Assistant Secretaries, and Agency heads, information regarding the identification and extent of invasive plants in the U.S. and to coordinate federal agency management of these species. In 2003 the FICMNEW set out a conceptual design for a national EDRR system for invasive plants in the US (FICMNEW, 2003).

Australia

Australia does not have a formal early warning system in place, but early detection and rapid response is part of The Australian Weeds Strategy (AWS) which has been developed by the Australian Weeds Committee (AWC). The AWC oversees the administration of the AWS, which is the overarching policy for weed management in Australia. The AWS outlines goals and actions required to keep Australia's economic, environmental and social assets secure from the impacts of weeds. All land managers, communities, research institutions, and all levels of government have a role in the early detection and eradication of weeds. These are requested to be aware of new infestations and report potential new weeds or new outbreaks to their local council, or state or territory weed management agencies. Once a newly-discovered weed is identified, experts can assess the infestation and determine the most appropriate early response method. The aim of eradication is to eliminate a species or number of species from an area. A number of lists have been created that identify plants of particular concern or plants that have been through an assessment process. These lists can inform us of particular types of management practices for particular species, and some are part of legislation to help ensure their control or prevent trade. It is unclear if *A. artemisiifolia* is also specified by the system.

Website: www.weeds.gov.au

Canada

Since 2004, Canada has a strategy in place which is called 'An Invasive Alien Species Strategy for Canada'. This strategy establishes a coordinated national policy and management framework which minimizes the various risks of IAS. This strategy sets out to do this through prevention, early detection, rapid response and management (containment, eradication). The strategy specifies the key actions to reach these goals.

Website: www.ec.gc.ca/eee-ias/

2.4 Summary

A number of countries worldwide have formal or informal systems for the early warning and rapid response to alien invasive species in place. Some of these address *A. artemisiifolia* specifically or as one of a list of targeted species. Other countries provide a definition of species to be targeted by the early warning system.

There are several factors that contribute to a successful early warning system. First, there should be laws and regulations in place for people to report and control ragweed. Second, programmes should be in place to educate the public. Third, there should be an easy way for the public to report sighting and control actions to authorities such as online forms, hotlines or the close involvement of local authorities that are close to the public. It is also very important for the functioning of the system that there is an adequate knowledge base behind the system for rapid assessment and response.

In order to set up an adequate early warning system for Europe it is important to pay extra attention to those examples that are in place in highly decentralized countries. The examples prove that there is a need for one central organization because species tend not to pay much attention to borders, but there is also a need to engage agencies or authorities at the national or sub-national level within the different European countries to adequately engage local communities and strengthen the capacity of the system. Therefore systems in place in highly decentralized countries, like the United States, tend to be more suited as examples for the European case.

3 Relevant stakeholders, competent authorities and A. artemisiifolia experts

The term ‘stakeholder’ covers a wide spectrum of people, organizations, or groups that affect or can be affected by a process or an action. Because of its wide scope, it is important to distinguish between a number of categories of stakeholders that are relevant in connection to early warning systems for *A. artemisiifolia*. Here we distinguish three categories of stakeholders:

1. *Contributors:* Stakeholders that contribute to the introduction or the spread of *A. artemisiifolia*, e.g. by transporting seeds through international trade, or by accidentally including seeds in the production chain.
2. *Affected:* Stakeholders that are affected by the introduction of *A. artemisiifolia*, such as people suffering from allergic reactions to its pollen, or farmers seeing their crops contaminated.
3. *Responding parties:* Stakeholders that respond to the introduction and spread of *A. artemisiifolia*, for example by making policy, carrying out research, developing eradication measures, or implementing such measures.

Relevant stakeholders have been identified in the national cases, by the national experts and other sources. Detailed lists for each responding country are included in Annex 3 (Competent authorities), Annex 4 (scientific stakeholders) and Annex 5 (other stakeholders). The types of stakeholders are listed by the above categories in table 8.1. The same stakeholder type may be listed in multiple categories as they may have multiple stakes in relation to *A. artemisiifolia* (e.g. in most cases contributors and affected will also be responding parties).

Table 8.1 Overview of stakeholders involved in contributing to, affected by, and responding to *A. artemisiifolia* arrival and spread in Europe.

Contributing parties	**Affected parties**	**Responding parties**
Garden centre (accidental introduction of seeds and seedlings) Farm advisory body (recommending seed mixtures that may include ragweed seeds) Gardening company (using plant material that may be polluted with ragweed seeds) Botanic garden (ragweed in live collection; using plant material that may be polluted with ragweed seeds) Trade companies (accidental or deliberate introduction of seeds or plants) Seed producers and retail (accidental or deliberate inclusion of ragweed seeds in seed mixtures) Bird feed producers and retail (accidental or deliberate inclusion of ragweed seeds in bird seed mixtures)	Garden centre (polluted material may reduce sales; liability when selling polluted material; extra costs for eradication) Gardening company (liability when using polluted material; extra costs) Health insurance company (extra costs for treating allergic reactions) Botanic garden (liability; extra costs for eradication) Citizen (allergic reaction) Farmer (crops polluted with ragweed)	Research institute National government agency Ministries (environment, public health, economy, trade, nature, agriculture) Feed inspection unit/department; control authorities Local authority Regional authority Nature conservation organizations Farm advisory body Farmers union Garden centre Parks department (Rail)road maintenance Gardening company Volunteer naturalists Construction company Health service Health insurance company Citizen (e.g. gardener, hiker) Consultancy European Commission European Environment Agency European umbrella organization Prisoner/convict/community service Meteorological service Forestry service Botanic garden Customs

For each stakeholder type an indication is given about their connection to *A. artemisiifolia*. In terms of early warning and rapid response, the category of 'responding parties' is the most relevant one, as they may have a specific role to play in an aspect of an early warning system. This specific role of responding parties is described in more detail in section 7 of this chapter.

4 Existing invasive species databases and inventories

Species databases have been developed for a wide range of geographical scales and purposes for many decades. A number of these databases focus on invasive alien species (IAS) with the purpose to identify new arrivals, monitor spread and allow relevant stakeholders to take appropriate action (Vandekerkhove & Cardoso, 2011; ETC/BD, 2011). This section describes a number of European and global databases and inventories that include IAS and *A. artemisiifolia* in particular. The descriptions of the databases are taken from or to a large extent based on the EEA report (2010) and on the respective websites.

4.1 European

EPPO - European and Mediterranean Plant Protection Organization

EPPO as an organization and network is described in section 2.2. Here we focus on inventories managed by EPPO.

The EPPO maintains a global list of invasive alien plant species. The initial list consisted of approximately 500 invasive alien plants in the EPPO region but now there are 35 plants listed. A preliminary prioritization of these species was done by expert judgment based on whether the plant is considered invasive or potentially invasive by several EPPO countries, whether the plant is absent or still containable by appropriate measures in several EPPO countries, whether the plant is reported to be actively spreading or becoming more damaging in its current distribution area, and the potential of the plant for further spread and damage into significant areas where it is absent.

Additional information was then gathered from official contacts in EPPO member countries about the plants' typical habitats, geographical distribution within countries, identification of areas where a species is creating most problems, abundance, existence of current pathways, mode(s) of spread, type of spread, cultivation, official control, etc. Then the species were rescored based on general invasiveness, damage to crop, natural flora and habitats, and man-made disturbed areas, and the current spreading trends.

EPPO also maintains a database on quarantine pests called PQR (Plant Quarantine data Retrieval system). This provides detailed information on the geographical distribution and host plants of quarantine pests. Its search tools also allow users to identify commodities which may act as pathways in international trade for the movement of pests and diseases. In recent years, the database has been extended to cover invasive alien plants. The new PQR version also includes world maps, pictures and active links to the EPPO Reporting Service.

EPPO displays datasheets on quarantine pests and invasive alien plants, which are aligned to those in the CAB International (CABI) Crop Protection Compendium. The list includes a draft datasheet as well as a Pest Risk Analysis (PRA) on *A. artemisiifolia*.

Website: www.eppo.int

NOBANIS - European Network on Invasive Alien Species

NOBANIS is described in 2.2. It provides a gateway to information on alien and invasive species in 20 countries of north and central Europe. NOBANIS covers marine, freshwater and terrestrial environments and provides a distributed but integrated database on introduced species in the region.

NOBANIS holds an inventory that provides minimal information for more than 8,200 species. Invasiveness is assessed independently for each country. NOBANIS provides references for each individual species reported in a country, allowing traceability and verification of information. Species covered by NOBANIS represent 49% of all species identified as alien by any EU member state plus Norway (Vandekerkhove & Cardoso, 2011).

Detailed fact sheets on 64 species provide sufficient information to answer the initiation and categorisation stages of the risk analysis, and would provide a good starting point to perform a full risk assessment on the species. *A. artemisiifolia* is currently not included in the database or factsheets. Other useful tools include a catalogue of regulations relevant to invasive species in participating countries and a literature database connecting to regional and global networks and projects on invasive aliens species.

Website: www.nobanis.org

DAISIE - Delivering Alien Invasive Species Inventories for Europe

The DAISIE portal and associated database provide the first pan‐European inventory of invasive alien species with extensive taxonomic and geographic scope. DAISIE was originally funded by the Sixth Framework Programme of the European Commission. After the project ended in 2008 the database has been kept online and is complemented in an *ad hoc* way. It provides an extensive inventory of invasive species that threaten European terrestrial, freshwater and marine environments, with information to help prevent and control biological invasions through the understanding of the environmental, social, economic and other factors involved. The data currently available (assembled and verified by experts) refer to alien vertebrates, invertebrates, marine and inland aquatic organisms and plants from the wider Europe (63 countries). In total it covers 11,595 alien species recorded in Europe.

The largest database on invasive species in the world, DAISIE also aims to assess and summarise the ecological, economic and health risks and impacts of the most widespread and noxious invasive alien species. With free and direct access to national knowledge bases throughout Europe, it provides comprehensive data on which species are invasive or potentially invasive in particular habitats. It thereby aims to gather all information useful to prevent spread and impact, and to apply effective and appropriate control strategies. However, despite its size, DAISIE covers only 71% of species identified as alien to any of the EU member states and Norway (Vandekerkhove & Cardoso, 2011).

Information on species distribution in each country is based on the advice of experts provided according to predefined status categories (e.g. 'alien/established', 'alien/non-established', 'alien/extinct', 'alien', 'cryptogenic/established').

DAISIE also includes detailed species accounts for a sample of '100 worst' invasive aliens in Europe, covering a broad spectrum of life forms and representing some of the species that have the greatest impact on biodiversity, the economy and health. Each species account contains information on synonyms, description, biology/ecology, habitats (on the basis of the EUNIS codes[1]), distribution worldwide (with a map of European distribution), impact and management. *A. artemisiifolia* is included as one of the 100 worst invasives.

DAISIE species descriptions can help identify newly introduced taxa, although in most cases specific tools — and taxonomic expertise — are essential. In the context of an early warning and rapid response system, the information provided could be sufficient to complete the initiation and categorisation stages of risk analysis. Other stages of risk assessment (probability of entry, establishment, spread and impact) would require substantial additional information.

Website: http://www.europe-aliens.org.

4.2 Global

REABIC - Regional Euro-Asian Biological Invasions Centre

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[1] http://eunis.eea.europa.eu/habitats-code-browser.jsp

REABIC is a largely virtual institute providing on-line information services in the area of biological invasions research and management. Facilitation of international cooperation on the invasive species related issues, linking the international research community and the general public, managers and decision-makers as well as other interested stakeholders are among the main REABIC objectives.

The REABIC started in 2001 as a web portal, providing access to the global, regional, sub-regional and national Internet resources on biological invasions (the Regional Biological Invasions Centre project, RBIC). At present REABIC serves as an independent virtual data centre for applied research and management of invasive species focusing on the Euro-Asian region and providing online services for interested stakeholders around the World.

REABIC focuses on aquatic environments and includes a set of species fact sheets (AquaInvader database) and an alien species experts registry. The extension of RBIC to REABIC was largely based on further development as part of the FP6 project ALARM[2] and the FP7 project EnviroGRIDS[3].

Website: www.reabic.net

GISD - Global Invasive Species Database

GISD is considered the most authoritative and comprehensive database on invasive alien species that threaten biodiversity. Accessible for free online, it provides detailed and constantly updated information for 615 invasive alien species. Information covers matters such as taxonomy, description, habitats, general impacts, uses, geographical range, introduction pathways to new locations, local dispersal methods and reproduction.

Distribution data and other information are well documented and referenced. The information is sufficient to answer the initiation and categorisation stages of the pest risk analysis, and would provide a good starting point to perform a full risk assessment on the species. GISD also contains detailed information on management techniques, to enhance response. The strength of GISD is the network of IUCN experts that constantly provide updates and information on a voluntary basis. Its weakness is that GISD only covers species for which a profile has been produced and does not take into account those species for which only simple records of presence are available.

[2] http://www.alarmproject.net/alarm/
[3] http://envirogrids.net/

Apart from the general database, GISD also lists 100 of the World's Worst Invasive Alien Species. This list does not include *A. artemisiifolia.*

The GISD aims to increase awareness about invasive alien species and to facilitate effective prevention and management activities. It is managed by the Invasive Species Specialist Group (ISSG) of the Species Survival Commission of IUCN.

Website: www.issg.org/database/welcome/

GISIN - Global Invasive Species Information Network

The Global Invasive Species Information Network (GISIN) provides a platform for sharing invasive species information at a global level, via the Internet and other digital means.

Website: www.gisin.org

4.2 National databases

In addition to the international databases described above, many European countries have developed and manage their own national or subnational species databases. In most cases these include or are focused on IAS. An inventory of these databases, based on input by the national contacts, is presented in Annex 6 (see also Vandekerkhove & Cardoso, 2011; ETC/BD, 2011).

5 Monitoring systems and the inclusion of A. artemisiifolia

Species-based monitoring programmes are widespread in Europe and very diverse in content and format. The EuMon project (EU-wide monitoring methods and systems of surveillance for species and habitats of Community interest[4]) identified 456 species monitoring schemes in Europe. Ninety of these schemes are reported to cover invasive alien species, including ten for plant species. Although it cannot be derived from the EuMon inventory, it can be assumed that some of the plant-based monitoring schemes (totalling 34) will include *A. artemisiifolia*.

The majority of these monitoring schemes rely heavily on volunteer input. This is a strength and a weakness at the same time. It is a strength because of the high number of highly experienced volunteers being available in many countries. This allows surveillance and monitoring to happen in large parts of a given country or region and at very low cost. It is a weakness though in terms of

[4] http://eumon.ckff.si

volunteers being able to plan their contributions over longer periods of time and in a structured way, at the same time maintaining accountability for the quality of their observations. The latter is more easy to manage when involving scientists or consultants, but is obviously much more expensive (see Task 5).

An excellent way to overcome some of the weaknesses concerning volunteer input is through the establishment of coordinated participatory monitoring networks. These are well-organized networks in which professional organizations (often national NGOs) coordinate and facilitate volunteer input by offering training, steering the priorities, executing data control, providing volunteer feedback, liaising with scientific and policy communities etc. One such network is the UK Biological Records Centre (BRC), which is a national focus for terrestrial and freshwater species recording[5]. BRC works closely with the voluntary recording community, principally through support of national recording schemes and societies.

With the continued development of interactive internet-based applications, it is becoming increasingly easy for volunteers and interested naturalists to report observations of a large number of species at very high spatial and temporal resolutions. National (and international) observation portals based on Google map technology allow for instant reporting and feedback. Some of such portals are described in section 8. However, the data collected by such portals do not automatically make up a monitoring system. Rather, they serve as excellent detection tools that can for instance help in reporting new arrivals of IAS such as *A. artemisiifolia*.

Considering the monitoring systems in place, *A. artemisiifolia* is already generally considered a great risk and is included in various systems, at both national and European levels. Where this is not the case it should be relatively easy to include it. The effectiveness of the monitoring and subsequent eradication lies in the formal character of a system. Making the reporting of sightings mandatory and appointing a central authority to collect the reports, process data and issue alerts and control advice to the appropriate local authorities or organizations, is a key factor for a successful early warning and response system (see section 9, also Task 7,9).

There are a few systems in place that focus specifically on *A. artemisiifolia* and in some instances there are even formal response and management approaches linked to them as part of a wider early warning and rapid response system. For example, the Dutch *Natuurkalender*[6] is an informal network

[5] http://www.brc.ac.uk
[6] www.natuurkalender.nl

of phenological observers that specifically and actively report *A. artemisiifolia* sightings, among other species and phenological events. Sightings are reported to participants in the network and listed by Wageningen University. This information is compiled centrally by the Netherlands Food and Consumer Product Safety Authority (NVWA) which provides an overview of the spread of *A. artemisiifolia* in The Netherlands and advises landowners, local authorities, and other stakeholders on how to eradicate the species from their land.

A formal, and arguably more effective, monitoring and management instrument specifically for *A. artemisiifolia* is in place in Switzerland. Since the species is listed as a particularly dangerous weed it is mandatory to report sightings to the local authorities. Landowners or managers of sites that are contaminated with *A. artemisiifolia* are obliged to take the appropriate measures to remove the species. A website provides guidelines to identify the species and also means to report it to the local authorities. These relay the sighting report to the Federal Office of the Environment (FOEN) which issues information and control requirements to the appropriate local authorities

Although not monitoring systems in their own right, in recent years observation portals have been developed for most countries in Europe. These portals can play a very important role in detection of first arrivals, surveillance and indicating spread of *A. artemisiifolia.* In addition to the above-mentioned *Natuurkalender* well-advanced examples include the UK Springwatch[7] and Autumnwatch initiatives that invite citizens to record phenological events. More general observation portals are the Swedish Species Gateway[8] and the Dutch www.waarneming.nl and its copies in other countries (e.g. www.waarnemingen.be). The Recording Invasive Species Counts (RISC[9]) project in the UK provides a portal for volunteer recording of selected non-native species (*A. artemisiifolia* is not included). It is co-ordinated by the National Biodiversity Network and BRC and the information is fed to the GB Non-native Species Secretariat. Based on the waarneming.nl system and developed by the same people, a global recording portal has been developed: www.observado.org. This portal allows any person with access to the internet to record any observation of any species any time anywhere in the world. By using Google maps as the geographic layer it allows collection of sightings at very high spatial resolution.

The EEA together with Microsoft have developed the Eye on Earth platform for environmental applications (http://watch.eyeonearth.org). Currently citizens can report measurements or other

[7] http://www.bbc.co.uk/programmes/b007qgm3
[8] http://artportalen.se/default.asp
[9] https:// secure.fera.defra.gov.uk/nonnativespecies/index.cfm?pageid=234

observations on air and water quality and on noise. For biodiversity the EEA is considering the development of NatureWatch to collect species observations using citizen science.

6 Communication, information dissemination and awareness raising

As for most IAS, prevention of arrival or spread of *A. artemisiifolia* is better than managment or eradication (see Task 7,9). Once a species is established, it can be very hard, if not impossible, to eradicate. Therefore, effective communication campaigns are essential to raise awareness of the relevant stakeholders and to mobilize them to contribute in preventing invasions (see also Task 7,9).

We found many excellent and effective national or subnational examples of communication campaigns, some of which are referred to in Section 2. On the basis of these findings there seems not to be a need for additional communication campaigns on *A. artemisiifolia* at the European level. Rather, for those countries where no campaign or information material is available yet, a European effort could help in identifying best practices, translating existing materials in other EU languages, or exchanging experiences.

Typically, the communication activities in support of preventing invasion of *A. artemisiifolia* include the following components:

- identification of target groups;
- formulating the message;
- identifying means of communication.

6.1 Identification of target groups:

Section 3 provided a full overview of relevant stakeholders and their connection to aspects of managing *A. artemisiifolia*. In principle all of the identified stakeholders fall into a target group for focussed communication. We distinguish four main groups here, most of which can be divided into contributing, affected and responding target groups (see also Table 8.1):

a) General public:
   a. Contributing (e.g. garden owners)
   b. Affected (e.g. people with allergic reactions)
   c. Responding (e.g. garden owners or volunteer naturalists)

b) Economic sectors:
   a. Contributing (e.g. bird feed producers)
   b. Affected (e.g. health insurance companies or farmers)
   c. Responding (e.g. seed manufacturing)

c) Decision makers:
    a. Contributing (e.g. authorities not taking preventative measures)
    b. Affected (e.g. national agency with alert function)
    c. Responding (all levels)

d) Experts (e.g. research institutes, plant health agencies, civil society organizations)

6.2 Formulating the message:

Messages to be communicated will vary greatly by target group, objective and sender of a message. A number of examples are listed here below, clustered by communication objective.

Raising awareness of all target groups on the impacts of *A. artemisiifolia* and the importance of taking control measures:

- What is the problem?
- Why is it a problem?
- How does it affect me?
- What does the plant look like?
- How does it get here?
- How do I recognize health effects?
- What do I do if I get allergic reactions?
- Can crops affected by ragweed still be used?

Prevent arrival or further spread of *A. artemisiifolia*:

- Where do I buy bird feed that has no ragweed seeds?
- What do I do if I detect a plant or seed?
- Who do I report an observation to?
- What can I do to prevent it to grow or to eradicate it?
- How do I make sure that the plant does not return?
- What incentives work best to engage relevant actors in preventative measures (laws, fines, awards, …)?
- How do I ensure there are no ragweed seeds in my seed mixture?

6.3 Identifying the most effective means of communication

For each of the combinations of target group and message the most suitable communication tools can be identified. A single communication tool can serve multiple objectives and reach multiple target groups. Examples of communication tools that have been applied for managing *A. artemisiifolia* in MS include:

- Dedicated websites providing background information, identification sheets, online tools for reporting observations, response tips, contact information etc.
- Leaflets and posters for distribution in town halls, at sectoral events, via nature organizations, etc.
- Short easy-access articles in general newspapers and specialized magazines (e.g. gardening magazines, botanists newsletters, farmers newsletters, etc).
- Conferences and workshops for specialized audiences (e.g. health insurance, medical staff, researchers).
- Short videos for distribution via TV programmes (including News) and via YouTube and other websites.
- Information stands at events for sectors, public, nature organizations etc (e.g. garden shows, farm days, health fairs).

6.4 Communication plan for Europe

Given the strong role of national authorities in managing *A. Artemisiifolia,* communication in support of raising awareness of the public and other stakeholder groups is best implemented at a national level. Experience in Switzerland demonstrates that targeted awareness campaigns can be very effective in reducing the spread of *A. artemisiifolia* (Bohren, 2007).

However, since the threat posed by *A. artemisiifolia* has a European scope and many countries have no awareness campaign for ragweed yet, European effort to coordinate and stimulate national awareness campaigns is urgently needed. A European body in charge of IAS could support national efforts by facilitating exchange of knowledge, information and communication materials, by funding national activities or by cooperating with national partners. An example of a similar approach can be found in the USA, where efforts at Federal level help individual states. For example, the National Invasive Weeds Awareness Week is implemented with active involvement of the Federal Interagency Committee for the Management of Noxious and Exotic Weeds[10].

[10] http://www.fs.fed.us/ficmnew/awareness.shtml

Table 8.2 provides a matrix overview of the various types of communication means and the target groups that are potentially reached with such tools. Although primarily applicable at national or lower scales, a European awareness raising campaign could focus on elements of such matrix.

As stated earlier, because for *A. artemisiifolia* national efforts seem to be well developed and coordination of reporting from national authorities to European level already takes place in the framework of the EPPO, we believe that developing a European awareness campaign for *A. artemisiifolia* is not a priority. Facilitating exchange of best practice between countries, however, is a priority.

Table 8.2. Communication matrix showing which target groups are reached by communication tools

Communication tool	General public	Economic sectors	Decision makers	Experts
Website	X	X	X	X
Leaflets and posters	X	X		
Articles	X	X	X	
Conferences and workshops		X	X	X
Videos	X	X	X	
Information stand	X	X		

7 Roles and responsibilities in early warning systems

Implementing an early warning and rapid response system (EWWR) involves many different actions, roles and responsibilities in which a wide range of stakeholders is involved. Section 3 listed the types of stakeholders and actors in connection to *A. artemisiifolia*. Here we describe the types of actions that these stakeholders may be involved in and suggest roles and responsibilities for key actors.

7.1 Types of actions

Typical elements of an EWWR include (EEA, 2010):

1. detection (surveillance and monitoring);
2. diagnosis and data processing;
3. risk assessment (or quick screening);
4. reporting to competent authorities and circulation of information;
5. response action;
6. follow up.

Each of these broad categories contains a number of more specific actions, as listed below:

Detection (surveillance and monitoring):

- collecting distribution information of plants;

- monitoring pollen concentration;
- reporting observations;
- gathering data;
- carrying out surveillance;
- developing surveillance programmes (both active and passive).

Diagnosis and data processing:

- carrying out research;
- verifying records;
- developing and maintaining databases/information systems.

Risk assessment (or quick screening):

- identifying threats (magnitude and probability of entry, establishment, spread and impact);
- carrying out vulnerability check;
- identifying management options.

Reporting to competent authorities and circulation of information:

- exchange information;
- reporting (e.g. online ragweed atlas, weekly updated bulletin).

Response action:

- (experimenting with) control measures;
- raising awareness;
- developing communication plan;
- implementing communication measures;
- policymaking/improve legislative framework;
- securing resources/funding;
- carrying out border control;
- capacity building;
- managing sites;
- educating;
- providing advisory services (e.g. to farmers and garden centres);
- clearing land from ragweed;
- clearing feed stuff, seed products etc. from ragweed seeds;
- coordinating and facilitating;
- preventing import of ragweed seeds;
- encouraging citizen participation (e.g. by issues awards);
- training;

- containment;
- issuing alerts.

Follow up:

- inspection;
- monitoring (protocols).

7.2 Roles of key actors

In section 3 we identified the types of stakeholders of relevance to *A. artemisiifolia* management. One particular group included the responding parties: those actors that can play an active role in managing *A. artemisiifolia*. Table 8.3 suggests possible roles for each of the listed responding parties.

7.3 Responsibilities of key actors in a future European EWRR system

When developing a future European early warning and rapid response system for invasive alien species in general and *A. artemisiifolia* in particular, it is essential to agree clear responsibilities for all of the actors involved. Section 9.5 proposes a European institutional setup for such EWWR on IAS, including an outline of key responsibilities.

8 The use of new technologies

We explored the possibilities and their feasibility in relation to the best ways to utilise new technologies in the development of an EWRR. Thus, applications such as remote sensing, automated monitoring of the levels of pollen in the air, but also the use of social media which are rapidly growing in both the popularity and variety of their application were all given consideration.

Social media, such as Facebook, YouTube and Twitter, and, to some extent, Smartphone apps, have become the latest tools to link scientists with the public. These tools empower people to act on the scientists' behalf by monitoring species, observing behavioural patterns, reporting the presence of invasive species, as well as changes in climate, vegetation, and populations. Additionally, scientists are utilizing social networking, such as Twitter, to conduct critical analysis and evaluation of research data, disseminate research output, and conduct primary research.

Social media has proven to be a successful notification and information gathering tool during and after natural disasters, such as the Tohoku earthquake and devastating tsunami of March 2011. Official local authority Twitter accounts set up at the time of the earthquake were useful, well followed and retweeted extensively, especially when warnings of an imminent tsunami were predicted. Updates highlighting specific happenings such as the rise and fall of the sea, burning buildings and explosions were extremely beneficial.

Table 8.3. Matrix connecting possible roles in managing *A. artemisiifolia* to responding parties

Responding party / **Role**	**Communication, awareness raising**	**Control & inspection**	**Coordination**	**Database**	**Eradication & managment**	**Financial compensation**	**Funding**	**Information exchange**	**Legal support**	**Legislation & policy**	**Prevention**	**Reporting**	**Reporting of observations**	**Research**	**Surveillance & monitoring**	**Training & education**
Botanic garden	X										x					X
Citizen (e.g. gardener, hiker)					X								X			
Construction company	X				X						X		X			X
Consultancy	X													X	X	X
Control authorities		X														
Customs	X	X									X					
European Commission	X		X				X			X						
European Environment Agency	X			X				X								
European umbrella organization	X		X									X				
Farm advisory body	X										X					X
Farmers union	X					X			X							
Feed inspection unit/department		X														
Forestry service	X											X			X	X
Garden centre	X										X		X			
Gardening company	X				X						X				X	X
Health insurance company	X					X	X									
Health service	X															
Land owner		X			X		X				X		X			
Local authority	X				X											
Meteorological service	X															
Ministries (environment, public health, trade, economy, nature, agriculture)	X		X				X			X						
National government agency	X		X	X						X						
Nature conservation organization	X				X								X		X	X
Parks department	X				X										X	X
Prisoner/convict/community service					X										X	
(Rail)road maintenance	X				X										X	X
Regional authority			X		X											
Research institute														X		
Volunteer naturalists					X								X		X	X

8.1 Observation portals

There is a multitude of projects already utilizing web portals, apps and social media to identify, track, and manage various species around the globe. Some examples are listed here.

iNaturalist.org, an online community created by students at University of California, Berkeley's School of Information allows users to upload photos and talk about sightings. The site allows users to create and participate in projects. For example, the Colombian Herpetological Association created a project to get users to help to map the over 1400 amphibian and reptile species distributed in Colombia.

Project BudBurst (www.neoninc.org/budburst), sponsored by the National Ecological Observatory Network in the USA, has registered nearly 12,000 volunteer observers since 2007. Participants have uploaded tens of thousands of observations on their chosen plants' first leaf, first flower, first pollen, and other phenological phases. The data is currently being used by scientists and educators in the Project BudBurst network.

See also section 5 for a description of some European and national observation portals.

8.2 Smartphone applications

Project Noah (www.projectnoah.org) is a more commercial version of an environmental community, which was launched in early 2010 as an app for Smartphone. This application allows users to document sightings of wildlife around the globe with pictures. The user's location is automatically updated and the user can choose to identify the species themselves or leave it open for someone else to do. So far, participants have uploaded over 240,000 'spottings'. Users can also sign up to contribute to scientific research such as the International Spider Survey and the Global Coral Reef Monitoring Network.

iMapInvasives is an online invasive species database currently covering six states of the USA that allows concerned citizens and other actors to directly report sightings of invasive species through a Smartphone application.

Similar apps are available for (subsets of) invasive species, mostly in the USA, Canada and Australia, such as Report-a-weed in Canada (IAAP) and the Bugwood app IveGot1 in Florida.

For Europe the RINSE project (Reducing the Impacts of Invasive Non-native Species in Europe: http://www.rinse-europe.eu) aims at developing an app to report IAS.

AmbrosiaSCOUT is a German Smartphone app that is specifically developed for Smartphone owners in Berlin to report sightings of *A. artemisiifolia* in the fight against allergies. A short video on YouTube[11] informs citizens about ragweed and the use of the app.

Ambrosia Melder is a Dutch iPhone App that allows users to identify ragweed and to report observations. The observations are automatically reported to land owners such as municipalities or nature managers. Also this App is supported by an online video[12]

Leaf Watch (http://www.ourweboflife.org.uk/index.html; http://naturelocator.ilrt.bris.ac.uk/) is an app developed by the project 'Leaf Watch' in order to crowd-source geospatially tagged, photographic data on the UK distribution of the invasive horse-chestnut leaf miner moth *Cameraria ohridella*. Prior to the app's production, data collection had been crowd sourced but the project was reliant on people submitting their data using a website form. Submissions over the season numbered about 500 and were text based only. Verification of records, therefore, was not possible and the location of affected trees had to be recorded using an Ordnance Survey map. The app has greatly facilitated the data collection and submission process (by making it portable) while simultaneously increasing data accuracy by incorporating a GPS tagged photographic image of the subject. The convenience factor which the app provides has encouraged many more people to participate in the study and yielded a much larger data set; 5500 records were collected from all over the UK in the four month recording period. The project has also developed a website application to enable crowd sourcing of the validation of the collected records.

PlantTracker (http://planttracker.naturelocator.org/) is a recently launched app by the UK's Environment Agency which allows recording of three particular invasive plants (*Fallopia japonica, Impatiens glandulifera, Hydrocotyle ranunculoides*). The app enables data to be collected by interested members of the public in the field. Critically, each record collected is verifiable since it is comprised of a photograph along with other relevant metadata. Records are also accurately geo-located using GPS. Data collected by the PlantTracker app is being stored in the 'Indicia' data warehouse, hosted by the BRC.

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[11] http://www.youtube.com/watch?v=vIUoxp_uYz8

[12]http://www.vwa.nl/onderwerpen/gevaren/dossier/ambrosia/nieuwsoverzicht/nieuwsbericht/2024761/video-app-om-hooikoortsplant-te-herkennen-en-te-bestrijden

8.3 Social media

YouTube has a growing number of short videos in many languages informing people about *A. artemisiifolia*, how to recognize the species, what is being done about it, why it is important, its allergic impacts, how you can eradicate it, etc.

The Smithsonian has utilized crowdsourcing to quickly gather data. Recently, they put out an emergency call on Facebook for specialists to identify 5,000 freshly collected fish specimens from Guyana to export paperwork. Within 24 hours, ichthyologists around the world supplied partial or complete answers for almost 90 per cent.

The examples above demonstrate the potential of integrating these new technologies into an invasive species control programme. The information is disseminated and gathered quickly; the technology is available, easy to use, and accessible to the majority of the public. There is one potential issue pertaining to the reliability of Twitter updates or sightings reported through apps or observation portals: observers could incorrectly label observations. In the case of tweeting, this could be improved if official hashtags were announced and utilized. Hashtags are keywords prefixed with the # symbol that would normally allow users to filter updates of interest. Additionally, clicking on a hashtagged word in any message shows you all other tweets in that category.

8.4 Remote sensing

Results of studies on the use of satellite images to detect large populations of *A. artemisiifolia* show promising perspectives. A study in the Rhône-Alpes region in France shows that the species can be detected relatively reliably on the basis of the difference of its spectral reflectance compared to neighbouring species (Auda *et al*., 2011). However, the experiment showed that detection is only reliable at small scale (<10 km^2) and within homogeneous soil conditions . Also, it remains difficult to distinguish *A. artemisiifolia* from similar plants in the genuses *Artemisia* and *Aclepias* (Auda *et al*., 2011; Maupin *et al*., 2000). Further research is needed to allow the use of satellite remote sensing at a European scale.

Remote sensing based on polarimetric radar provides the potential to detect ragweed in uniform croplands, as demonstrated for ragweed infection in sunflower fields in Hungary (Nádor *et al*., 2011). It may be possible to identify ragweed spread over larger agricultural areas before actual pollination starts and therefore facilitate timely weed control.

It is clear from other studies that a single remote sensing solution will not suffice and that a combination of techniques (such as remote sensing, GIS and GPS; Csornai *et al*., 2011) will need to be applied in order for detection to be more effective.

8.5 DNA Barcoding

DNA barcoding is a technique that can help in assigning a plant sample to a given taxon based on a short sequence genetic marker. It allows identification based on a fragment of an organism, such as a leaf or a seed instead of a flowering or fruiting plant. The application of DNA barcoding does not require a professional taxonomist to be involved. Based on small amounts of tissue, non-experts can obtain DNA barcodes following the appropriate laboratory protocols.

Although DNA barcoding is still subject of much debate and research, for flowering plants a number of loci in the mitochondrial DNA have been identified that can be used to identify organisms to the species level (Kress *et al*., 2005; Kress & Erickson, 2008; Ausubel, 2009; CBOL Plant Working Group, 2009).

A DNA barcode for *A. artemisiifolia* has been proposed (Kress *et al*., 2005). This offers potential for custom services to identify arrival of *A. artemisiifolia* as seeds or plants, as demonstrated for other plant species (e.g. Lahaye *et al*., 2008; Gao *et al*., 2010).

9 Recommended approach for an early warning system for A. artemisiifolia in the EU

In 2010 the European Environment Agency presented an overall assessment of the conditions for developing a European early warning and information system for invasive alien species (EEA, 2010). The report also presented five options for a European Early Warning and Rapid Response (EWRR) framework, including a cost indication and an analysis of the strengths, weaknesses, opportunities and threats of each of these options. Although the mentioned EEA study is generic in nature, covering all invasive species, it provides a strong basis for the approach recommended here for *A. artemisiifolia*.

The basic logical framework for an effective early warning system presented by the EEA (2010) and covered partly in the previous sections of this chapter includes six elements:

1. detection (surveillance and monitoring);
2. diagnosis and data processing;
3. risk assessment (or quick screening);
4. reporting to competent authorities and circulation of information;
5. response action;
6. follow up.

These six steps are the general steps that apply to newly arrived IAS in Europe. They are particularly relevant to enable quick action when a new, non-native and potentially invasive species has been reported in a European country. For the specific case of *A. artemisiifolia*, however, it can be assumed that steps 1-3 are not very relevant when considering Europe as a whole. The species has been detected and is present in large parts of Europe (as extensively documented in chapter 3), it is convincingly diagnosed as an invasive species which poses a risk to public health and agricultural production (see Task 4). Therefore, establishing an 'early' warning system at this scale is no longer required.

Nevertheless, in large parts of Europe *A. artemisiifolia* is not (yet) present or abundant although it may be so in the near future (see Task 6). This is particularly true for southern Europe, large parts of France, Ireland and Poland, where there seems to be potential for further spread. It is also true for those habitats and areas that are potentially suitable for the species but that have not been invaded yet.

For many other IAS, however, a dedicated European EWRR system covering all steps is needed and is yet to be established.

The six elements will be described in more detail in the following pages, focusing on how they may apply to the case of *A. artemisiifolia* in Europe.

9.1 Detection (surveillance and monitoring)

Determining ragweed plants

Although some confusion may exist with similar species (e.g. *Ambrosia psilostachya*), *A. artemisiifolia* can be recognized and detected relatively easily using existing descriptions (e.g. Fig. 1). Also, *A. artemisiifolia* mainly occurs in disturbed environments such as roadsides, river banks, gardens and urban areas, which makes it an easily detectable species. Species factsheets and reference material for easy determination and recognition of the species have been developed in a number of forms and languages for a variety of target groups (see section 2).

Based on the ease of determination and detection of full-grown plants as well as the increased awareness about its allergenic effects, a number of countries have developed targeted surveillance and monitoring programmes or included *A. artemisiifolia* in wider monitoring programmes. Websites and other communication materials have been developed to support the reporting of observations of the species by experts and citizens, although these materials and platforms may not be sufficiently known to the wider public. A growing number of European countries (of which eight are presented in section 2) have operational monitoring systems in place that include *A. artemisiifolia* as a target species.

Given the many existing materials, at the European level there is no need for additional determination keys, facts sheets or other descriptions of *A. artemisiifolia*. However, there may be a need to translate current information into languages that are currently not covered yet. There is also a continuing need to make the information easily accessible and available to many target groups.

Key for determining common ragweed[2]

Stem
Answer "yes" or "no" to the following questions:
Is the cross section of the stem round?
The stem is hairy?
The stem is filled (not hollow)?

Continue to the next set of questions if all the answers are "yes".
If one or more answers are "no", then it is probably not a common ragweed. Have a look at the list of species that may be mistaken for common ragweed.

Leaf
Answer "yes" or "no" to the following questions:
Has the top- and underside of the leaf about the same colour?
Are the leaf nerves whitish?
Is the leaf divided into several lobes, which in turn often are split up almost to the rib?
Has the lobe-tip a fine spike?

Continue to the next set of questions if all the answers are "yes".
If one or more answers are "no", then it is probably not a common ragweed. Have a look at the species that may be mistaken for common ragweed.

Flower
Answer "yes" or "no" to the following questions:
Are there small green bell-shaped flowers in spike-like flower heads at the end of the upper branches?
Are there pale spots or yellow pollen dust at the flowers?
Are there other small flowerlike organs sitting at the axils of some of the upper leaves?

If the answer is "yes" to at least two of the questions and to all the questions about stem and leaf then the plant probably is a common ragweed.
If two or more of the questions are "no" then it is probably not a common ragweed. Have a look at the species that may be mistaken for common ragweed.

Figure 8.1. Example of a key for determining *A. artemisiifolia* (Basset & Crompton, 1975 in Buttenschøn *et al*., 2009)

Determining ragweed fruits

A. artemisiifolia produces a woody reddishbrown indehiscent fruit (achenes, siconia) with one seed per fruit, 3-4 mm long. The fruits are dry, somewhat hairy fruit with characteristic thorns, and relatively heavy (Fig. 2).

Unlike for the full-grown plants of *Ambrosia*, agricultural producers have a key role to play in the detection of *Ambrosia* siconia in stored products such as seeds, grains and fodder. Based on the size of the siconia compared to that of a number of crops (e.g. maize or grain) sets of sieves are mostly used to detect presence of *Ambrosia*. These practices are already widely applied in the agricultural sector to reduce contamination of harvested crops with weed seeds, and it is a key task for farmers organizations and farm advisory bodies to raise awareness among farmers and seed producers of the importance of applying seed detection systems.

Figure 8.2. Achenes of *A. artemisiifolia*. (Photo: Steve Hurst @ USDA-NRCS PLANTS Database)

Detection in bird feed is carried out by national control authorities (e.g. in Denmark, Germany, Slovenia and Switzerland - Frick *et al*., 2011), also using a mix of sieves with different mesh sizes, using the IAG method (IAG, 2009).

Determining ragweed pollen

For the detection of pollen of *Ambrosia*, two aerobiological sampling methods are commonly used: the Cour method (Cour, 1974) and the Hirst method (Hirst, 1952) using a pollen trap. Most European countries have a network of pollen count stations that publish their data online. A European portal to provide easy access to these data is provided by www.polleninfo.org. Pollen distribution of *A. artemisiifolia* is aggregated and published on European maps three times per month (Fig. 3).

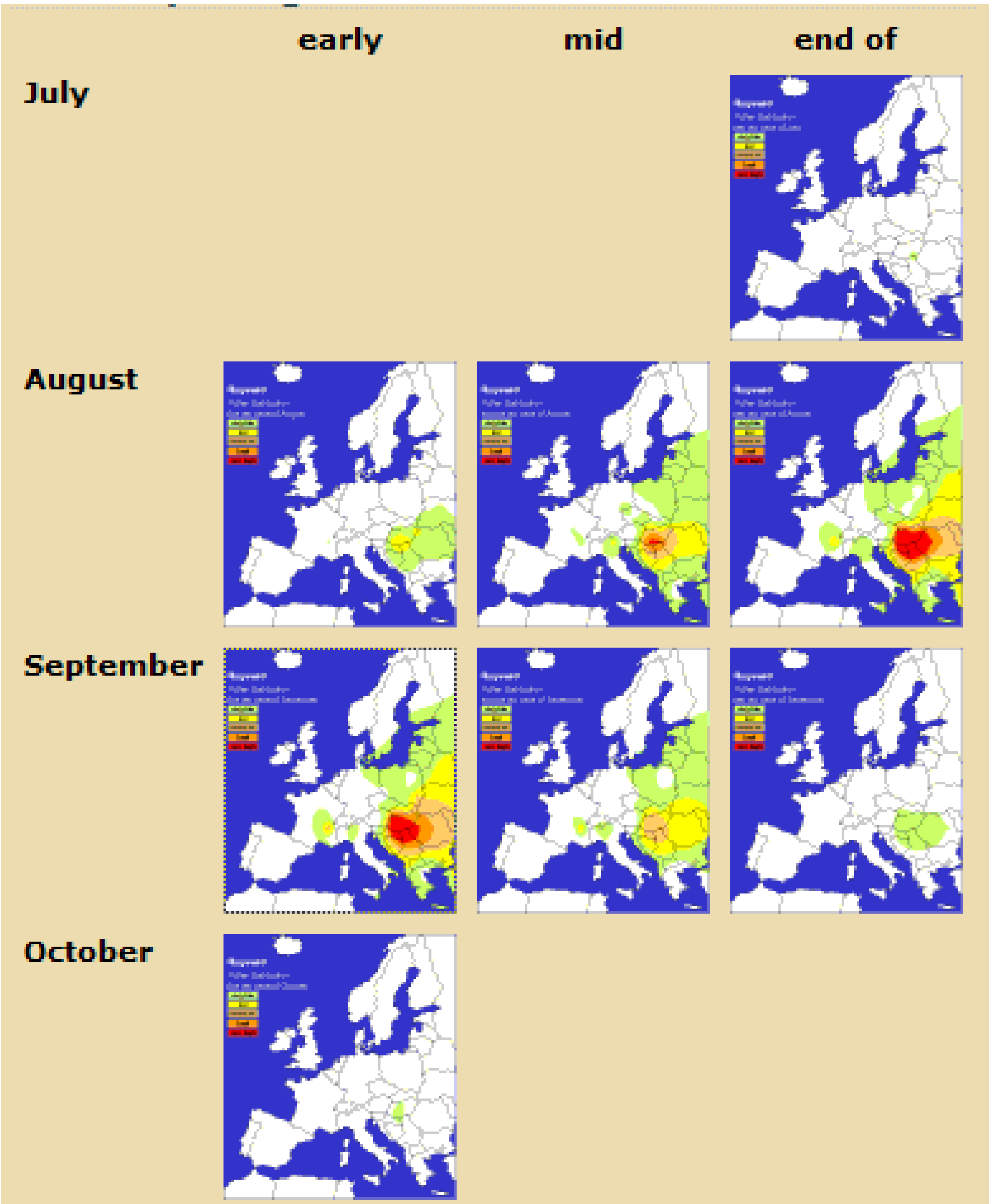

Figure 8.3. Time series of distribution of ragweed pollen concentration in Europe (source: www.polleninfo.org).

Surveillance

Surveillance with regard to IAS is described by the EEA (2010) as an activity aimed at identifying alien species new to a country, and as such is a pivotal element of prevention (see Task 7,9). As a consequence, surveillance is preferably done at entry points (such as border controls). *A. artemisiifolia* has been recorded in at least 23 EU member states (Task 3; DAISIE, 2008; EPPO, 2011; GISD, 2009; V. Vladimirov, pers. comm.). Therefore, surveillance as defined here (new arrival) is possibly only of relevance to four EU member states: Cyprus, Estonia, Greece, and Malta.

Monitoring

Some existing monitoring approaches are described in section 5.

9.2 Diagnosis, data processing and risk assessment

A. artemisiifolia has been recognized by all European countries as an invasive species that is non-native to Europe and it is listed among Europe's 100 worst invasives, mainly because it is one of the most allergenic species (DAISIE project; Burbach *et al*., 2009). Therefore, there is no need for further diagnosis and risk assessment of this particular species in Europe. Its mere presence (either as fruit or as plant) is sufficient reason for taking rapid action in order to control the species. Detection of pollen is less of a reason for taking immediate action in terms of eradication, since pollen are easily wind-dispersed and can cause allergic reactions 200 km away from a plant (Buttenschøn *et al*., 2009) and can even be transported over a 1000 km away from the source under unusual conditions of atmospheric circulation (Belmonte *et al*., 2000). On the other hand, although detection of pollen is not necessarily a reason for taking local eradication measures, it underlines the need for a coordinated early warning and rapid response system at European level. A sudden marked increase in allergic reactions due to ragweed pollen in a given area may trigger a more detailed geographic analysis as to where potentially new infestations of ragweed have occurred. This requires the use of European information systems and concerted action between countries.

9.3 Reporting

Compiling data on the distribution of *A. artemisiifolia* in Europe requires action at the European level. Current practice is that systematic monitoring programmes that focus on or include *A. artemisiifolia* are implemented at the national or subnational levels. This is for good reasons and should not be changed. There is a need, however, to centrally compile these (sub)national data and present them on a European scale, in aggregated form where appropriate. At the same time, there is an urgent need to encourage those countries and regions in Europe that have no data collection and processing programme in place yet to set up such system soon. When doing so, the experience and lessons learned by those countries with active programmes should be made available and European action should be coordinated by a central European body, as also advocated by the EEA (2010) and NOBANIS (2010).

Reporting is, like risk assessment, of high importance for new arrivals of (potentially) invasive species. Since *A. artemisiifolia* already is widespread across large parts of Europe reporting may seem to be of less relevance. However, reporting with regard to *A. artemisiifolia* (and any other invasive species) remains of high importance in connection to its distribution throughout Europe, the measures taken to control the species, and the success of such measures. Therefore, it is essential that national-level information is compiled and summarized at the European level. This will allow the monitoring of the actual spread and distribution patterns of the species as well as the changes in this distribution. Regularly updated reports will also provide a tool to monitor success of measures taken to control the species. European countries already report sightings of *A. artemisiifolia* to the EPPO. Tools for citizens and other stakeholders to report sightings online are described in section 5.

Specific mention needs to be made here of the possible role of the Biodiversity Information System for Europe[13]. The Biodiversity Information System for Europe (BISE) is a single entry point for data and information on biodiversity in the EU. Bringing together facts and figures on biodiversity and ecosystem services, it links to related policies, environmental data centres, assessments and research findings from various sources. It is being developed to strengthen the knowledge base and support decision-making on biodiversity. As an information system and portal it provides leads to information sources and databases, rather than providing data in its own right. No specific information on *A. artemisiifolia* is included, nor does it currently provide a platform for reporting on ragweed. Despite the fact that there is limited evidence for *A. artemisiifolia* impacts on biodiversity (Task 4), BISE may in future be one of the platforms for reporting sightings of ragweed and other IAS.

It is not advisable to develop a new reporting framework for a single species. A range of reporting frameworks is already in place, either for nature conservation purposes or for agriculture or health. The reporting service of the European and Mediterranean Plant Protection Organization (EPPO) is recognized as a well-functioning system that already includes general information on *A. artemisiifolia* (data sheet and pest risk assessment). Regularly updated distribution data of relatively high geographical resolution are however not reported through this system.

9.4 Response action and follow-up

At the European level, a number of gaps need to be filled with regard to monitoring *A. artemisiifolia* and reporting about its distribution and trends. The key need is in raising awareness with the general public and other target groups in order to stimulating action for *A. artemisiifolia* in those countries

[13] http://biodiversity.europa.eu

that have yet to start, while using the expertise and experience that has been built up in other countries. This may be particularly the case in those countries where ragweed is currently uncommon, but where ragweed may increase under climate change (see Task 6).

In addition to reporting of the occurrence of the species, its fruits or its pollen, other response action should be taken at European level. Such action includes raising awareness, taking legal measures/penalizing, capacity building, monitoring, funding, exchange of experience/knowledge/information (see section 7).

9.5 Institutional structures

The previous sections have demonstrated that many stakeholders are involved with, and many actions are part of, any early warning and rapid response (EWRR) system. In the case of Invasive Alien Species (IAS) key instances and institutions involved operate in the sectoral fields of public health, forestry and agriculture, fisheries and aquaculture, trade, environment, and infrastructure. The types of institutions and organizations involved in the six steps in early warning include actors such as civil society organizations, research institutes, government agencies, public authorities, border control, inspection services, healthcare, and insurance companies.

For most of the sectoral fields listed above and the range of institution types, structures and networks have already been set up at the European level. Also, discussions on developing a European structure for EWRR for IAS have been held by a number of networks for some years now. Some of the key initiatives and publications in this respect include:

- the EEA publication 'Towards an early warning and information system for invasive alien species (IAS) threatening biodiversity in Europe' (EEA, 2010), which describes the key elements of an early warning system and proposes five options for a future institutional setup;
- the recommendations from the NOBANIS workshop 'Developing and early warning system for invasive alien species (IAS) based on the NOBANIS database' held in June 2010 (NOBANIS, 2010);
- the IEEP report 'Assessment to support continued development of the EU Strategy to combat invasive alien species' (Shine *et al*., 2010);
- the 'Scoping document on Early Warning and Rapid Response' as developed by the EC DG Environment Working Group on Invasive Alien Species/Early Warning and Rapid Response (EC, 2011), which presents a series of options for an EWRR for IAS.

The above initiatives and publications have formulated a number of common recommendations to be taken into account when considering the setting up of a European system for EWRR for IAS. These recommendations are summarized below:

- as far as possible, build on existing systems so as to avoid duplication and unnecessary burden to member states (MS) and relevant actors (e.g. plant health, agriculture, public health, environment);
- MS have a central role in any EU Early Warning and Rapid Response system because of their role to notify or alert about new occurrences of IAS and because in many cases they have set up national systems already;
- there is a need for a central coordinating body at EU level (various names and formats are proposed, such as: standing committee, data centre, central authority, information system, dedicated technical scientific body, technical structure, centralized technical body, scientific panel, observatory, centralised agency, network of experts and/or scientific institutions);
- a hierarchical approach needs to be adopted, with clearly defined roles for the identified competent authorities at the appropriate scale (EU, MS, local and regional actors) and an associated hierarchical system of focal points;
- awareness raising, capacity building and communication are seen as essential tools in any EWRR system;
- citizens and volunteers have a very important role in making an EWRR system for IAS successful. Incentives are needed to encourage and motivate their continued input;
- the added value of establishing a central EU body for IAS is particularly in its role on reporting and circulation of information. However, for each of the steps that form part of the early warning and rapid response process added value of a European approach can be identified;
- European and (sub)national policies and legal frameworks should be revised to remove current barriers for an effective European EWRR approach.

Currently, the main bottlenecks (at national and EU level) that are reported to prevent a proper response include (EEA, 2010; Hulme *et al*., 2009);

- lack of resources;
- inadequate legal framework;
- lack of policy coherence between sectors and administrations;
- prominence of the Common Agricultural Policy;
- lack of authorities with clear competences for biological invasions;
- several departments and agencies responsible for some aspect of IAS prevention and management;
- decentralization of responsibility for environmental policy and nature conservation to subnational authorities;
- complex separation of roles and responsibilities;
- lack of coordinated mechanisms;

- lack of awareness of IAS;
- absence of intra-Community barriers;
- gaps within and between MS in capacity, research and data;
- low prominence to global IAS issues.

In its 2010 report, the EEA formulated 5 future options for a European EWRR framework and dedicated information system. The options range from least to most formal and binding and are described in some detail in the EEA report. Table 8.4 summarizes for each option the tentative estimated costs, the strengths, weaknesses, opportunities and threats. The options presented are:

A. Voluntary network of national authorities
B. Non-institutional European panel
C. European observatory
D. EU agency based on new or revised legislation
E. EU central authority.

Based on the EEA assessment as summarized in table 8.4, we recommend an approach that is based on the proposal by Hulme *et al*. (2009) that combines options C and D: a European coordination centre for invasive species management embedded within an existing European agency. Such proposal would not go as far as Hulme's proposal in that it does not establish a new European agency, which is politically currently not realistic. Instead, we propose a coordination centre that would be independent in its operations and that at the same time formally is part of an Agency. The independence of operation is essential because early warning and rapid response require a body that is permanently staffed, that has direct access to information systems, experts and national authorities and that can issue communications and alerts at any time.

Table 8.4. Options for a European EWWR framework and information system (from EEA, 2010).

Option	**Indicative costs €Myr^{-1}**	**Strengths**	**Weaknesses**	**Opportunities**	**Threats**
A: Voluntary network of national authorities	10	No external decision process required; simple organizational design	Difficulty to mobilize all required skills and expertise	No new body or authority to be set up; least onerous option	Not in line with EC Communications; lack of sound implementation of EWWR system; risk of inconsistencies between MS; limited advance from current unsatisfactory level of action; does not allow Community issues to be addressed; lack of action by one MS may jeopardize others; limited use of existing tools; lack of mandatory commitment
B: non-institutional European panel	0.5-0.7	Few institutional constraints; technical and scientific focus; no European decision process needed; successful examples; existing financing options	Lack of legal basis and political mandate; dependent on voluntary commitment and uncertain resources; lack of financial mechanism	Valuable technical and scientific support to MS and European institutions; build upon existing tools	Limited power to coordinate actions; no regulatory role; no ability to address complex legal issues; no guarantee of enforcement; limited use of existing tools
C: European observatory	1.5-2	Simple internal organization; enhanced technical capacity through specialized permanent staff; continued financial support for medium term	Requires careful design; lack of formal recognition may limit greater commitment for horizontal activities; non-permanent financial support and no strong policy commitment	No complex decision process; formal recognition may facilitate medium-term funding; greater technical support to MS and European institutions; facilitates national/local enforcement	Strong political commitment required; no guarantee for long-term operation; limited enforcement power
D: European Agency on Invasive Species	3-6	Recruiting specialists ensures synergies and technical capacity; perm. financial support	Current policy is not to establish new agencies; significant work and resources required	Best use and interaction of existing tools; effective improvements in enforcement	Roles and competencies need clear distribution with other institutions; dependent on legislative approaches

Option	Indicative costs €Myr^{-1}	Strengths	Weaknesses	Opportunities	Threats
E: EU central authority	10,000 largely by reallocation, optimization	Best use of existing resources and optimized synergies	Deep revision of entire EU legal framework	Most cost-effective response to impacts from invasive species in Europe	Complexity may discourage authorities to engage

Key elements in this respect include the following:

1. Establish a coordination centre on IAS for the EU. Such a coordination centre should receive a formal mandate to act as the single pan-European coordinating body on any matters relating to IAS management in Europe. The coordination centre should be embedded into an existing European agency that already has a mandate regarding environmental information. Giving the cross-cutting nature of the topic of IAS, we advise the consideration of establishing a European Topic Centre on Invasive Alien Species as part of the ETC structure of the EEA. It should be noted that invasive alien plants fall under the IPPC and CBD frameworks, and there is a Memorandum of collaboration of these two institutions to deal with IAP. There are currently discussions on whether plants should fall under the DG SANCO or the DG Environment responsibility. The outcome of that discussion may define whether IAP should be covered by the same body as all IAS or not.
2. Establish formal and direct connections to existing European bodies and networks with a current role regarding IAS in order to build on existing knowledge and capacity and to make best use of available resources. Such connections can be through participation in a possible ETC consortium or as part of an advisory board of such ETC. Bodies to establish formal connections with include:
   a. EPPO: for IAS matters in connection to phytosanitary issues, including environmental impacts of IAS;
   b. EFSA: for IAS matters in connection to food safety issues;
   c. NOBANIS: for ensuring cooperation between MS through the existing network of representatives of public authorities that form part of NOBANIS. The current NOBANIS network needs to be expanded to cover all MS.
   d. DAISIE: for scientific underpinning and full data coverage at EU27 scale.
3. Build on existing national infrastructures (as part of the above-mentioned networks) and fill gaps where needed. If an ETC/IAS would be opted for, than the EEA network of National Reference Centres and National Focal Points within Eionet would ensure coverage in 32 European countries and a further 7 cooperating countries.
4. Establish commonly agreed roles and responsibilities for the ETC/IAS and the networks that it cooperates with and fix these as part of a Memorandum of Cooperation.

A proposed list of roles and responsibilities of a pan-European coordination centre on IAS would include (based on EEA, 2010 and NOBANIS, 2010):

- coordinate establishment of national surveillance and monitoring systems (inventory and promoting of monitoring programmes);
- checking of provided information before circulation;
- rapid screening of new records (facilitated by existing identification tools; inventory of IAS;

register of experts);

- support activities at (sub)national level and by other European networks (integration of databases; research; guides and manuals);
- support and/or perform quick screening or risk assessment for the European level;
- establish web-based information exchange mechanism, incl. alarm list, black list etc. (Using existing information systems EPPO PQR Database, DAISIE and NOBANIS and integrated or connected into BISE) (the recently launched European Alien Species Information Network (EASIN[1]) is set up to serve this purpose);
- provide capacity building and training to countries and sectors (e.g. on best practices for eradication or effective stakeholder involvement);
- facilitate awareness raising (e.g. by ensuring availability of information in any European language);
- inform and cooperate with relevant sectors (e.g. for awareness raising of border control authorities or Codes of Conduct for seed and bird feed producers);
- harmonize national policy and legal approaches;
- direct liaison with national authorities;
- collect and disseminate best practice and methodologies and ensure a standardised approach for early warning and rapid response (a common understanding of methodology, criteria and terminology etc.);
- support efforts with education and awareness material;
- identify and provide funding opportunities, including capacity building and contingency funding;
- identify ways to include other relevant non-EU countries in the European Early Warning and Rapid Response system (e.g. through EPPO and its geographic reach of 50 countries).

Fundamental to the success of the proposed structure is the establishment in all EU MS of 'an officially recognised technical body, with a clear mandate and terms of reference, composed of a team of 'leading experts'. This should take the form of an agency or equivalent network or mechanism, with the task of leading and coordinating all responsible agencies and subnational governments dealing with IAS. The team of leading experts should have the necessary expertise in all fields of alien species management and all related legal and policy issues, and if appropriate include

[1] http://easin.jrc.ec.europa.eu/

representatives of local departments and agencies.' (EEA, 2010) The list in Annex 3 provides an overview of such national authorities and their current role.

A possible flow of steps to be taken in managing *A. artemisiifolia* at European level was developed by the EC DG Environment working group on IAS-EWRR (EC, 2011). This model fits nicely to the roles and responsibilities listed above. Figure 8.4 complements the process flow model by connecting it to information systems and relevant stakeholders.

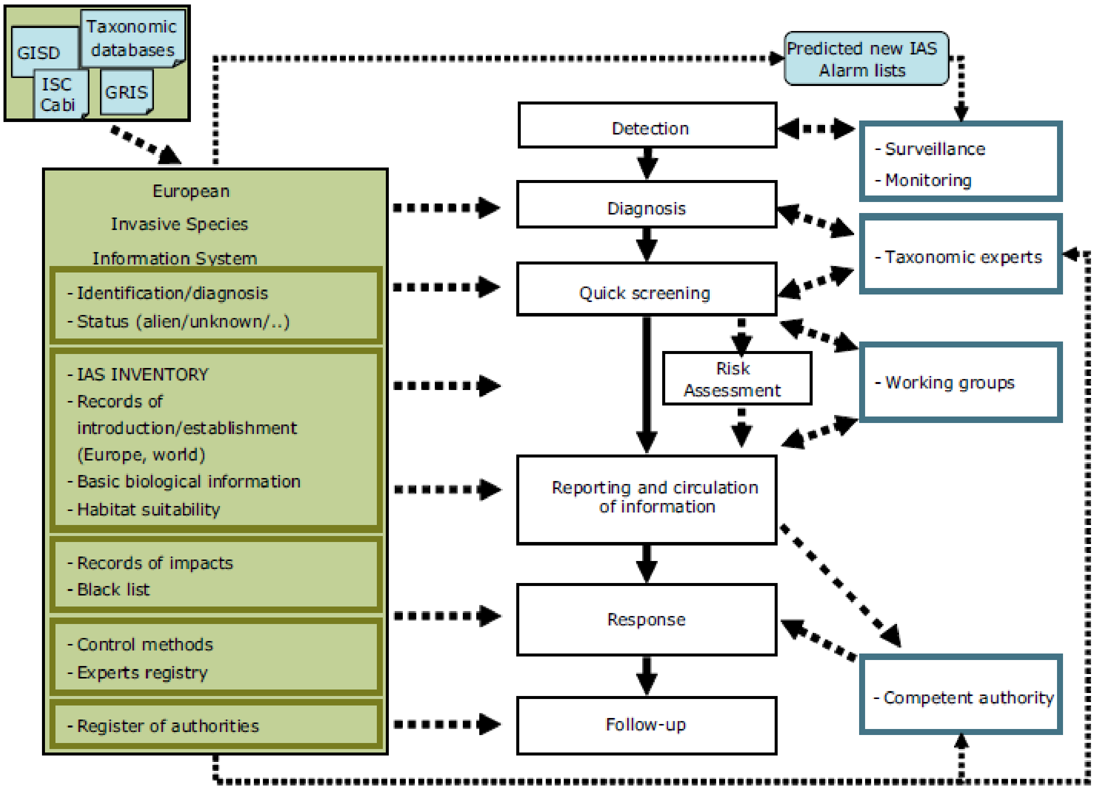

Figure 8.4. Structure of a pan-European early warning and rapid response framework (from EEA, 2010)

A proposed institutional setup for a European EWRR for IAS and associated roles for various stakeholders is presented in Figure 8.5.

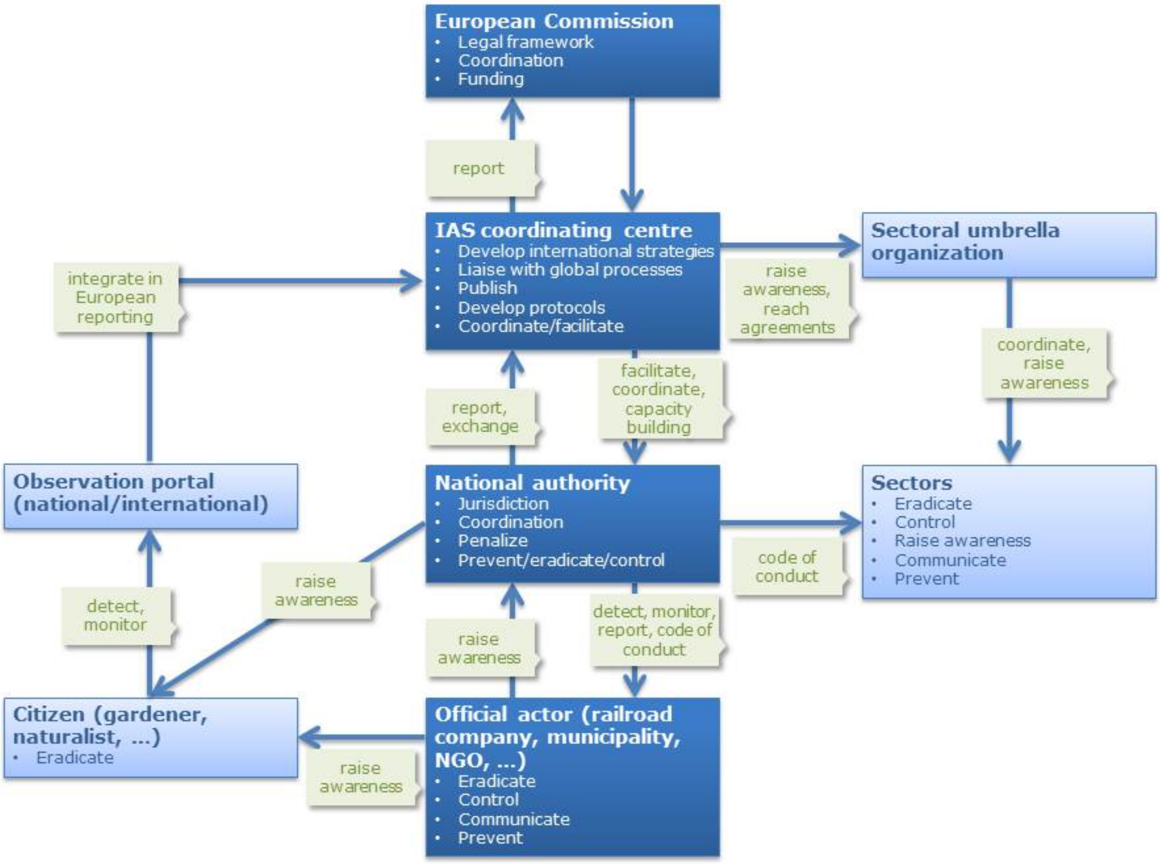

Figure 8.5.Proposed institutional setup and roles for a European EWRR system for IAS.

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Task 10: Workshop report

1 Introduction

The final task for the project was to organise a one day workshop to present and discuss the contents of the draft final report and disseminate the project outputs.

The workshop was held at the European Commission DG Environment in Brussels on 24th July 2012. The following report is a synthesis of the workshop and the discussions held throughout the event. The project report (Tasks 1-9) was updated to reflect the feedback from the workshop.

2 Participants

The consortium was represented by individuals from each of the key organisations (Table 10.1).

Table 10.1. Consortium partner attendees at the workshop

Name	Organisation
James Bullock	Centre for Ecology and Hydrology
Belinda Wheeler	NatureBureau
Thomas Haynes	NatureBureau
Stephen Beal	NatureBureau
Ian Dickie	Eftec
Zara Phang	Eftec
Dan Chapman	Centre for Ecology and Hydrology
Kristijan Čivić	ECNC

To ensure that the project outcomes were disseminated effectively, participants were invited to attend from a range of organisations with interests including:

- Invasive alien species policy development
- Invasive alien species data coordination
- *A. artemisiifolia* research
- National or international control of invasive alien species
- Health and allergies

All participants were approved by the European Commission prior to being invited. Table 10.2 lists the participants who attended on the day. Table 10.3 lists European Commission representatives who attended on the day.

Table 10.2. Invited attendees

Name	Organisation
Melanie Josefsson	European Environment Agency (EEA)
Franz Essl	Austrian Environment Agency
Hana Skálová	Institute of Botany of the Czech Academy of Sciences
Uwe Starfinger	Julius Kuehn Institute
Riccardo Scalera	Invasive Species Specialist Group (ISSG)
Bernadett Csonka	Institute of Geodesy, Cartography and Remote Sensing (Hungary)
Ulrike Sölter	Julius Kuehn Institute
György Surek	Institute of Geodesy, Cartography and Remote Sensing (Hungary)
Gerhard Karrer	Co-ordinator of Austrian Ragweed project and partner in HALT AMBROSIA
Gero Vogl	Physics Department, University of Vienna
Sara Tramontini	European Food Safety Authority (EFSA) Plant Health unit
Roberta Savli	European Federation of Allergy and Airways Diseases Patients' Associations

Table 10.3. Attendees from the European Commission

Valentina Bastino	European Commission
Myriam Dumortier	European Commission

3 Task presentations

The outcomes of each task were presented at the beginning of the workshop. The order of the presentations is given in Table 10.4.

Table 10.4. Task presentations

Tasks	**Title/Description**	Presenter(s)
Tasks 1/2	Condition, vectors and spreading mechanisms of *Ambrosia artemisiifolia*	Belinda Wheeler (NatureBureau)
Task 3	Mapping *Ambrosia artemisiifolia* across the EU27	Thomas Haynes & Stephen Beal (NatureBureau)
Task 4	Social, environmental and economic impacts of Ambrosia artemisiifolia and probable future impacts	James Bullock (CEH)
Task 5	Quantitative and costs analysis of the social, environmental and economic impacts of *A. artemisiifolia*	Ian Dickie (Eftec)
Task 6	Modelling the spread and harmful effects of *Ambrosia artemisiifolia*	Dan Chapman (CEH)
Tasks 7/9	Methods of controlling and managing *A.artemisiifolia*	Kristijan Čivić (ECNC)
Task 8	Establishing an *Ambrosia artemisiifolia* early warning system across the EU	Kristijan Čivić (ECNC)

4 Discussion

Once presentations were completed James Bullock led a discussion on the synthesis of the project. Here the details of the topics discussed are presented.

Referring to Task 9, Melanie Josefsson stated that the European Alien Species Information Network (EASIN) project has been online for only one month and currently consists of 43 invasive species databases, mostly for marine species. It is unlikely that this will be extended to terrestrial species. Further investigation however showed that EASIN is already including terrestrial, aquatic and marine species.

Melanie Josefsson also discussed the European Environment Agency (EEA) funded ‘Eye on Earth’ project which will use citizen science to report on noise, water and air pollution. A number of test species were currently being trialled for the project (including *A. artemisiifolia*), which will assess the potential of using the system for reporting on invasive alien species.

Ulrike Sölter asked how the casual and established populations were represented in the mapping exercise and also mentioned that the Netherlands populations are based on casual records. Tom Haynes explained that very few data sets hold this type of data and also explained that the definition of such information is often project specific, making a holistic assessment difficult. The gathering of such evidence would also prolong the process of obtaining individual records from data recorders; records would have to be checked over several years to assess if populations were casual or persistent. Indeed, given the annual nature of ragweed, many populations will be technically transient even within the core invaded area. Dan Chapman commented that with the *A. artemisiifolia* spread model it is possible to ‘turn off’ seed imports, which removes suspected casual populations.

Melanie Josefsson mentioned that *A. artemisiifolia* distribution maps relating to the project had been released by the Swedish media, which had caused concern amongst the general public. As no maps were officially published at this stage in the project, Tom Haynes requested further information regarding the maps and specifically whether they were related to ENV.B2/ETU/2010/0037. No further information has been received.

Ian Dickie requested clarifications on the assumptions relating to seed imports being made for the economic modelling work (Task 5). The key areas that required further information were: -

- What countries are the seeds assumed to be imported from? Some countries are more likely to be exporting seeds contaminated with *A. artemisiifolia* seeds.

- What are the seeds being imported for? Different industries importing seeds have different control measures depending on the intended use of the seed.

Bernadett Csonka talked about the Hungarian monitoring and early warning system. The Hungarian Government is using sophisticated remote sensing technology to help detect *A. artemisiifolia* infestation in crops. A strong political will has led to the creation of laws which oblige farmers to remove *A. artemisiifolia* populations from their land or face financial penalties. The control programme has been further supported by Hungarian tax laws which allow citizens to choose where 1% of their taxes are spent. This information has been incorporated into the Task 7/9 and Task 8 reports.

Hana Skálová proposed another vector assisting the spread of *A. artemisiifolia* which was not considered in the report. The presence of ragweed as a woodland understory species is likely to be due to the use of seed to feed woodland game species (specifically deer). Woodland clearance could therefore present an opportunity for expansion of the species in these habitats.

Riccardo Scalera highlighted that ragweed could also invade crop fields after the harvesting season.

The productivity of staff affected by ragweed related allergies was discussed and identified as a problem. However, separating those affected by allergies caused by ragweed and by other species was indicated to be very difficult to quantify. Roberta Savli stated that the European Federation of Allergy and Airways Diseases Patients' Associations do have data but it is only for allergy sufferers and not specifically related to allergenic species.

5 Focus group discussions

For the final section of the workshop the participants split into two focus groups to discuss specific issues/questions relating to the project tasks.

The two topics discussed by the focus groups were: -

- Economic impacts
- What would a future control strategy for Europe look like?

Below is an outline of the discussions held by each focus group.

5.1 Focus Group 1 – Economic Impacts

In this focus group the Hungarian approach to assessment and control was discussed. The Hungarian 'invasion probability mapping' project was discussed and how it utilises Light Detection and Ranging (LiDAR) technology and high resolution aerial photography.

By utilising this method it is possible to narrow the scope of field work (by assessors), thus reducing field survey costs. It was also discussed by the group that such an approach is only really viable in areas where there is a significant infestation of *A. artemisiifolia* as the remote-sensing cannot distinguish ragweed from visually similar plants (such as mugwort *Artemisia vulgaris*). Such an approach would not be feasible in a country with local infestations or frequent sporadic records.

The group identified that it is important to consider the density of the species, as this will affect the approach (and consequently, the costs) required for assessment.

It was discussed that the 'Sentinel Satellite System' will be up and running during 2013, providing freely available satellite data for the entire EU. This could make the techniques used by the Hungarian Government financially viable for countries with similar levels of infestation.

The Shine report was discussed, which looked at the economic costs and impacts on a sample of invasive alien species: Shine, C., Kettunen, M., ten Brink, P., Genovesi, P. & Gollasch, S. 2009. Technical support to EU strategy on invasive alien species (IAS) – Recommendations on policy options to control the negative impacts of IAS on biodiversity in Europe and the EU. Final report for the European Commission. Institute for European Environmental Policy (IEEP), Brussels, Belgium. 35 pp. Concerns were raised about the difference in costs between the Shine project and the current Ragweed project and the implications that this could have for invasive alien species policy. These differences are discussed in the updated Task 5 report, but it should be noted that the Shine report uses partial cost data, while Task 5 has attempted a comprehensive modelling of ragweed economic impacts in the EU

The high cost assigned to Italy was also discussed and Riccardo Scalera explained that the species is highly local in distribution and therefore the cost would only apply on a local scale. The updated version of Task 5 allows for such local impacts in Italy and other relevant territories.

Ian Dickie and Dan Chapman discussed the assumption that the ragweed impact was linearly related to the product of ragweed occupancy probability, climatic quality and invadable land cover. Workshop participants felt this overestimated economic impacts in little-impacted areas. It was decided that the model should be adjusted to concentrate the impacts of ragweed only to the areas where the climate is the most suitable.

5.2 Focus Group 2 – What would a future control strategy for Europe look like?

The focus group began with Uwe Starfinger explaining the work being carried out by the EU-funded HALT Ambrosia project. The project is researching methods to reduce the prevalence of *A. artemisiifolia* and its pollen in European countries, which focus on biology, ecology and seed dormancy. Control measures are also being investigated via desk based research.

The most effective control measures were then discussed with Uwe Starfinger explaining that effective elimination of the species could be achieved during a given season and place, but the timing of the methods (e.g. herbicide application, mechanical mowing, etc.) must be correct. He also discussed the potential use of biological controls. Awareness raising and education of farmers about *A. artemisiifolia* ecology; impacts; and control measures were also highlighted by Bernadett Csonka as an effective control measure. It was agreed that implementing such measures requires legal backing with strong government and public support.

Further details were given by Bernadett Csonka on the measures used in Hungary where two approaches are implemented to control the species:

1. Eradication of the species
2. Government support to cut and remove plants in regions by supplying tools and equipment to local communities.

Both projects have had positive effects both socially and environmentally.

James Bullock asked if the Hungarian system could by applied across Europe, particularly in countries where ragweed is less of a problem. It was discussed that in some countries the measures might conflict with other existing schemes. For example, in the UK, where field stubble is maintained during the winter to provide feed for birds (as part of agri-environment schemes). Under the Hungarian system, winter stubble would be removed.

Issues relating to the implementation of control measures were discussed with Melanie Josefsson explaining that in Sweden, public interest is often lost quickly after the initial awareness raising process. The public need to know that the work being done is having a positive impact but it is difficult for people to fully engage with something for which they cannot see the results.

Hana Skálová explained that any control strategy needs to have EU co-ordination because some countries which have a relatively low infestation (e.g. Czech Republic) are affected by pollen arriving from nearby countries.

James Bullock discussed how the climate models predict the future spread of ragweed into new regions and therefore regions already infested with ragweed need to work on eradication; and regions with the potential to be invaded need to focus on prevention. This would have an effect on EU policy and James posed the question: how would the EU impose a control strategy?

Valentina Bastino explained that the EU would not be setting a Europe-wide control strategy specifically for ragweed, also considering the different circumstances of Member States (e.g. invasion stage, pathway, ecological conditions). Rather, the European Commission is seeking to design a regulatory framework able to cater for different species and for the different circumstances of Member States.

Gerhard Karrer discussed that in north-west Europe (where the species is predicted to spread in the future) steps should be taken to empower citizens to take responsibility for preventing the arrival and spread of the species. Gerhard Karrer also suggested that in south-east Europe (where infestation levels are greatest) laws are required with strong political backing to effectively tackle the problem. There may be scope to implement a system whereby Member States have to report to the EU on their progress which would give more structure and strength to the control system.

Uwe Starfinger highlighted the new EU regulation, effective from 01/01/2012, that prohibits the use of products intended for animal feed (e.g. seed) which contain levels of *A.artemisiifolia* seeds above 50 mg/kg: Commission Regulation (EU) No 574/2011. It was widely agreed upon that this was a positive step being taken and was a good example of the type of policy that can be implemented from European level.

Gerhard Karrer stated that any control measures must be sustainable. For example mowing will not prevent regrowth, but ploughing will.

6 Future applications

To close the workshop a short group discussion was held to discuss potential future applications of the work.

Valentina Bastino explained that the EU is currently developing legislation on invasive alien species. The risk posed by invasive alien species will be assessed on the basis of scientific evidence of the effects on biodiversity and socio-economic impacts. The legislative proposal is expected to be published by the end of 2012 with prevention being the priority level and reporting and management making up the supporting levels.

Tom Haynes proposed that with funding, the distribution map could be kept ‘live’, allowing it to be regularly updated as and when new distribution data becomes available. This would prevent the map becoming static and outdated and it could play a vital role in EWS and management strategies.

7 Participant Feedback

At the close of the workshop all participants were presented with a form giving them the opportunity to provide feedback on the workshop. A copy of the feedback form is presented in Annex 8.

The feedback form consisted of two sections. Part 1 was a list of statements which the participants were asked to rate on a scale of 1 – 5 (with 1 being the lowest and 5 being the highest). Part 2 was a list of questions to which the participants were able to give written responses.

In total 11 completed feedback forms were returned, the results of which are discussed below.

7.1 Results from Part 1

On a scale of 1-5 (with 1 being the lowest and 5 the highest) the participants were asked to answer a series of questions. Figs 10.1-10.7 show the responses.

Fig 10.1. Responses to question regarding organisation of workshop (including pre-workshop communication). Numbers indicate the answer given (1-5) and sections the proportion of responses

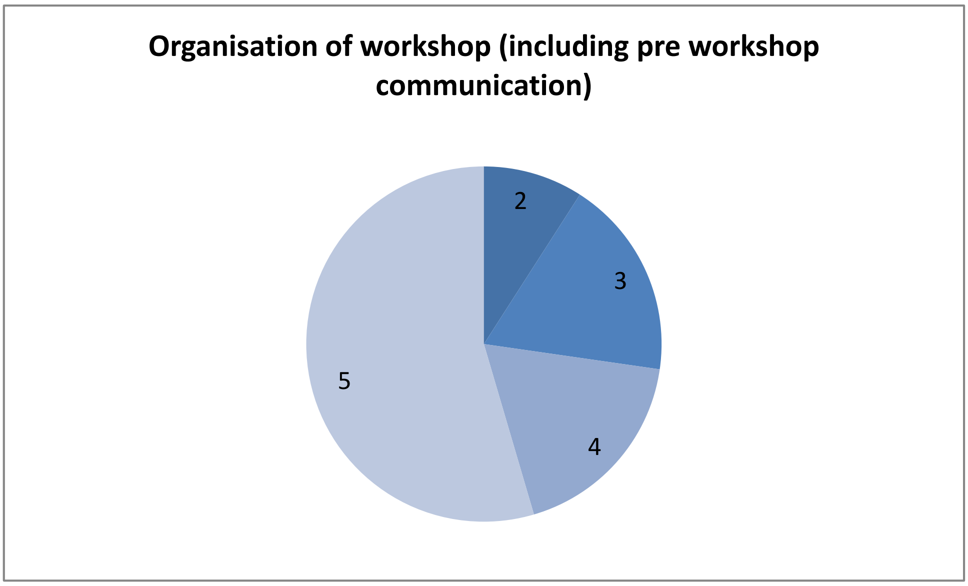


Fig 10.2. Responses to question regarding facilities (buildings, location, etc). Numbers indicate the answer given (1-5) and sections the proportion of responses

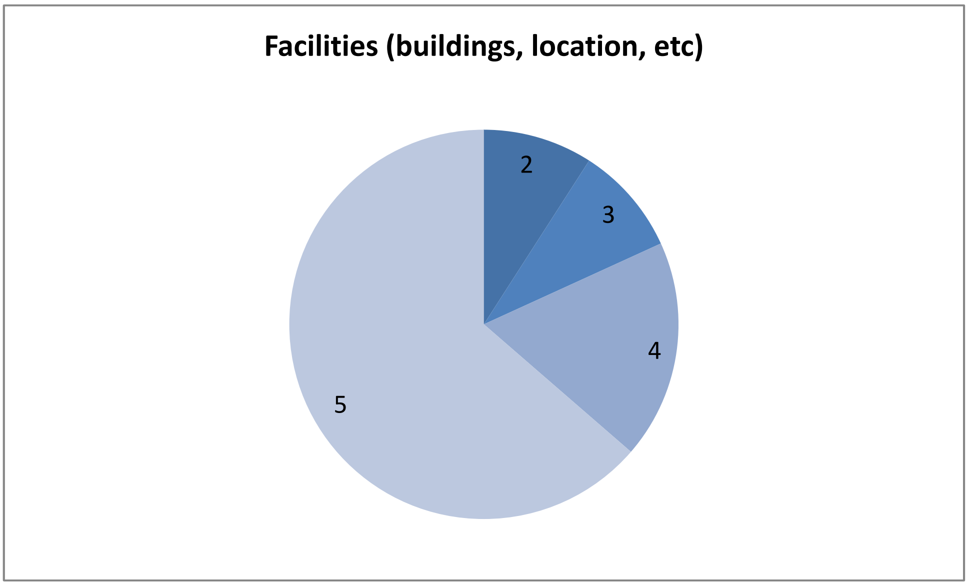


Fig. 10.3. Responses to question regarding the overall content of presentations. Numbers indicate the answer given (1-5) and sections the proportion of responses

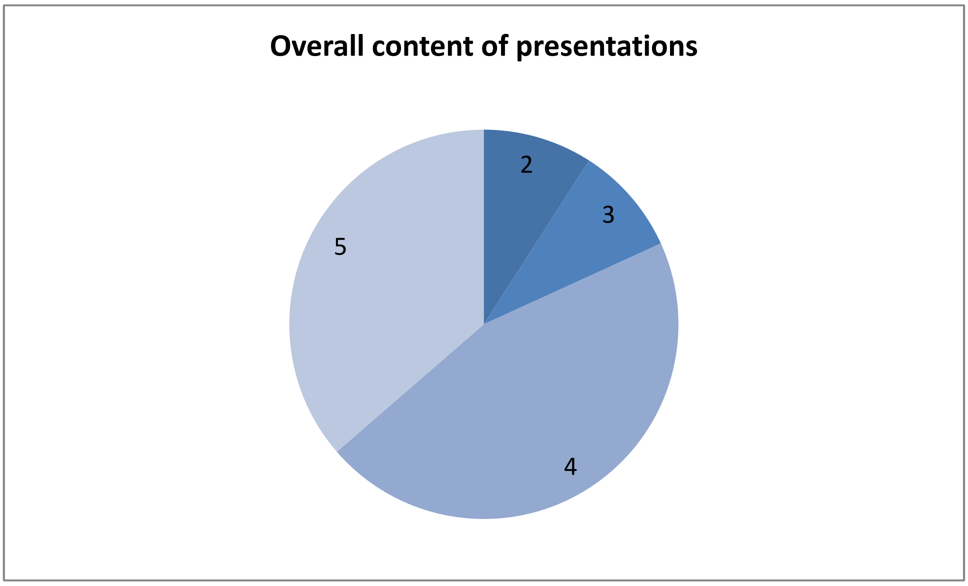


Fig. 10.4. Responses to question regarding the relevance of the workshop to participants' interests. Numbers indicate the answer given (1-5) and sections the proportion of responses

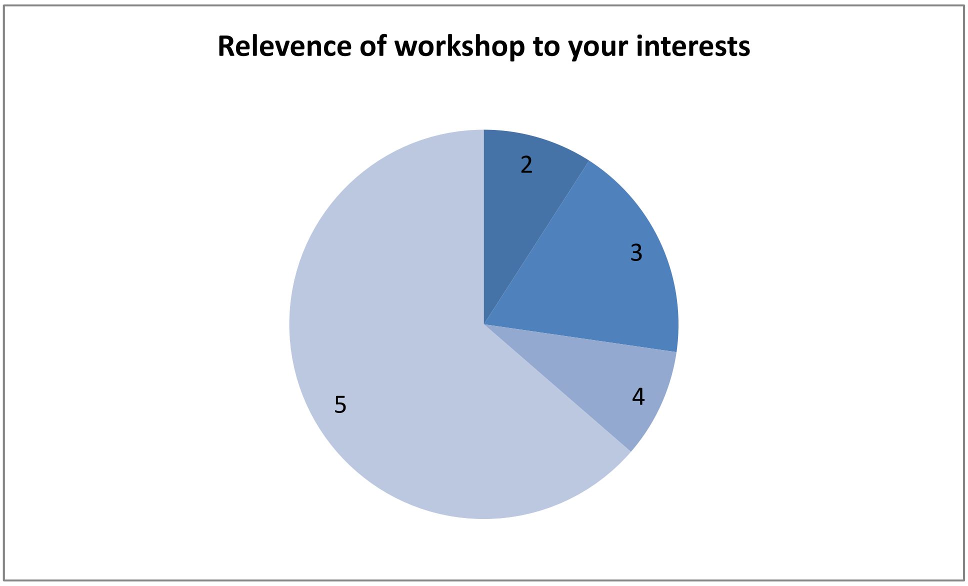


Fig. 10.5. Responses to question regarding the usefulness of focus group discussions. Numbers indicate the answer given (1-5) and sections the proportion of responses

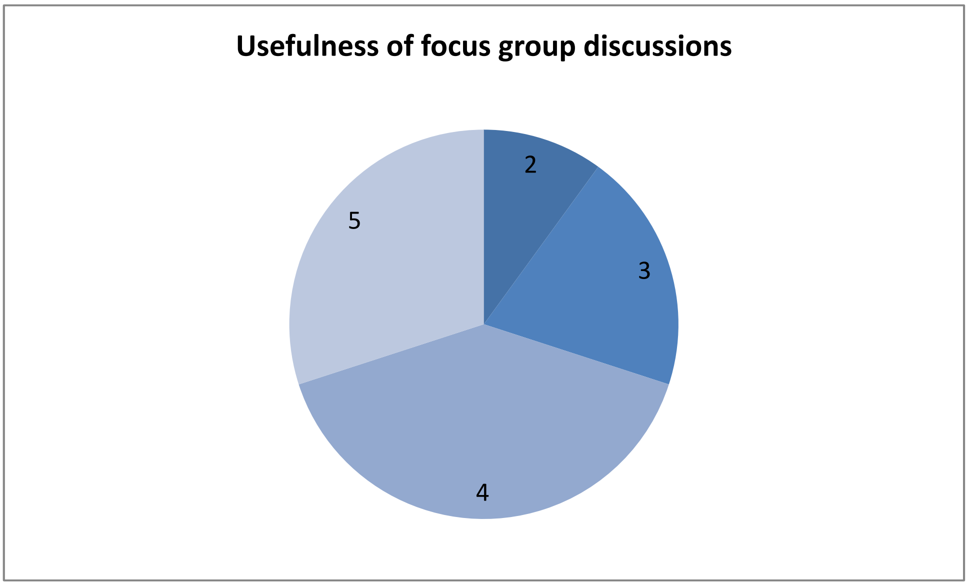


Fig. 10.6 Responses to question regarding networking opportunities. Numbers indicate the answer given (1-5) and sections the proportion of responses.

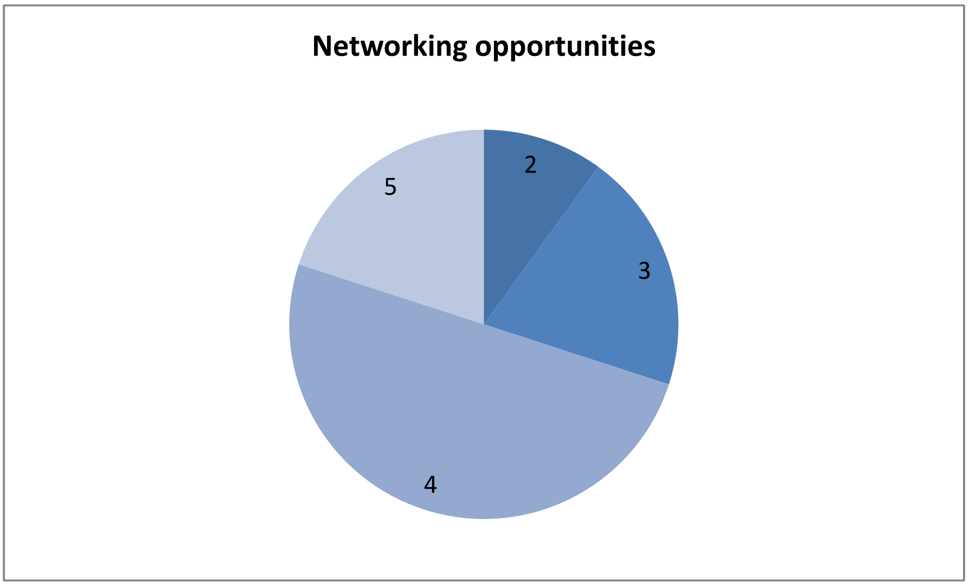
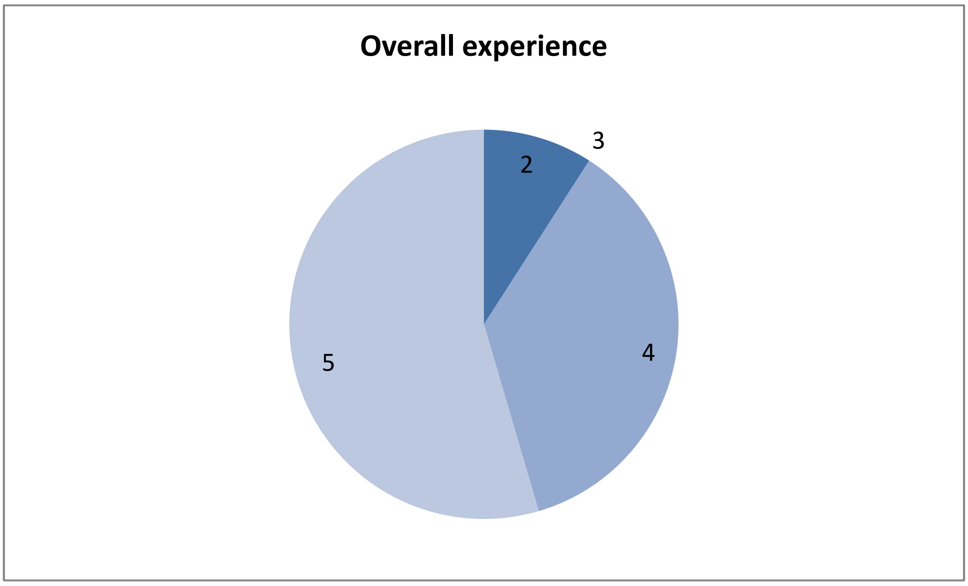


Fig. 10.7. Responses to question regarding the overall experience of the workshop. Numbers indicate the answer given (1-5) and sections the proportion of responses



The feedback provided in section 1 was generally positive. The workshop organisation, facilities, relevance, and overall experience were rated highest with the majority of respondents giving these the maximum score. Overall content of presentations, focus group discussions and networking opportunities were scored slightly lower but still scored above average.

7.2 Results from Part 2

The second section of the questionnaire allowed the participants the opportunity to give written responses and provide more detailed feedback on a variety of topics relating to the workshop. Overall the responses were positive with some interesting feedback on how the workshop could have been improved and how successfully information was disseminated via the workshop.

When asked whether they were aware of the issues relating to *A. artemisiifolia* prior to the workshop the vast majority (ten of the eleven respondents) said 'yes'.

Most participants said that they gained a better understanding of *A. artemisiifolia* (and the issues relating to the species; its management and control) from the workshop; with nine out of the eleven respondents stating this.

The participants were then asked what further information they would like to have about *A. artemisiifolia* issues, its management and control. This question yielded a variety of different responses which highlighted the differing backgrounds and interests of the participants. Ten responses were received for this question with two of those stating that they would like a copy of the final report when completed. Other responses included: "More data related to the health effects and allergic reactions" and "Cost - benefit of control to avoid further damage".

When asked whether they believed the methodology used could be applied to other invasive alien species, eight of the ten respondents believed it could, with a variety of different species and taxonomic groups suggested. Species suggested by the participants included: *Fallopia* spp., *Impatiens glandulifera* and *Heracleum manteggazianum*.

The participants were also asked what they gained most from the workshop, "contact/networking" and "up to date information" were the most frequent responses.

When asked if the respondents would do anything differently to make the workshop more effective, nine people responded with two of them stating they would not change anything. Three other respondents suggested that the workshop could have been longer whilst other answers included providing more materials to participants prior to the workshop and using a simpler level of English for the presentations.

8 Conclusions

Based on the participant responses it can be said that the workshop was a success. The majority of the responses received in Part 1 rated these questions as either 4 or 5 (out of 5). Of particular note, ten of the eleven respondents rated their overall experience as either 4 or 5 (out of 5).

The question regarding the relevance of the workshop to the participant's interests also scored highly which suggests that the most suitable people were identified and invited to attend the workshop.

The responses from Part 2 of the questionnaire were also mostly positive. The main aim of the workshop was to disseminate the project outputs amongst the relevant community. Nine of the eleven respondents said that after the workshop they had a better understanding of the *A. artemisiifolia* issues, its management and control, therefore it can be said that the workshop was highly effective at disseminating the required information.

ANNEX 1: THE NATIONAL EXPERT QUESTIONNAIRE

The national experts were provided with Excel-based questionnaires linked to the deliveries of all their Tasks. The two questionnaires are given below.

1st questionnaire. The experts were also asked to supply. Information sources (links, references, etc) for each item added

Task 1: Ragweed spreading mechanisms								
Name of spreading mechanism (e.g. Agricultural harvesting machines, Road networks)	How is the spread of *A. artemisiifolia* facilitated by this mechanism?	Is this a natural or anthropogenic mechanism?	What evidence is there of this spreading mechanism?	Where is this spreading mechanism known from?	How important is this spreading mechanism to the spread of *A. artemisiifolia* in your study region? (Score 1-10) 1=of low important, 10=of high importance	Importance of the spreading mechanism (comment box)	Is the evidence based on good quality research?	Is there any contradicting evidence for this spreading mechanism?

Task 2: The conditions and vectors that favour the spreading of ragweed									
Subject type: Condition, vector or driver	Name of Condition/ Vector/ Driver that favours the spread of *A.artemisiifolia* (e.g. disturbed ground)	How does this condition/ vector/ driver favour the spread of *A.artemisiifolia?*	What is known about the limits (upper and lower) of this condition/ vector/ driver?	Is this a natural or artificially manipulated process?	What evidence is there of this condition/ vector/ driver?	Where is this condition/ vector/ driver known or believed to be important?	How important is this condition/ vector/ driver considered to be to the spread of *A. artemisiifolia* in the past, present and/or future?	Is the evidence based on good quality research?	Is there any contradicting evidence?

Task 3a: Explore local data holders and literature for information and data on the distribution of *A. artemisiifolia* in your study region (including the closely related species *Ambrosia psilostachya* and *Ambrosia trifida*). Please also attempt to retrieve any such data.											
Data details, including region covered	Source of data	Data retrieved?	Cartographic projection used in data	Georeferenced or grid based data?	Data access restrictions	Organisation name	Contact name	Address	Tel.	Email	Website
Task 3b: Distribution											

Where has *A .artemisiifolia* spread in the past 30 years within your review region?	Where and when was *A. artemisiifolia* first established/ introduced?	Where is *A .artemisiifolia* predicted to spread in the future?	Do A. artemisiifolia records represent well established populations or short lived casual occurrences?	What is known about the rate of *A. artemisiifolia's* spread within your review region?	What is the current distribution of the closely related species *Ambrosia psilostachya* and *Ambrosia trifida* in your region?	Where has the closely related species *Ambrosia psilostachya* and *Ambrosia trifida* spread in the past 30 years within your review region?	Is there evidence that Ambrosia species distribution has been grouped (i.e. more than one species accounting for distribution data?) specify which datasets this applies to.

Task 8: Early warning system

Is there an existing Early Warning System (EWS) for invasive alien species (IAS) and/or specifically for common ragweed in your study region?	
If yes please provide us with possible sources of information (e.g. links and references to any strategic documents, relevant publications available, websites, institutions etc.).	
To reflect the existing institutional capacity; human resources; and knowledge base (for the establishment) of an early warning system please try to provide the following information:	

a) a list of competent authorities dealing with the common ragweed related issues (in relation to data gathering, monitoring, awareness raising, policy making) with description of their involvement/interest and their capacity	b) the list of scientific and other institutions doing research/ gathering information on common ragweed and its effects, with short description of their work	c) a list of any other relevant stakeholders (individuals and/or organizations) dealing with common ragweed, including a description of their role in connection with the issue;	d) a list of existing inventories/databases/ monitoring programmes in the country which already include or could include common ragweed data and are or could be a part of an early warning system (for existing monitoring systems please provide some details on the monitoring methodology)	e) examples of existing targeted information dissemination and awareness raising campaigns on common ragweed and other IAS targeted at different audiences (e.g. websites, mass media, posters, leaflets, identification guides, workshops, codes of practice for the key pathways). Please also include your judgment of the success of these communication efforts (e.g. reach, response, impact).	h) any other information you find relevant for the establishment of an early warning system

2nd questionnaire. The experts were also asked to supply Information sources (links, references, etc) for each item added. In addition, for the Task 4/5 questions the date and geographic location of the referenced study were requested.

<table>
<tr><td colspan="6">Task 4 & 5a: Human health impacts</td></tr>
<tr><td>1) Have human allergic reactions to ragweed been reported in your region?</td><td colspan="5"></td></tr>
<tr><td>Types of reaction reported (e.g. hayfever, asthma, contact dermatitis)</td><td>Incidence of allergic reactions (e.g. number of reports, % of population affected)</td><td>Are there any hospitalisations due to the allergic events - if so how many days is an average episode (or another measure)?</td><td colspan="2">Have the reactions affected people’s ability to attend work - if so how many work days are lost (or another measure)?</td><td>Other comments</td></tr>
<tr><td>2) Has the incidence of allergic reactions increased over the last 10 years?</td><td colspan="5"></td></tr>
<tr><td>Types of reaction reported (e.g. hayfever, asthma, contact dermatitis)</td><td colspan="2">Data describing the change in incidence</td><td colspan="3">Other comments</td></tr>
<tr><td>3) Are the allergic reactions reported to be worse, less, or no different from those to other plant allergens (e.g. grass or Brassica napus pollen) in your region?</td><td colspan="5"></td></tr>
<tr><td>Types of reaction considered (e.g. hayfever, asthma, contact dermatitis)</td><td colspan="2">Data describing the difference in reactions, including the plant species against which ragweed was compared</td><td colspan="3">Other comments</td></tr>
<tr><td>4) Over what distances from ragweed infestations are allergic reactions to its pollen manifest?</td><td colspan="5"></td></tr>
<tr><td>Types of reaction considered (e.g. hayfever, asthma)</td><td colspan="2">Data describing the distances at which allergic reactions are manifest</td><td colspan="3">Other comments</td></tr>
<tr><td>5) What concentrations of ragweed pollen cause allergic symptoms: i.e. what is the minimum</td><td colspan="5"></td></tr>
</table>

concentration for which responses are reported				
Types of reaction considered (e.g. hayfever, asthma)	The minimum concentration for which responses are reported	Change in the response with pollen concentration	Other comments	
6) Are certain sectors of the human population more affected by ragweed and its pollen?				
Types of reaction considered (e.g. hayfever, asthma)	Determinants of sensitivity reported	Define groups more affected and the size of the effect on these groups relative to others.	What percentage of the total population do these groups make up?	Other comments
7) Has sensitisation to ragweed and its pollen has led to sensitivity to other allergens?				
Types of reaction considered (e.g. hayfever, asthma)	Other allergens to which ragweed has increased sensitivity	Other comments		
8) What medication is used to relieve allergic responses				
Types of reaction considered (e.g. hayfever, asthma)	The name of the medication used	Which other allergies is this used for?	The unit or total cost of such medication (note the currency)	Other comments
9) What are the costs of treatment for ragweed allergic responses				
Types of reaction considered (e.g. hayfever, asthma)	Cost of medication (average per treatment)	Impact of treatment, e.g. slight alleviation of symptoms, total cure?	Other treatments (specify)	Other comments
10) Is other evidence is available to calculate the economic effects of these impacts on human health?				
Specify the evidence: type and findings	Other comments			

11) Has any research been carried out to estimate QALYs (quality adjusted life years) affected by ragweed?				
Specify the evidence	Other comments			
Task 4 & 5b: Animal health impacts				
1) Have allergic reactions of animals to ragweed been reported in your region?				
Animal species affected (pets, livestock, etc)	Types of reaction reported	Incidence of allergic reactions (e.g. number of reports, % affected)		
2) Has the incidence of allergic reactions increased over the last 10 years?				
Animal species considered	Types of reaction reported	Data describing the change in incidence	Other comments	
3) Are the allergic reactions reported to be worse, less, or no different from those to other plant allergens (e.g. grass or *Brassica napus* pollen)?				
Animal species considered	Types of reaction considered	Data describing the difference in reactions, including the plant species against which ragweed was compared	Other comments	
4) Over what distances from ragweed infestations are allergic reactions to its pollen manifest?				
Animal species considered	Types of reaction considered	Data describing the distances at which allergic reactions are manifest	Other comments	
5) What concentrations of ragweed pollen cause allergic symptoms: i.e. what is the minimum concentration for which responses are reported?				
Animal species considered	Types of reaction considered	The minimum concentration for which responses are reported	Change in the response with pollen concentration	Other comments
Task 4 & 5c: Biodiversity impacts				

1) Which ecosystems are most invaded by ragweed in your region, and does this vary across your region?					
Ecosystems studied (use a row for each)	For each ecosystem studied (use a row for each), give any quantitative or qualitative measure of the degree of invasion, e.g. % area lost to ragweed	Is this ecosystem type protected for nature conservation in your region?	What impacts are reported on the biodiversity of each ecosystem (e.g. decline of native species)?	Report any information on the effect of time since invasion or ragweed density on the impacts	Other comments

2) Are protected sites invaded by ragweed – e.g. Natura 2000 sites?				
Protected sites (e.g. Natura 2000) studied (use a row for each)	For each site studied (use a row for each), give a quantitative or qualitative measure of the degree of invasion	What impacts are reported on the biodiversity of each site (e.g. decline of native species)?	Have any local studies been carried out to value the Natura site? summarise the method and present the results – See Note 1 on summarising stated preference surveys)	Other comments

3) Are species of conservation concern affected by ragweed?			
Wild species considered (use a row for each)	Designation of each species: e.g. Red Data Book (use a row for each)	Describe the reported impacts on this species ascribed to ragweed?	Other comments

4) How serious are the effects of ragweed in the context on national conservation goals and strategies?		
National conservation goal or strategy considered	Reported impact of ragweed on achieving the conservation goal	Other comments

5) Willingness to pay studies for affected habitats or biodiversity protection						
Resource Valued	Sample Size and Type	Payment Vehicle	Mean W.T.P.	95% confidence interval for W.T.P.	Survey Method	Valuation Method

Task 4 & 5d: Impacts on the wider environment
1) What are the impacts of ragweed on the functioning and services of invaded

ecosystems				
Ecosystems studied (use a row for each)	The ecosystem functions or services which are reported to be affected by ragweed invasion of this ecosystem type	Report quantitative or qualitative data on the effect of ragweed on this function or service	Other comments	
2) What effects do ragweed control measures on have on ecosystem functions and services				
Ecosystems studied (use a row for each)	Ragweed control or eradication measure used	The ecosystem functions or services reported to be affected by the control or eradication measure and quantitative or qualitative data describing the effect	Other comments	
Task 4 & 5e: Impacts on arable agriculture and horticulture				
1) Is ragweed an agricultural weed in your region?				
Is ragweed a serious, moderate or minor agricultural weed in the region?	The size of the cropped area affected by ragweed	Other comments		
2) Which crops are affected by ragweed in your region?				
Crops considered: include horticulture, orchards, etc (use a row for each)	The area of this crop affected by ragweed	Yield losses of this crop as a result of ragweed infestation	Income per ha for this crop without ragweed	Management (e.g. herbicide) costs to control ragweed in this crop
3) Are certain agricultural systems more likely to suffer ragweed problems: e.g. organic farms; or farms with agri-environment management such as birdseed strips?				
Agricultural systems assessed	Evidence for differential susceptibility of ragweed invasion	Other comments		
4) Does ragweed invasion cause other problems in agriculture and horticulture, such as restricting access of humans of livestock (through allergenicity), interfering with machinery, or contaminating agricultural products?				

Problem caused	Quantitative data on the problem (for economic assessment)	Other comments	
5) Is other evidence is available to calculate the economic effects of these impacts on arable agriculture?			
Specify the evidence: type and findings	Other comments		
Task 4 & 5f: Impacts on other sectors			
1) Have construction projects (buildings, roads, etc) been disrupted by ragweed invasions?			
Construction project considered	Form of the disruption (e.g. evacuation of the site, the need for ragweed control, the use of safety equipment)	Economic impact of the disruption (e.g. lost work days, increased spending)	Other comments
2) Have ragweed invasions of transport links (roads, railways, waterways) restricted private and/or business travel?			
Transport link affected	Form of the disruption (e.g. road closure)	Economic impact of the disruption (e.g. lost work days, increased spending)	Other comments
3) Do ragweed infestations affect leisure, recreation or tourism?			
Type of activity or site affected	Form of the disruption (e.g. restricting access to amenity - including city parks - or tourism sites, or causing health problems amongst visitors to such sites)	Economic impact of the disruption (e.g. lost revenue, increased spending)	Other comments
4) Is other evidence is available to calculate the economic effects of ragweed impacts on these or other sectors not considered elsewhere?			
Specify the evidence: type and findings	Other comments		
Task 7: Describe measures/practices to prevent introduction or further spread			
General information			

Country/region	Contact person if available	Prescribed by law/regulation	Implementing body	Purpose of the measure
Provide geographical area where the measure is applied	Possible contact to a person who could provide more information	e.g. compulsory or not; provide also the name of the law/regulation if applicable, incl. regulating level (national, regional, local)	Name the body responsible for the implementation of the measure or coordination in implementation	Select between the 3 offered options: prevent introduction; prevent further spread; reduce or mitigate harmful effects

The measures

Measure taken	Description of the measures/method	Level of approach	Specific location of application	Sectors it applies to
title/name of the measure implemented (ensure all measures are listed)	ensure all measures described in specific terms	geographical/administrative area within which measures apply (e.g. municipality, county, national)	indicate where (ecosystems/habitats etc.) measures are applied in practice	which sector applies the measures (e.g. agriculture, building , industry, citizens, etc.)

Observed impact of measures (short term)

Impact on common ragweed	Negative/positive impacts on other species	Negative/positive impact on habitats	Environmental impacts	Other impacts/risks/benefits related to the measure taken
Describe the expected effectiveness of the measures	Describe any possible impact the measure may have on other species	Describe any possible impact the measure may have on habitats where it is applied	Describe any possible impact the measure may have on the environmental quality (e.g. air, ground or surface water quality)	Describe any other possible impact/risk/benefit the measure may have on society (e.g. human health when using pesticides, costs to society, access to land, damage to crops)

Stakeholder/public involvement

Stakeholder involvement	General public involvement
If not covered above in relation to sectors give brief indication of involvement of stakeholders in planning/execution of measures	e.g. publicity campaigns, voluntary action, research etc.

Evaluation of measures (incl. potential long term impacts)

Applicability for other invasive species	Durability	Selectivity	Replication potential	Effectiveness of the measure	Results quantifiable and how	Costs per unit	Human resources required	Level of knowledge/ capacity building required	Potential for long term involvement of stakeholders/ public	Key factors for success of the measure	Limitations

If possible name the species to which the measures also could apply	Describe the durability of the measures	Describe the selectivity of the measure especially in terms of affecting the native species	Is it possible to apply the measure in other countries/ region/ habitats	Describe the effectiveness of the measure	Describe possible quantification of results and effectiveness of the measure	Provide estimated costs per unit if possible	Provide more details on the human resources required to implement the measure	Describe the knowledge required for implementing the measure and possible capacity building requirements	Describe the potential for further public/stakeholder implementation of the measures without dedicated programme	Describe the key factors critical for the success of the measures	Describe the possible limitation of the measures

Conclusions

Key issues	Benefits	Conditions for success	Limitations	Barriers and bottlenecks	Cost effectiveness	Other comments
What are the key issues related to the measure in general	What are the benefits of applying this measure	Describe the pre-conditions for success of the measure	Describe the possible limitations of the measure	Describe any possible barriers and bottlenecks for implementation of the measure	A comparison of the costs per unit and effectiveness of different options. This can be qualitative, if the effectiveness can be quantified (i.e. unit cost/unit effectiveness) or qualitative.	Any other comments/conclusions

Sources/references

Relevant references	Relevant experts
Provide a full list of references relevant for this measure (including web references), including evidence on effectiveness	Provide a full list of relevant experts with contact details if available

ANNEX 2: Laws and regulations in concerning invasive alien species in Europe (Task 7, 9)

Country	Legislation in Place	Description
Belgium	Species Decree 2009 (Flanders); Royal Decree from May 2009 (Federal level); and various Acts at federal and regional level	Institute for Nature and Forest Research (INBO) is legally appointed to coordinate the follow-up of (potentially) invasive species. Royal Decree provides for a ban on the import, export, transit and detention of 20 IAS from the black list. Legilsation follows the National Biodiversity Strategy (2006) - operational objective n°3.7. : " Avoid the introduction and mitigate the impact of IAS on biodiversity" operational objective n°5.7.: " Consider the potential impact on biodiversity, and in particular the invasiveness of species, in making import and export decisions".
Croatia	Proclaimed ordinance on obligatory eradication of Ambrosia	Ministry of Agriculture, Fisheries and Rural Development is responsible. Municipalities have their own local ordinances as well.
Czech Republic	Various Acts	These require the Central Institute for Supervising and Testing in Agriculture to monitor and control aspects of feedstuffs, seeds and soil.
Demark	Protection of Nature Act Act no. 835 of 1997, and later changes, Chapter 5	§30 Regulations for the purpose of protecting or regulating the exploitation of wild animals and plant species. The regulation may be used to prohibit or restrict importation of some species. §31 Release of non-native animals is prohibited. Rules may be put forward regarding to the deliberate release of non-native animals and plants. This regulation pertains to land areas, territorial waters and the fishing territories. In relation to the introduction of animal species guidelines on the informational demands before release have been developed.
	New regulation passed that will enter into force 1 January 2012.	The Danish Plant Directorate is responsible for this legislation, which regulates the maximum content of *A. artemisiifolia* seed that are allowed in birdfood. Generally the maximum level will be 50 mg/kilo. For food mainly consisting of millet and sorghum through 200 mg.
France	Rules of public health legislation, circular of 14 April 1989	A collection of laws giving prefects and mayors an option to enact specific bylaws concerning *A. artemisiifolia*. As a result, prefects of the polluted regions have made it obligatory to clear land set aside.
Italy	Decree No. 7257 of 4 May 2004 (Health General Directorate No. 389)	Guidelines for the prevention of *A. artemisiifolia* related allergopathies in Lombardy for the years 2004-2006
	Decree GR 24 Luglio 2008 - No. 8/7736	Requires monitoring, containment, and eradication of invasive plant species on the black list.
	Local Rules of Hygiene (Milan)	This order was issued in 2011 and requires supervision and mowing operations to reduce the spread of *A. artemisiifolia*.
Hungary	Act 2008/46	This pertains to the food chain and its official supervision. This requires the land lessee to block the growth of *A. artemisiifolia* flower buds on his/her land parcel till 30 June of the given year, and maintain this status till the end of the vegetation period.
	Government Decree	Pertains to the official protection of public interest against *A.*

Country	Legislation in Place	Description
	221/2008	*artemisiifolia*, and provides detailed rules of establishing and requesting its costs.
	Government Decree 214/2007	Outlines detailed plant protection fines.
	Government Decree 194/2008	Pertains to fines calculation and their rates related to the control of the food chain.
Latvia	Law on Protection of Species and Habitats Law of Latvia Republic 16.03.2000 Chapter IV, Article 18	The law prohibits release and intentional introduction of species alien to Latvia. Exceptions such as if the introduction is needed to satisfy importunate economic or social needs is permitted only if a complex environmental assessment is carried out and a permit by the responsible institutions is issued. In a case if a species is introduced, the initiator of the introduction must carry out a monitoring of the introduced populations and their ecological effect and the results must be regularly submitted to the responsible institution.
	National Programme on Biological Diversity Chapter 14, 21	This program describes the distribution of invasive introduced species, promotes study of distribution of introduced species and their entry to natural communities, controls the distribution and removal of aggressive species, develops/implements regulations on introduction of new crops, and stipulates grower responsibility for damages ensued to local species and communities. The program also addresses the control spread of alien species in cities.
	Plant Protection Law Law of the Latvian Republic	The law provides a definition of invasive alien plant species, defines the general order of the system how to gather information on invasive alien plant species, invaded areas, how to control and monitor invasive alien plant species, the responsibilities and basis of the control system.
	Regulations Regarding Restriction of the Distribution of Invasive Alien Plant Species Regulation by the Cabinet of Minister No. 467 (30.06.2008.)	The regulation defines the order of monitoring, surveillance, control and providing information on invasive alien plant species as well as the order how a species can be included in the list of invasive alien plant species and how it can be used for scientific purposes.
	List of invasive plant species Regulation by the Cabinet of Ministers No. 468 (30.06.2008.)	The regulation states the list of invasive plant species. By 2010, only one species – *Heracleum sosnowskyi* is being included in this list.
Poland	Law on Protection of Crop Plants of 18 Sep 2001, 18 Dec 2003, 26 Mar 2004	Regulations for prevention of introduction and spread of plant and plant production pests, thus including IAS, but no reference to IAS.
	Nature Conservation Act of 16 Apr 2004	§1-4 regulations for introduction of alien fungi, plants and animals and on import of alien species posing threat to native biodiversity.
	Act on State Inspection for Environmental	Environmental regulations for control of environment law compliance, thus including laws regulating introduction of IAS, but no

Country	Legislation in Place	Description
	Protection	explicit reference to IAS.
Switzerland	2005 ordinance on animal feedstuff	The Federal Department for Economic Affairs adapted this ordinance that sets the restriction that all types of feedstuff put into circulation must be free from *A. artemisiifolia* seeds. A 2006 amendment declared *A. artemisiifolia* subject to official control.
	Plant Protection Ordinance of 28 February 2001	*A. artemisiifolia* is listed as a particularly dangerous weed, which requires mandatory reporting of sightings to the local cantonal authorities. It also requires owners and managers of land that is contaminated to remove the plants using the appropriate measures.
Ukraine	Unspecified law	There is a special law on quarantine and a corresponding inspection, which monitors the introduction and spread of scheduled animals, plants, and fungi across the country, including *A. artemisiifolia*.

ANNEX 3: Relevant stakeholders in developing an EWS: Competent authorities (Task 8)

Country	*Competent Authorities dealing with Common Ragweed related issues*	*Description*	*Contact Details*
Austria	Amt der Niederösterreichischen Landesregierung, Abt. Straßendienst (Office of the Provincial Government of Lower Austria, Dep. of Road Service)	Gathering of distribution information regarding the provincial roads, operating experiments on ragweed control at road sides, awareness raising etc	Ing. Sabine Auer Mr. Klaus Krickl post.st1@noel.gv.at
	Amt der Niederösterreichischen Landesregierung, Abt. Umwelthygiene (Office of the Government of Lower Austria, Dep. of Environment Hygiene)	Has made contributions to the study of the Floridsdorfer Allergiezentrum. They also deal with awareness raising etc	Dr. Ulrike Schauer post.gs2@noel.gv.at
	Niederösterreichische Landesakademie (State Academy of Lower Austria)	(BBN is responsible for northern Burgenland.) Gathering of distribution information regarding the provincial roads, operating experiments on ragweed control at road sides, awareness raising etc.	Dr. Michael Mayer Ing. Wolfgang Lanner fa18b@stmk.gv.at
	Amt der Steirischen Landesregierung, Fachabteilung 10b Landwirtschaftliches Versuchszentrum (Office of the Styrian Provincial Government, Agricultural Experimental Center)	Gathering distribution data, awareness raising etc	HR Dipl.-Ing. Josef Pusterhofer fa18b@stmk.gv.at
	Magistrat der Stadt Wien, MA 42 Stadtgartenamt, Amtlicher Pflanzenschutzdienst für Wien (City of Vienna, MA 42 Garden City Office, Official Plant Protection Service for Vienna)	Vienna as a city state is not that much affected than the other ones in eastern Austria, but far more than the authorities believe. There is obviously little activity here.	Mr. Christian Eigner
	Interessengemeinschaft Allergievermeidung (IGAV)	The objectives of IGAV are to spread the knowledge of the scientific research to those affected and interested parties, to provide stimuli to the scientific research through direct contact with the affected, and to offer those affected a voice for their concerns and worries".	Ass. Prof. Dr. Siegfried Jäger siegfried.jaeger@univie.ac.at
Belgium	Scientific Institute of Public Health	Federal service performing research on public health matters in Belgium.	Monique Detandt Monique.Detandt@wiv-isp.be tel. 0032(0)2 642 55 17
	Institute for Nature and Forest Research (INBO)	INBO, scientific institute of the Flemish Region, is legally appointed to coordinate the follow-up of (potentially) invasive species (Species Decree 2009). Therefore, the institute is involved in the setting-up of an early warning system for IAS. For this	www.inbo.be

Country	***Competent Authorities dealing with Common Ragweed related issues***	***Description***	***Contact Details***
		project specifically, capacity is 0.2 FTE at INBO and 0.1 VTE based at the Agency for Nature and Forest.	
Bulgaria	Ministry of Environment and Water (incl. Executive Environmental Agency)	State institution - ministry and regional structures; responsible on policy making and control Responsible according to the Biodiversity Act for control of the alien species. No real involvement concerning invasive species.	http://www.moew.government.bg/
	Ministry of Agriculture and Food (incl. Executive Forest Agency and National plant protection service)	State institution - ministry and regional structures	http://www.mzh.government.bg
Croatia	Ministry of Culture, Nature Protection Directorate	Competent for nature protection; preparing laws and regulations including the Act on Nature Conservation, Ordinance on risk assessment study of introductions and reintroductions	www.zastita-prirode.hr www.min-kulture.hr/default.aspx?id=4616
	State Institute for Nature Protection	The Institute carries out expert tasks of nature protection for the Republic of Croatia including inventories, monitoring and assessing the state of nature, background studies to laws and bylaws.	www.dzzp.hr
	Ministry of Agriculture, Fisheries and Rural Development	Proclaimed Ordinance on obligatory eradication of Ambrosia.	
	Institute of Public Health 'Andrija Stampar'	Pollen concentration monitoring; awareness raising campaigns; advisory role.	www.stampar.hr
	Croatian Institute of Public Health (with county offices)	Pollen concentration monitoring, awareness raising campaigns, advisory role, networking and information exchange in the country and at European level.	http://www.hzjz.hr
	Municipalities (cities)	Local ordinances, awareness raising campaigns, subsidies for eradication.	
Czech Republic	State Phytosanitary Administration	The State Phytosanitary Administration (SPA) is the administrative phytosanitary care authority with competence for the Czech Republic and is subordinate to the Ministry of Agriculture. SPA is a state plant protection organization in accordance with the International Plant Protection Convention and is the authority responsible for exercising its powers in the field of phytosanitary care in compliance with the laws of the European Community.	http://eagri.cz/public/web/en/srs/contacts

Country	Competent Authorities dealing with Common Ragweed related issues	Description	Contact Details
	Central Institute for Supervising and Testing in Agriculture	The Institute performs the administration and carries out some other administrative activities, expert and testing tasks and control and monitoring activities in accordance with special acts in the areas of viniculture, feeding stuffs, varieties, seeds and seedlings of the grown plants, protection of hops, fertilizers, soil improvers, growth regulators and substrates and agrochemical examination of agricultural soil, plant variety rights protection and in the area of the animal production.	http://www.ukzuz.cz/ChangeLang.aspx?Lang=EN
	Agency for Nature Conservation and Landscape Protection of the Czech Republic (ANCLP)	A governmental body established by the Ministry of the Environment. The main aim of ANCLP is to protect and conserve nature and landscape on the whole territory of the Czech Republic.	http://www.ochranaprirody.cz/wps/portal/cs/aopkcr/aopk-cr
	The National Institute of Public Health	A budgetary organization of the Ministry of Health. This covers activities comprising creation of the basis for national public health policy, health promotion and protection, providing methodical reference activities and monitoring related to public health, researching the environmental impact on human health, international collaboration, post-graduate education in medical fields and health-related education of the general public.	http://www.szu.cz/
Denmark	Danish Plant Directorate, Ministry of Food, Agriculture and Fisheries	Responsible authority in relation to preparation of new legislation in relation to invasive plant species, responsible in relation RASFF system as it is described above , includes a number of inspectors visiting farms and private forest areas - and reporting on invasive species	http://pdir.fvm.dk/English.aspx?ID=13274
	Health Agency, Ministry of Interior and Health	Responsible authority in relation to health risk related to among other invasive species. Involved in daily pollen counting and provision of information to allergic persons, including as a test counting of pollen from Common Ragweed	http://www.im.dk/ http://www.sst.dk/English.aspx
	Nature Agency, Ministry of Environment	Responsible for among other Danish Biodiversity Information Facility, action planning on invasive species, information portal on invasive species and homepage where reporting on observations can be	www.nst.dk http://www.naturstyrelsen.dk/English

Country	***Competent Authorities dealing with Common Ragweed related issues***	***Description***	***Contact Details***
		placed by anybody	
France	FCBN	data gathering (natural and semi-natural habitats)	
	Ministère santé	policy maker for the national level	
	DRASS Rhône-Alpes et Conseil Régional Rhône-Alpes en partenariat avec le RNSA (Réseau National de Surveillance Aérobiologique).	awareness raising	http://www.ambroisie.info/
	Observatoire de l'ambroisie	awareness raising and monitoring ? Created in June 2011	bruno.chauvel@dijon.inra.fr
	AFEDA	awareness raising and monitoring Medical data consist of pollen counts. The priority is to predict the period of pollination, the number of sufferer and the intensity of symptoms… but not the presence of the plant…	C. Déchamp afeda@wanadoo.fr http://afeda.assoc.pagespro-orange.fr/index.htm
	CETIOM	data gathering (agricultural data) Agricultural data are not published for strategic reasons: farmers could be taken to court because of local legislations specifying the land must be cleared of ragweed (Chauvel, personal communication, July 2011) The mayors of numerous polluted communes have made bylaws concerning the eradication of ragweed. But some mayors do not want to make bylaws for in rural places because it is impossible to apply, thereby it is too late to eradicate the plant there	Christophe SAUSSE tel : 01 30 79 95 67 fax : 01 30 79 95 90 sausse@cetiom.fr
	APRR	data gathering (roadsides data for east of France) French legislation, non specific to ragweed, concerning « Rules of public health », circular of 14 April 1989, published in the Journal Officiel of 26 July 1989 presents a collection of laws and notably the possibilities that this legislation has given to the prefects and mayors to enact specific bylaws concerning ragweed (before the new Community Guidelines on the quality of air came in). So the Prefects of the polluted regions have made it obligatory	Etienne Cuenot

Country	***Competent Authorities dealing with Common Ragweed related issues***	***Description***	***Contact Details***
		to clear land set aside.	
	ANSES	monitoring identified parcels all over the country	Guillaume Fried
	CBNMED	data gathering for the south of France early detection for different species of ragweed for the south of France (Mediterranean climate)	Isabelle Mandon-Dalger http://flore.silene.eu/index.php?cont=accueil - http://www.invmed.fr
Germany	Julius Kühn Institute, Federal Research Centre for Cultivated Plants	Since 2005, the Julius Kühn Institute coordinates an interdisciplinary working group on ragweed that convenes twice yearly. The action program Ragweed as initiated in 2007 and charged with stemming the spread of ragweed. This program is being coordinated by the Julius Kühn Institute and has three columns: - A Germany-wide monitoring to have better knowledge about the spread of ragweed - Measures to prevent the import and spread of ragweed seeds and to fight against existing ragweed plants and seeds - Information for administrative agencies, politics, and the public All reports about ragweed locations from the federal states are to be collected and coordinated in the Julius Kühn Institute. To this day, however, no consistent monitoring exists nor are there methodological standards.	www.jki.bund.de/ambrosia Dr. Uwe Starfinger Julius Kühn Institut Braunschweig, Institut für Pflanzengesundheit
	Federal Ministry of Food, Agriculture and Consumer Protection (BMELV)	National action programme ragweed is also a central element in the 2007 Action Plan of the Federal Ministry for Food, Agriculture, and Consumer Protection (BMELV) against allergies. Aim of the plan is to reduce allergies and to make daily life more bearable for persons with allergies.	Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz http://www.aktionsplan-allergien.de

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	The Federal Agency of Nature Conservation (BfN)	The BfN together with the project group Biodiversity and Landscape Ecology in 2007 carried out a survey among the 424 lower-level nature protection agencies, of which 284 (68%) provided information regarding incidence of ragweed, populated space, ways of introduction, distribution tendencies, and resulting problems. Since counties from all German regions participated in the survey and additional information about ragweed locations was added by the researchers, This project for the first time provided a comprehensive overview about the incidence of ragweed in Germany (as of December 2007). NeoFlora (Information of the BfN in collaboration with the working group Neobiota). Description, consequences, measures, and incidence of ragweed in Germany (including a distribution map for ragweed (as of 12/2006). Basis data for the map: the inventory of distribution data in the context of the flora mapping of Germany is a continuing project carried out on the basis of voluntary participation.	Frank Klingenstein Bundesamt für Naturschutz Konstantinstr. 110 53179 Bonn

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	The Bavarian State Ministry for Environment and Public Health (StMUG)	The Bavarian State Ministry for Environment and Public Health (StMUG) since 2007 calls attention annually to the combat against ragweed through a highly visible action program. People are encouraged to register large amounts of ragweed (more than 100 plants) at their local county agencies (county commissioners, city administrations) accompanied by explicitly labelled photos (prints or CDs). The combat against these large amounts of ragweed is intended to commence only after confirmation and advice by the local county agencies. The county administrations register confirmed amounts of ragweed with the Bavarian State Institute for Agriculture (LfL). Since 2009 county administrations are also asked to fill in the form "Location/Combat Registration" and to send this also to the LfL.	Matin Hicke, Bayerisches Staatsministerium für Umwelt und Gesundheit (StMUG) http://www.stmug.bayern.de/gesundheit/aufklaerung_vorbeugung/umweltgesund/ambrosia/index.htm
	Landesanstalt für Umwelt, Messungen und Naturschutz Baden- Württemberg (LUBW)	The action program ragweed aims at controlling the existence of ragweed in order to reduce its amount and, where possible, to eliminate it in order to prevent a further distribution of ragweed. The state agency (LUBW) requests registration of ragweed incidence and locations.	Landesanstalt für Umwelt, Messungen und Naturschutz Herrn Dr. Harald Gebhardt, Referat 23 Postfach 100163, 76231 Karlsruhe Tel.: 0721/5600-1222 E-mail: ambrosia@lubw.bwl.de
	Landesamt für Natur, Umwelt und Verbraucherschutz Nordrhein- Westfalen (Agency for Nature, Environment and Consumer Protection((LANUV)	The state agency requests registration of ragweed locations	Landesamt für Natur, Umwelt und Verbraucherschutz Leibnizstr. 10, 45659 Recklinghausen Postfach 101052, 45610 Recklinghausen Telefon 02361 305-0 Telefax 02361 3305-3215 E-mail: poststelle@lanuv.nrw.de www.lanuv.nrw.de

Country	Competent Authorities dealing with Common Ragweed related issues	Description	Contact Details
	Ministry of Environment, Health and Consumer Protection of the Federal State of Brandenburg.	In March 2009, the Brandenburg Working Group Ragweed constituted itself with representatives from the areas environment-related health services, workers protection, plant protection, agriculture, nature protection, consumer protection, law and order, and highway construction and maintenance. Their task was to design the action program for Brandenburg. The city and community association and the state-wide association of counties in Brandenburg join the working group. Brandenburg's The action program ragweed aims at controlling the existence of ragweed in order to reduce its amount and, where possible, to eliminate it in order to prevent a further distribution of ragweed. The key goals are to contain the health risks for the population, to avoid production losses for agriculture, and to avoid a reduction in biodiversity due to combat measures against ragweed. Brandenburg currently does not monitor ragweed. To capture all location report from the population, the administrative agencies, and other state offices, a collaboration with the Berlin action program was agreed upon; as a result, the entire Berlin-Brandenburg ragweed atlas is being used.	Ministerium für Umwelt, Gesundheit und Verbraucherschutz des Landes Brandenburg "Lindenstrasse 34 a 14467 Potsdam" Regine Baecker E-Mail: regine.baeker@mugv.brandenburg.de
	Landesamt für Natur und Umwelt (Agency for Nature and Environment) Schleswig Holstein		Dr. Silke Lütt E-Mail: sluett@lanu.landsh.de

Country	***Competent Authorities dealing with Common Ragweed related issues***	***Description***	***Contact Details***
	Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz Berlin	In a joint project, the department of health, environment and consumer protection, the department of city planning, and office for plant protection, together with other regional actors, decided to fight against ragweed decisively because of the high allergy risk of that species. Besides generally keeping the population informed, the city districts of Friedrichshain-Kreuzberg, Spandau, Charlottenburg-Wilmersdorf, Neukölln, Lichtenberg und Treptow-Köpenick are systematically search for the existence of ragweed. The incidence and amount of ragweed in those districts is registered, mapped, and eliminated, if possible. The Institute for Meteorology of the Free University Berlin inputs all relevant information into a data bank regarding the location of ragweed. That information is then made available to the population through the ragweed atlas that is being continuously revised.	Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz Brückenstrasse 6 10179 Berlin Dr. G. Luck-Bertschat http://www.fu-berlin.de/ambrosia
	Senatsverwaltung für Stadtentwicklung mit dem Pflanzenschutzamt Berlin	See above	
Italy	Ministry of Environment	Development of the Biodiversity Strategy The Biodiversity Strategy includes provisions regarding mapping of flora on a regional scale, and foresees to develop and strengthen early warning and rapid response system to prevent the impact of invasive alien species	Ministry for Environment and Territory and Sea, Direction for the Protection of Nature and Sea http://www.minambiente.it/home_it/index.html?lang=it
	Lombardia Region and Natural History museum of Milan	Project "non-native flora of Lombardia" launched in 2008. The aim is to compile regional database and a manual on non-native flora of the region	Celesti-Grapow L., Pretto F., Brundu G., Carli E., Blasi C..
	Lombardia Region	Development and implementation of Decree No. 7257 of 4 May 2004 (Health General Directorate No. 389)	http://www.comune.monza.it/export/sites/default/portale/doc/monzaservizi/Ambiente/ambrosia_DecretoDG7257del2004.pdf
	Milano No.1 Province Local Health Unit	The Public Hygiene and Health Service has implemented several initiatives, such as communication campaigns, training courses, proposal of legal ordinances, aerobiological surveys for the delivery of	http://85.18.108.230/sitisat/sisp-monitoraggiopollini/index.htm

Country	Competent Authorities dealing with Common Ragweed related issues	Description	Contact Details
		pollen bulletins, etc.	
	Piedmont Region	In 2005 the Public Hygiene and Health Service of the "Assessorato alla Tutela della Salute e Sanità" of the Piemonte Region has implemented a containment programme for A. artemisiifolia in collaboration with representatives of the Allergology Network, the Regional Agency for the Protection of the Environment and other stakeholders which have been invited to participate to public conferences.	http://www.regione.piemonte.it/sanita/sanpub/igiene/document_sisp.htm http://rsaonline.arpa.piemonte.it
	ARPAV Regional Agency for Environmental Prevention of Veneto	Information on pollens and allergies in Veneto, including an updated weekly bulletin	http://www.arpa.veneto.it/bollettini/htm/allergenici.asp
	A.R.T.A. - Regional Agency for Environmental Protection (Abruzzo)	Information on pollens and allergies in Abruzzo, including an updated weekly bulletin	http://www.artaabruzzo.it/pollini.php?id_page=6
	Pesaro Urbino province	Information on pollens and allergies in Pesaro Urbino, including an updated weekly bulletin	http://www.ambiente.provincia.pu.it/index.php?id=2275
	ARPA Regional Agency for Prevention and Environment of Emilia-Romagna	Information on pollens and allergies in Emilia-Romagna, including an updated weekly bulletin	http://www.arpa.emr.it/pollini/
Hungary	Ministry of Rural Development	This ministry is the leader for the following 3 Institute: Central Agricultural Office (MgSzH) Institute of Geodesy, Cartography and Remote Sensing (FÖMI) Hungarian Land Administration (Földhivatal)	http://www.kormany.hu/hu/videkfejlesztesi-miniszterium
	Central Agricultural Office (MgSzH)	The CAO is a central office directed by the Minister of Agriculture and Rural Development. The Office holds a centre and 19 regional organizations, including 144 district centers. The organization is responsible for the extensive authority activities of the whole agriculture and food industry. From the point of view of Ambrosia the important responsibility is plant health control of vegetative reproductive material and seeds and agricultural environmental protection, plant protection, soil protection. This organization is responsible for the	http://www.mgszh.gov.hu

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		penalty and official compulsory protection again ragweed.	
	Institute of Geodesy, Cartography and Remote Sensing (FÖMI)	Fomi is a large Institute directed by the Ministry of Rural Development and deals with geodesy, cartography and remote sensing. This Institute make the maps of ragweed hazard areas	www.fomi.hu
	Hungarian Land Administration (Földhivatal)	The land office investigates the ragweed areas and provides data from the land register and the land lease register for further action. The land office starts on-site inspections on 1 July every year to check if the land lessees observe the order to block the growth of ragweed flower buds on land parcels till 30 June of the given year, and maintain this status till the end of the vegetation period. If they find the omission of the obligation, they take the minutes and forward them together with the data indicated in the relevant Governmental Decree for further action to the Office of Agricultural Professional Administration (MgSzH) that had ordered the protection of public interest.	www.foldhivatal.hu
Latvia	State Plant Protection Service	The State Plant Protection Service has been established pursuant to Plant Protection Law. The Institution is performing detection, monitoring and assessment of invasive plant species in agricultural land.	Phone: +371 6702 7098 info@vaad.gov.lv http://www.vaad.gov.lv
Moldova	Ministry of Environment and Sustainable Development	Central authority responsible with decision making and policy development for environmental protection/ monitoring programmes design and implementation	
	Ministry of Health	Central authority responsible with decision making and policy development for human population health assessment	
The Netherlands	Ministry of Economic Affairs, Agriculture & Innovation, Food and Consumer Product Safety Authority (nVWA)	The task of the Food and Consumer Product Safety Authority is to protect human and animal health. It monitors food and consumer products to safeguard public health and animal health and welfare. The Authority controls the whole production chain, from raw materials and processing aids to end products and consumption.	http://www.vwa.nl/onderwerpen/gevaren/dossier/ambrosia1

Country	Competent Authorities dealing with Common Ragweed related issues	Description	Contact Details
Poland	Main Inspectorate of Plant Health and Seed Inspection.	**Inspection's** main assignments are to monitor: plant health conditions, trade and the use of plant protection remedies and their production, verification and the trade of seed material. In particular: protect Poland's territory against pest organisms, protect crops against pest organisms, prevent their spreading across the country, supervise correctness of trade and use of plant protection remedies, outdoors and laboratory verification of seed material, control conditions of plant seed material production and its trading. **Seed Inspection** outdoors and laboratory verification of seeding material, controlling conditions of plant seeding material production and its trading.	http://piorin.gov.pl/index.php?pid=102
	The Institute of Plant Protection - National Research Institute	The Institute aims to conduct research providing the basis for plant protection and to develop better control means against pests and to promote environmentally-sympathetic agriculture in Poland.	http://www.ior.poznan.pl/lang:2
	Institute of Soil Science and Plant Cultivation, Department of Ecology and Weed Control	Identification of weed species resistant to herbicides.	http://www.iung.wroclaw.pl/
	The Plant Breeding and Acclimatization Institute (IHAR)	National Research Institute is the largest Polish research centre in the multi-disciplinary area of crop improvement, biotechnology, germplasm conservation and enhancement. Research of weeds biodiversity (Denise Fu Dostatny).	http://www.ihar.edu.pl/en/
	Polish Academy of Sciences, Kraków	Research centre specializing in systematics and geography of plants as well as paleobotany (biosystematic, palynotaxonomy, and paleoecology). In the institute is located one of the biggest herbarium in Poland (KRAM) - about 800 000 specimens.	W. Szafer http://info.botany.pl/Institute/english.htm
Romania	Environmental Protection Agency	Local agencies of Ministry of Environment and Forests responsible for policy implementation and monitoring programs at local/ regional level.	
	Public Health Authority	Local agencies of Ministry of Health responsible for human health assessment, survey, protection at local/regional level.	

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	Agency for Agriculture and Rural Development	Local agencies of Ministry of Agriculture and Rural Development responsible with policy implementation at local level.	
	Ministry of Environment and Forests	Central authority responsible with decision making and policy development for environmental protection/monitoring program design and implementation.	
	Ministry of Health	Central authority responsible with decision making and policy development for human population health assessment.	
	Ministry of Agriculture and Rural Development	Central authority responsible with decision making and policy development for agricultural sector and rural areas.	
Serbia	Ministry of Agriculture, Trade, Forestry and Water Management of Republic of Serbia	Directorate for plant protection, Department for Plant Health and Plant Quarantine. Duties include policy making and data gathering.	http://www.mpt.gov.rs
	Ministry of Environment, Mining and Spatial Planning	Duties include policy making and data gathering.	www.ekoplan.gov.rs
	Provincial Secretariat for Environmental Protection and Sustainable Development (The Executive Council of Autonomous Province of Vojvodina)	Duties include policy making and data gathering.	http://www.eko.vojvodina.gov.rs/
	Provincial Secretariat for Agriculture, Water Management and Forestry (The Executive Council of Autonomous Province of Vojvodina)	Duties include policy making and data gathering.	http://www.psp.vojvodina.gov.rs/
	Serbian Environmental Protection Agency	Duties include monitoring, information system, data gathering, and pollen monitoring.	www.sepa.gov.rs
	JKP Zelenilo (Public Utility Company) Novi Sad	Centre for the Suppression of ragweed and other allergenic plants. Deals with systematic suppression of ragweed and other allergenic plants on the territory of the City of Novi Sad.	http://www.zelenilo.com/i2.php?tabid=1&cid=589&portalid=1&a=readMore
	City of Belgrade	Secretariat for environmental protection. Maps Ambrosia in the territory of the City of Belgrade. Also drafts and implements plant and animal control programs; implements measures for and organizing and coordinating public animal hygiene, environmental awareness programs and projects; processing, systematization, storage of data and record-keeping relating to status tracking, quality-control	http://www.beograd.rs/cms/view.php?id=202038

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		and other environmental protection measures; informing the public and publishing data and information, issuing the Ekološki bilten (Environmental Bulletin). This Secretariat closely cooperate in its activities related to suppression and monitoring of alien invasive species, especially Ambrosia, with Sector for Environmental Protection Inspection Supervision (City Environmental Protection Inspectors) - inspection supervision responsibilities delegated to it, in the area of environmental protection.	
Switzerland	Federal Office	deals with legislation	
	Federal Office for Environment, Forests and Landscape (BAFU) - CRSF map - AGIN informs cantons	data map section comes under this department - CRSF and AGIN section informs cantons of issues, needs to control etc	www.csrf.ch Christian Bohren, Chair of National Ambrosia Control Working Group christian.bohren@rac.admin.ch
	Federal Department of Economy (includes Agriculture) - Agroscope (ACW) section - provides the knowledge on control measures ALP section does import controls on potentially contaminated grains		www.ambrosia.ch Christian Bohren
	Federal Office of Health	is reactive, not proactive, however, it is the health implications which have allowed others to organize a campaign so successfully.	www.ambrosia.ch Christian Bohren
	Cantons	provide the plant protection services to the communes (bit like regions and counties)	www.ambrosia.ch Christian Bohren
	Communes	day to day management - removal of any plants found by them or public in their areas	www.ambrosia.ch Christian Bohren
Ukraine	Ministry of Agrigultural Policy and Food	governmental responsibility. Developed State Programme 2012-2017 for fighting against Ambrosia	Volodymyr Domashlinets (Ministry of Ecology and Natural Resources of Ukraine)

ANNEX 4: Relevant stakeholders in developing an EWS: Scientific stakeholders (Task 8)

Country	***Scientific and other institutions dealing with Common Ragweed related issues***	***Description***	***Contact Details***
Austria	University of Natural Resources and Applied Life Sciences Vienna, Department of Integrative Biology and Biodiversity Research, Institute of Botany	Gerhard Karrer is project coordinator and project leader of several ragweed projects on state, national and international level. Together with several co-workers and graduates he works on the biological aspects of ragweed: spread, spreading mechanisms and vectors, weed control. They are also doing research on population genetics and on the seedbank of ragweed. They are more or less the national collectors of ragweed distribution data, which they are forwarding to the Federal Environment Agency for further processing and analysis.	Gerhard Karrer gerhard.karrer@boku.ac.at www.dib.boku.ac.at/botanik/ ragweed.boku.ac.at/ www.halt-ambrosia.de/index.php?menuid=1
	Federal Environment Agency (Umweltbundesamt), Dep. of Nature Protection	Nationally funded research institution. Author of the "Austrian action plan on invasive alien species" and other works on alien species. Partner in the nationwide invasive alien species project and also deals with the spread of ragweed, its reconstruction, and prediction, including under the influence of global warming. Coordinates the technical aspects of the national gathering of distribution data of ragweed.	Dr. Franz Essl franz.essl@umweltbundesamt Dr. Wolfgang Rabitsch wolfgang.rabitsch@umweltbundesamt.at www.umweltbundesamt.at/umweltschutz/naturschutz
	University Vienna, Faculty of Life Sciences, Faculty Centre of Biodiversity (head of the Floristic Mapping project of Austria (FMA))	The FMA is one of the most important data sources integrated in the ragweed distribution research of the Federal Environment Agency and the Institute of Botany of the University of Natural Resources and Applied Life Sciences Vienna.	Dr. Harald Niklfeld harald.niklfeld@univie.ac.at www.botanik.univie.ac.at/index.php
	AGES - Österreichische Agentur für Gesundheit und Ernährungssicherheit (Austrian Agency for Health and Food Safety)	This group is involved in the gathering of ragweed distribution data and data of related species. It does research on the ragweed seedbank, resistance to composting, the effects of herbicides, and they perform competition and mitigation experiments. Partner in the nationwide invasive alien species project.	Gerald Hackl Dr. Swen Follak DI Sabine Fersak www.ages.at
	Universität Salzburg, Christian Doppler Labor für	Doing research on the allergenicity of ragweed pollen, e.g. its geographic	Dr. Fatima Ferreira fatima.ferreira@sbg.ac.at

Country	***Scientific and other institutions dealing with Common Ragweed related issues***	***Description***	***Contact Details***
	Allergiediagnostik und therapie (Christian Doppler Laboratory for Allergy Diagnosis and Therapy)	variability. Partner in the nationwide invasive alien species project.	www.uni-salzburg.at/portal/page?_pageid=146,404957&_dad=portal&_schema=PORTAL
	AKH Allgemeines Krankenhaus bzw. Medizinische Universität Wien, Universitätsklinik für Hals-, Nasen- und Ohrenkrankheiten (Vienna General Hospital resp. Medical University of Vienna, Dep. of ear, nose and throat diseases)	Siegfried Jäger is a biologist working on ragweed-issues, especially the Austrian pollen monitoring system. He is probably the most engaged person in the ragweed problem in Austria and had initiated many activities. Jäger also does research on the correlation between pollen loads and allergy rates.	Dr. Siegfried Jäger siegfried.jaeger@univie.ac.at www.meduniwien.ac.at/hno
	Floridsdorfer Allergiezentrum (Vienna)	Wolfgang Hemmer, together with Ulrike Schauer and others, has conducted a comprehensive study about the prevalence of ragweed pollen allergy in east Austria on behalf of, and in cooperation with, the government of Lower Austria.	Dr. Wolfgang Hemmer hemmer@faz.at www.faz.at
	Vinca (Vienna Institute for Nature Conservation & Analysis)	Vinca is a private company. Together with the Federal Environment Agency it has researched the potential future spreading of ragweed under the influence of global warming.	Ingrid Kleinbauer Ingrid.Kleinbauer@vinca.at Dr. Stefan Dullinger Stefan.Dullinger@vinca.at www.vinca.at
	Lacon (Landscape Planning Consulting, Vienna)	Lacon has made some research on ragweed mitigation on behalf of the government of Lower Austria. They continually gathering distribution and ecological data on ragweed through their other projects.	DI Elisabeth Ransmayr ransmayr@lacon.at DI Gerhard Gawalowksi gawalowski@lacon.at www.lacon.at
Belgium	Institute for Nature and Forest Research (INBO)	Responsible for inventory, distribution mapping, floristics, monitoring in the Flemish region.	www.inbo.be
	National Botanic Garden of Belgium	Responsible for inventory, distribution mapping, floristics, monitoring.	www.br.fgov.be
	University of Gembloux, Ecology Lab	Responsible for pest risk assessment and research (management). The faculty performs a federally funded project 'Pest Risk Analysis for Invasive Alien Plant Species' (PRAVEG) for ragweed according to EPPO standard procedure OEPP PM5/3. The lab also performed experiments on seed germination of ragweed in 2008 and	Marie-Solange Tiébré tiebre.ms@fsagx.ac.be Prof. Grégory Mahy mahy.g@fsagx.ac.be www.fsagx.ac.be/ec

Country	***Scientific and other institutions dealing with Common Ragweed related issues***	***Description***	***Contact Details***
		has researched the vectors of introduction in Belgium. The faculty also has a project on management of invasive plant species (not including common ragweed), with comprehensive fact sheets for managers.	
	Brussels Environment (IBGE-BIM)	Responsible for inventory, distribution mapping, floristics, monitoring in the Brussels Capital Region.	www.ibgebim.be
	Airallergy (Belgian Aerobiological Surveillance Network)	Responsible for pollen monitoring.	www.airallergy.be
Bulgaria	Institute of Biodiversity and Ecosystem Research	Scientific institute in the Bulgarian Academy of Sciences	www.iber.bas.bg
	Plant Protection Institute	Scientific institute of agriculture science	www.ppi-bg.org
	Sofia University, Faculty of Biology	Scientific and education institution	www.uni-sofia.bg
	Medical University Sofia (incl. Department of Allergology)	Scientific and education institution	medfac.mu-sofia.bg/kca
	Laboratory of Allergy, National Center of Infections and Parasitic Diseases	Public health institution	www.ncipd.org/?category=7&section=12
Croatia	Faculty of Agriculture, Zagreb University		www.pmf.unizg.hr/bz/en
	Faculty of Science Botanic Department, Zagreb University	Collects information on flora, including the invasive alien species. The data is stored in Flora Croatica Database.	www.agr.unizg.hr/index_eng.htm
	Faculty of Agriculture, Osijek University		www.pfos.hr/eng/index.php
	Institute Ruđer Bošković	It is the largest multidisciplinary research centre in Croatia with strengths in basic science and applied science research.	www.irb.hr/en
Czech Republic	Institute of Botany, Academy of Science of the Czech Republic (ASCR)	This is research institutes does fundamental research on species, populations, and communities of plants. Currently, it is especially concerned with biodiversity and evolutionary trends among plants, ecology of invasive species, responses of plants and vegetation to environmental changes, and the mechanisms that enable species to coexist in ecosystems.	www.ibot.cas.cz
	Department of Invasion Ecology, ASCR	This is part of Institute of Botany at ASCR. It studies biology and ecology of invasives,	www.ibot.cas.cz/invasions/index.htm

Country	***Scientific and other institutions dealing with Common Ragweed related issues***	***Description***	***Contact Details***
		as well as introduced and naturalized species. In addition, it is studying the effects of introduced species on native flora and communities. The department is a member of ALARM, DAISIE and PRATIQUE projects.	
	Department of Botany, Faculty of Science University of South Bohemia	Research and teaching covers various botanical disciplines, including the taxonomic and eco-physiological aspects of plants, plant populations and communities, their ecosystems, and invasive plants.	botanika.prf.jcu.cz/invaze
Denmark	Danish Environmental Research Institute	Responsible for plant monitoring program and specific scientific research in relation to invasive species.	www.dmu.dk
	Forest and Landscape Institute	Involved in reporting and research on plant species, including invasive species. The faculty are under the University of Copenhagen	www.sl.life.ku.dk/Soegeresultat.aspx?q=invasive%20arter
	Botanical Institute, University of Copenhagen	Involved in reporting and research on plant species, including invasive species.	www1.bio.ku.dk
	Botanical Institute, University of Aarhus	Involved in reporting and research on plant species, including invasive species.	biology.au.dk
France	French National Institute for Agricultural Research (INRA)	Their research focuses on worldwide challenges related to food and nutrition, the environment and land use facing the world of agriculture and agronomics today.	Bruno Chauvel +33(0)3.80.69.30.39 bruno.chauvel@dijon.inra.fr http://www.international.inra.fr/
	UMR	The Biology and Management of Weeds unit brings together ecologists, geneticists and agronomists to study weeds. Their mission is to analyze the diversity of weeds and their evolution in response to changes in agriculture. Their aim is to bring together basic and applied knowledge required for integrated management of weed infestations, restricting the use of herbicides, and the environmental impacts of farming systems.	François Bretagnolles francois.bretagnolle@dijon.inra.fr www2.dijon.inra.fr/bga/umrbga2009
	French Agency for Food, Environmental and Occupational Health & Safety (ANSES)	They conduct missions in areas of surveillance, expert appraisal, research and reference in a wide range of fields including human health, animal health and well-being, and plant health. They	Guillaume Fried www.anses.fr/index.htm

Country	***Scientific and other institutions dealing with Common Ragweed related issues***	***Description***	***Contact Details***
		provides a cross-functional perspective on health issues and can identify, overall, the risks to which people are exposed through their lifestyles and consumption patterns, as well as through the characteristics of their environment, including in the workplace.	
	Le Rèseau National de Surveillance Aérobiologique (RNSA)	The network's main purpose is to study how the contents of biological particles in air affect people with allergies. This includes a study of the content of the air pollen, mold, and the associated clinical data collection.	Michel Thibaudon www.pollens.fr/accueil.php
	Association Française d'Etude des Amroisies (AFEDA)	The French Association for Ragweed Study published a book that discusses modern dealing with ragweed and its health implications.	Chantal Déchamp afeda@wanadoo.fr
	Telédétection		
Germany	Freie Universität Berlin Institut für Meteorologie WG Ambrosia	Responsible for the Berlin-Brandenburg ragweed atlas	http://www.fu-berlin.de/ambrosia Th. Dümmel FU Berlin, Institut für Meteorologie Carl-Heinrich-Becker Weg 6-10 12165 Berlin E-Mail: ambrosia@met.fu-berlin.de www.fu-berlin.de/ambrosia
	Julius Kühn Institut Federal Research Centre for Cultivated Plants	He has been working on ragweed for years and is one of the co-organizers of the action program ragweed	Julius Kühn Institut (JKI) Bundesforschungsinstitut f. Kulturpflanzen Messeweg 11/12 38104 Braunschweig Dr. Uwe Starfinger
	Projektgruppe Biodiversität und Landschaftsökologie	It has been active in ragweed research for many years and is mostly responsible for research in the context of the ragweed program in Bavaria, did some research in Hessen too	Dr. B. Alberternst & St. Nawrath Hinter'm Alten Ort 9 61169 Friedberg Projektgruppe@online.de www.ambrosiainfo.de

Country	Scientific and other institutions dealing with Common Ragweed related issues	Description	Contact Details
	Projektgruppe Botanischer Garten und Botanisches Museum der FU Berlin Botanischer Garten und Botanisches Museum Berlin-Dahlem	A member of the network for the Berlin action program against ragweed	Freie Universität Berlin Königin-Luise-Strasse 6-8 14195 Berlin G. Hohlstein g.hohlsten@bgbm.org
	UfU e.V. Halle/Saale (Independent Institute for Environmental Issues)	This group did some work about invasive alien species in Saxony-Anhalt	Katrin Schneider http://www.ufu.de/en/home.html
	Universität Frankfurt, Abteilung Ökologie und Geobotanik; Institut für Ökologie, Evolution und Diversität	Junior-Professor for Ecology and Biogeografy at the Institute of Ecology, Evolution & Diversität at the Goethe-University Frankfurt	Oliver Tackenberg Institute of Ecology, Evolution & Diversity, Department of Ecology and Geobotany Siesmayerstr. 70 D-60323 Frankfurt am Main
	Brandenburgisch Technische Universität Cottbus	research project: GIS-based mapping of ragweed in Cottbus	Dr. Udo Bröring, Rene Grube Lehrstuhl Allgemeine Ökologie Brandenburgische Technische Universität Cottbus Postfach 101344 03013 Cottbus broering@tu-cottbus.de
	TU Berlin, Department of Ecology	With regards to the dispersal of ragweed along roads in Brandenburg	Andreas Lemke Rothenburgstr. 12 D-12165 Berlin andreas.lemke@mailbox.tu-berlin.de
Italy	Italian Botanic Society and Interuniversity Research Centre "Biodiversity, Plant Sociology and Landscape Ecology"	The project "A survey of the non-native flora of Italy," was developed in the years 2005–2008 and aimed at reporting on the current status of the non-indigenous species in the country. This program yielded a comprehensive inventory of the non-native vascular flora and related information on the distribution, status, and impact of each non-native species in the 21 administrative regions in Italy.	franco.bruno@uniromal.it sweb01.dbv.uniroma1.it/Ricerche_DBV/censimento_della_flora_esotica_in_italia_e_caratte.html
	Istituto Beni Culturali - Regione Emilia-Romagna	Data gathering on distribution and status in Emilia Romagna region. A database is being developed pertaining to the common ragweed in Emilia Romagna region.	Dr. Alessandro Alessandrini Tel: +39 0515276159

Country	Scientific and other institutions dealing with Common Ragweed related issues	Description	Contact Details
	Università di Pisa, Dipartimento di Biologia, Unità di Botanica generale e sistematica	Data gathering on distribution and status in Tuscany	Prof. Lucia Viegi Tel: + 39 0502211326 lviegi@vet.unipi.it lviegi@biologia.unipi.it
	Università di Torino, Dipartimento di Biologia Vegetale	Data gathering on distribution and status in Piedmont and Valle d'Aosta.	Prof. Consolata Siniscalco, PhD Tel: +39 0116705970
	Emanuele Del Guacchio	Data gathering on distribution and status in Campania. Del Guacchio authored the unpublished "Flora esotica della Campania" with La Valva.	edelgua@email.it
	Nello Biscotti	Data gathering on distribution and status in Puglia (Gargano).	www.vglobale.it/index.php?option=com_content&view=article&id=251&catid=305%3Acomplementari&Itemid=121&lang=it&showall=1
	Università degli Studi di Trieste, Dipartimento di Scienze della Vita	Data gathering on distribution and status in Friuli Venezia Giulia.	Prof. em. Livio Poldini Tel: +39 0405588713 poldini@units.it
	Museo di Storia Naturale di Milano, Sezione di Botanica	Data gathering on distribution and status in Lombardy.	Dr. Gabriele Galasso Tel: +39 0288463327 gabriele.galasso@comune.milano.it www.comune.milano.it/museostorianaturale
	Università di Roma, Tor Vergata	Monitoring activities on single known population present in Lazio (Rome).	Dr. Alessandro Travaglini Tel: +39 0672594342 Alessandro.travaglini@uniroma2.it
Hungary	Plant protection Institute of Hungarian Academy of Sciences, Dept. Plant Pathology	Effect of aphid species on the development of ragweed, effect of mowing on ragweed	Levente, Kiss Tel: +36 014877566 lkiss@nki.hu www.nki.hu/en
	Plant protection Institute of Hungarian Academy of Sciences, Department of Zoology	Plant virology	Gábor, Jenser Tel: +36 013918641 jenserg@julia-nki.hu www.nki.hu/en
	University of Pannonia, Georgikon Faculty of Agricultural Sciences	Plant virology	András, Takács +36 083545000 dh@georgikon.hu www.labome.org/expert/hungary/georgikon-faculty-of-agricultural-sciences-23901.html

Country	***Scientific and other institutions dealing with Common Ragweed related issues***	***Description***	***Contact Details***
	University of Pannonia, Georgikon Faculty of Agricultural Sciences, Institute for Plant Protection	Ragweed phenology, population biology, ragweed germination	Imre, Béres, Éva, Lehoczky +36 083545000 dh@georgikon.hu www.labome.org/expert/hungary/georgikon-faculty-of-agricultural-sciences-23901.html
	University of Kaposvár, Faculty of Animal Science, Dep. of Botany and Plant production	Competition between ragweed and crops, allelopathic effects.	Dr. Gabriella, Kazinczi +36 0682505800 Kazinczi.gabriella@ke.hu
	National Institute of Environmental Health	Pollution of ragweed, pollen concentration, air pollen monitoring-network.	Anna, Páldy, Dóra, Apatini Tel: +36 014761100 http://oki.wesper.hu/eng
	Hospital of the Hospitaller Brothers in Buda	Ragweed allergy.	Kristóf, Nékám Tel: +36 103350915 nekamkr.allergy@mail.datanet.hu
	Institute of Geodesy, Cartography and Remote Sensing (FÖMI)	Ragweed monitoring by remote sensing.	Gábor, Mikus Tel: +36 014604229 mikus.gabor@fom.hu www.fomi.hu
	University of West-Hungary, Faculty of Agricultural and Food Sciences	Herbicide control of ragweed.	Péter, Reisinger, Gábor, Kukorelli +36 099518100 www.uniwest.hu/index.php/2373
	University of West-Hungary, Faculty of Agricultural and Food Sciences	Distribution of ragweed in agricultural areas.	Gyula, Pinke, +36 099518100 www.uniwest.hu/index.php/2373
	Institute of Ecology and Botany, Hungarian Academy of Science	Ragweed ecology in non-crop habitats.	György, Kröel-Dulay, PhD +36 028360122 gyuri@botanika.hu
	University oy Szeged, Dep. of Climatology and landscape Ecology	Effect of meteorological variables on ragweed pollen.	Dr. László, Makra Tel: +36 062 544856 makra@geo.u-szeged.hu
	Hungarian Land Administration (Földhivatal)	The official on-site inspection in rural areas is the duty of the Land Office staff.	László, Jordán www.foldhivatal.hu
Latvia	Institute of Biology of the University of Latvia	Collection of specimen for the herbarium, including a casual collection of *A.artemisiifolia* specimen.	Dr Viesturs Šulcs Tel: +371 67945438 vsulcs@email.lubi.edu.lv www.lubi.edu.lv

Country	***Scientific and other institutions dealing with Common Ragweed related issues***	***Description***	***Contact Details***
	Faculty of Geography and Earth Sciences of the University of Latvia	Analyses of pollen distribution of *A.artemisiifolia*.	Olga Ritenberga Tel: +371 67331766 olga.ritenberga@lu.lv www.geo.lu.lv
Moldova	Botanical Garden (Institute) of Academy of Sciences -Chisinau		Prof.Teleuta Alexandru +373 22550443 director@gb.asm.md www.gradinabotanica.asm.md
	Botany Society of the Republic of Moldova		
The Netherlands	Floron (Foundation for flora research of the Netherlands)	Floron coordinates and stimulates volunteers that are involved in national inventories of wild flora. It provides education, advice, conducts ecological research in support of science, management and policy and it protects plants and their habitats. Floron has conducted (together with the Natuurkalender) a study on the status and trends of A. artemisiifolia in the Netherlands and derived recommendations for its eradication.	Baudewijn Odé Stichting FLORON Postbus 9010 6500 GL Nijmegen Telefoon: (+31) - 024 7410573 E-mail: info@floron.nl
Poland	Department of Environmental Biology, University of Rzeszów	Conducts studies on pollen concentrations in the air and directions of possible transport, especially in southern, eastern and central Poland. The concentration of pollen was also compared to weather conditions. Cooperation with Medical College of Jagiellonian University and Adam Mickiewicz University.	Idalia Kasprzyk idalia@univ.rzeszow.pl
	Faculty of Earth Sciences, University of Silesia	An assessment of ragweed pollen threat, especially in Upper Silesia (southern Poland).	Kazimiera Chłopek; kazimiera.chlopek@us.edu.pl
	Department of Plant Systematics, University of Silesia	Studies population biology and ecology of common ragweed in existing localities in southern Poland and molecular aspects of ragweed distribution and spread in Poland.	Barbara Tokarska-Guzik +48 322009479 barbara.tokarska-guzik@us.edu.pl prac.us.edu.pl/~zbs/ZBS/kontakt.html
	Department of Botany, University of Life Sciences, Lublin	Studies on ragweed pollen concentration in the air and on ecological features of common ragweed flowers.	Elżbieta Weryszko-Chmielewska elzbieta.weryszko@up.lublin.pl

Country	Scientific and other institutions dealing with Common Ragweed related issues	Description	Contact Details
	Laboratory of Aeropalynology, Adam Mickiwicz University, Poznań.	Monitors pollen and fungal spore concentrations (e.g. ragweed species), conducts phenological observations of selected allergenic plants in the Wielkopolska region, and investigates the impact of pollen on human health.	www.hialine.com/en/adam-mickiewicz-university.php
	Department of Botany and Nature Conservation, University of Szczecin, Szczecin, Poland	Studies of pollen concentration (e.g. ragweed) in the air in Szczecin.	Małgorzata Puc mapuc@univ.szczecin.pl
Romania	Banat's University Of Agricultural Science And Veterinary Medicine Timisoara, Faculty Of Agriculture	Maintains inventory of invasive plant species from western Romania. Also evaluates the dynamics and impacts of fast tools on the vegetation.	Dr. Sărățeanu Veronica www.usab-tm.ro/USAMVB-T_Facultatea-de-Agricultură_ro_2.html
	Banat's University Of Agricultural Science And Veterinary Medicine Timisoara, Faculty Of Agriculture	Conducts research project related to analysis of airborne common ragweed pollen in western part of Romania.	Dr. Ianovici Nicoleta www.usab-tm.ro/USAMVB-T_Facultatea-de-Agricultură_ro_2.html
	University Of Agricultural Science And Veterinary Medicine "I.I. De La Brad" Iasi	Conducts research on migration and invasion of adventive plants in some natural and manmade habitats in Moldova (Romania).	Dr. Culita Sarbu
	University of Oradea, Faculty of Environmental Protection	Conducts research on A. artemisiifolia distribution.	Dr. Nicolae Hodisan hodisann@yahoo.com
	University of Bucharest, Dept. of Botany and Microbiology	Conducts studies related to invasive species in Romania (DAISIE project collaborator).	Dr. Paulina Anastasiu anastasiup@yahoo.com
	Romanian Ecological Society	Conducts literature reviews and field observations.	Prof. Marin Andrei www.romanianecologicalsociety.ro/home.php
Serbia	Institute for Nature Protection of Serbia	Monitoring of alien invasive species and their impact on biodiversity.	+38111/2093-801 beograd@zzps.rs www.natureprotection.org.rs
	Provincial Institute for Nature Protection of AP Vojvodina	Monitoring of alien invasive species and their impact on biodiversity in AP Vojvodina.	+38 021 4896 301 novi.sad@pzzp.rs www.pzzp.rs
	University of Belgrade Faculty of Agriculture, Institute for Phytomedicine, Department for Pesticides	Conducts research activities related to invasive alien species and weeds in agriculture lands.	+38 02196 131 izbpfz@agrif.bg.ac.rs www.agrif.bg.ac.rs/cathedras/view/17
	University of Novi Sad, Faculty of Agriculture, Department for	Laboratory for Invasive and Quarantine Weed Species is involved in the project for the City of Novi Sad titled, "Mapping	Dr. Branko Konstantinovic +38 021/4853-319 brankok@polj.uns.ac.rs

Country	***Scientific and other institutions dealing with Common Ragweed related issues***	***Description***	***Contact Details***
	Phytomedicine and Environmental Protection	the terrain under the Ambrosia and other allergenic plants, laboratory and field research and monitoring," as well the project for the Autonomous Province of Vojvodina titled, "Prevention program for Ambrosia suppression in the territory of Autonomous Province of Vojvodina." The main activities within the project include identifying the presence of ragweed and other allergenic species, distribution, mapping, prevention and suppression (mechanical and chemical), monitoring emergence of new and subsequent generations, investigation of herbicide efficiency and the emergence of resistance.	polj.uns.ac.rs/~korovi/engleski/home.html
	University of Novi Sad, Faculty of Science, Department for Biology and Ecology	The Laboratory for Ragweed and Other Allergenic Plants focuses on monitoring populations of allergenic plants, tracking the spreading mechanisms of allergenic plants, researching activities related to ecological plasticity of allergenic plants, research of systems for mechanical and biological actions against allergenic invasive plants, cooperation with local government institutions in monitoring, and prevention of allergenic plants.	Prof. Dr. Boža Pal +381 21 485 2663, boza.pal@dbe.uns.ac.rs www.dbe.pmf.uns.ac.rs/ambrozija/index.html
	Institute for Pesticides and Environmental Protection	The Laboratory for Herbology participated in projects related to mapping Ambrosia in different municipalities in the City of Belgrade. The laboratory was also the quality control coordinator for the implementation of measures to combat and destroy weeds and ragweed in the territory of the City of Belgrade. They also conduct research and experimental development in biotechnical sciences as well as study the biological and other characteristics of all organisms important for phytomedicine, environment protection and public health. This includes the study of biological, ecological, and other characteristics of weeds and their communities as well as the effects of pesticides and other toxicants on	Dr. Vladan Jovanović vladan.jovanovic@pesting.org.rs www.pesting.org.rs

Country	Scientific and other institutions dealing with Common Ragweed related issues	Description	Contact Details
		organisms and the environment.	
	Institute for Plant Protection and Environment	Responsible for the biological control of weeds.	Tel: +381 11 266-00-49 office@izbis.org.rs www.izbis.com/odsek-za-stetocine-bilja.html
	Institute of Field and Vegetable Crops of Novi Sad	The research programs are primarily centered on the development of field and vegetable crop cultivars, including forage and industrial crops, medicinal plants and spice herbs. The breeding programs place emphasis on high yielding capacity, tolerance to major diseases, and resistance to unfavorable biotic and non-biotic factors.	Tel: +381 (021) 4898 100 institute@nsseme.com www.nsseme.com/en/
	The Maize Research Institute at Zemun Polje Department for Cropping Practices	The Weed Laboratory investigates the modes of control of the most noxious weeds within the ecosystem of maize and soybean, as well, as ecological safety of the application of certain measures of weed suppression. Studies are undertaken to develop integrated weed management as well as the effectiveness of herbicides in suppression of new weeds in maize, soybean and sunflower crops. The response of commercial maize inbred lines to herbicides is also evaluated for their safe application in seed maize production.	+381 11 37 56 704 mri@mrizp.rs www.mrizp.co.rs/index-en.php
	The Plant Protection Society of Serbia	The main activities are organizing scientific and professional meetings, lectures, and seminars pertaining to education and exchange of knowledge about current issues and solutions in the field of protection of cultivated plants and forestry. The Society publishes scientific, professional and similar publications dealing with plant protection.	Tel: +381 (0)11 3160-991 plantprs@eunet.rs www.plantprs.org.rs/?lang=sr&topicgroup=about&topic=society&subtopic=
	Serbian Herbological Society (the Serbian Weed Science Society)	Scientific organization and the members deal with problems related to weeds, herbicides and all other scientific problems regarding weeds, measures for weed suppression, monitoring and investigations.	

Country	***Scientific and other institutions dealing with Common Ragweed related issues***	***Description***	***Contact Details***
Switzerland	Agroscope (ACW)	This is part of the Federal Department of Economy, which includes Agriculture. The work relates to the control of all invasive plants and deals with crop research in general.	Christian Bohren Tel: +41 22 363 44 25 Christian.bohren@rac.admin.ch
Ukraine	Institute of Botany of National Academy of Science of Ukraine		Tel: +38 (044) 2344041 inst@botany.kiev.ua www.botany.kiev.ua/index_eng.htm

ANNEX 5: Relevant stakeholders in developing an EWS: Other stakeholders (Task 8)

Country	*Other stakeholders dealing with Common Ragweed related issues*	*Description*	*Contact Details*
Austria	Rolf Diran, Vegeterra (Vienna)	Rolf Diran does not specifically deal with ragweed; however, he is generally watching the spreading and establishment of neophytes especially in eastern Austria, often documenting them with phytosociological relevés. Moreover he is the author of the "Synopsis of Central European Vegetation", a phytosociological database which provides comprehensive information on the ecology and sociology of plants, and which actually includes more than 300 relevés in which ragweed occurs.	diran@vegeterra.at
	UMG Umweltbüro Grabher, Bregenz (Vorarlberg)	Public relations, author of the website "neophytes in Vorarlberg".	http://umg.at http://www.neophyten.net/
	inatura Erlebnis Naturschau GmbH Dornbirn (Vorarlberg)	Public relation, author of an Ambrosia-website and -folder.	http://www.inatura.at/Ragweed-Beifussblaettrige-Ambr.6062.0.html?&type=100
Bel	No data provided		
Bulgaria	Bulgarian Biodiversity Foundation	Non-governmental organization that is publishing the Conspectus of the Bulgarian Vascular Flora with species distribution maps. It has capacity to manage large scale conservation projects.	http://bbf.biodiversity.bg
Croatia	Various local NGOs. E.g. NGO for fighting Ambrosia in Virovitica	NGO organizes public activities of control and eradication as well as raising public awareness, education events and publications etc.	http://www.ambrozija.hr/
Czech Republic	Czech Union for Nature Conservation (ČSOP)	ČSOP is a civic association of people who share an active interest in nature conservation and the environment. Its mission is to protect and restore nature, the landscape and the environment, to promote environmental education, and support sustainable living. ČSOP is a member of IUCN and is a founding member of the UNEP Czech National Committee.	http://www.csop.cz/
	eAGRI (Farmer portal)	The data register and the farmers applications for Ministry of Agriculture.	http://eagri.cz/public/web/mze/farmar/
	Regional councils of regions in the Czech Republic	Regional authorities executing state administration. These are divided into sections and departments, including environment and health service.	http://www.statnisprava.cz/rstsp/ciselniky.nsf/i/d0045
	Ministry of Agriculture	This is a central authority of state administration for agriculture and is the authority for trading commodities coming from the agricultural industry and plant-care.	http://eagri.cz/public/web/en/mze/ministry/

Country	Other stakeholders dealing with Common Ragweed related issues	Description	Contact Details
Denmark	Danish Botanical Society	NGO based on an interest in plant species. Distributes the magazine "Urt" to members with articles on plant species, including invasive species	www.botaniskforening.dk
	Danish Asthma and Allergy Association	NGO based on interest in allergy, eczema, hayfever, and COPD. The organization provides information on pollen-allergy and uses campaigns to distribution information. Until now there has not been a campaign on Common Ragweed.	http://www.astma-allergi.dk/home
	Danish Association on Nature Protection	NGO based on general interest in nature protection. Produces magazine "Natur og miljø" with articles on plants, species, landscapes, nature protection, etc, including invasive species	www.dn.dk
France	Agence Regional de Sante	Website provides general information to the public about common ragweed, including control, removal, and health effects.	http://www.ars.rhonealpes.sante.fr/Ambroisie.91569.0.html
	Observatoire Regional de la Sante	A multidisciplinary organization whose purpose is to improve information on health status and needs of the regional population.	http://www.ors-rhone-alpes.org/
Germany	Stiftung Deutscher Polleninformationsdienst	Provides information about ragweed, particularly pollen flight.	www.pollenstiftung.de
	Landwirtschaftliches Technologiezentrum (LTG) Augustenberg (Agricultural Technology Center)	Provides information to hobby gardeners.	www.ltz-bw.de
Hungary	Ragweed round table	Forum of the governmental, non-governmental organizations, and parliament. It has a meeting about every quarter year. It can make suggestions to the parliament in order to make new or correct the already existing laws and decree	No contact details provided.
	Sustainable development committee of Parliament	Official forum of the parliament with different items on the agenda. In 2011 the new strategy against ragweed was one of the items.	No contact details provided.
Italy	Arpa Piemonte (in collaboration with the Dept. of Plant Biology of the Torino University)	They directs regional monitoring network of pollen and fungine spore and provides information on pollens and allergies in the region, including an updated weekly bulletin. They are also available for the identification of plants either collected or photographed by citizens.	Dr.ssa Maria Maddalena Calciati Email: m.calciati@arpa.piemonte.it annaangela.saglia@regione.piemonte.it

Country	***Other stakeholders dealing with Common Ragweed related issues***	***Description***	***Contact Details***
	Italian Association of Aerobiology	This coordinates the Italian Network for Aerobiology Monitoring (R.I.M.A.®). The network is comprised of Monitoring Centers distributed in all national territories and are regularly active.	Studio Marchetti Tel: +39 3346382437 Email: info@ilpolline.it www.ilpolline.it/ www.ilpolline.it/speciale-ambrosia-2010/
	Associazione Allergologi e Immunologi Territoriali ed Ospedalieri (Association of Allergology and Immunology) (A.A.I.T.O.)	This organization has a section for “Aerobiology, Ecology and Environmental Prevention” that manages the Italian Network for Monitoring Atmospheric pollens and fungine spores. In 2003 30 centers distributed all over Italy were part of the network. The network provides information on pollens and allergies in all regions, including an updated weekly bulletin.	www.pollinieallergia.net/bollettino-pollini.php
	Fondazione Edmund Mach (Istituto Agrario di San Michele all’Adige) - Centro di Monitoraggio Aerobiologico	Information on pollens and allergies in Trento, including an updated weekly bulletin. They monitore ragweed pollen concentration and trends and carries out biomolecular identification of allergenic pollen. It is possible to download historical data and graphics.	www.iasma.it/servizi_context2.jsp?ID_LINK=112&area=6
	POLLnet - Italian Network of Aerobiological Monitoring	POLLnet is an institutional network for aerobiological monitoring included in the system of Environmental Agency and is part of the National Environmental Information System (SINAnet) under the Institute Superior for the Environmental Protection and Research (ISPRA), which is part of a system of Environmental Agencies for 19 regions and 2 provinces as regulated by relevant laws. Provides information on pollens and allergies, including a weekly bulletin.	www.pollnet.it/default_it.asp
	Milano Municipality	The Environmental Policy sector has implemented a service dedicated to the validation of ragweed records made by citizens. A surveillance team of Local Ecological Police is also established to verify and confirm the records and implement the needed containment measures.	Tel: +39 288464472 DC.Salute@comune.milano.it sal.polsalute@comune.milano.it
	National Research Centre (CNR)	A national/regional network for monitoring allergens in the air and measuring the main allergenic pollens. The monitoring activities are organized by the Institute of Science of the Atmosphere and Climate of the Bologna CNR (Isac-CNR), in collaboration with the Italian Association of Aerobiology. The network includes about 90 sampling sites in the country and is linked to the European Aeroallergen Network (EAN).	www.epicentro.iss.it/problemi/asma/pollini.asp

Country	Other stakeholders dealing with Common Ragweed related issues	Description	Contact Details
Latvia	Dr. Agnese Priede, Nature Conservation Agency	Expert in invasive species	Tel: +37 129640959 E-mail: agnese.priede@daba.gov.lv
	Councils of local authorities	According to the law, local authorities are responsible for elimination measures in the corresponding areas	Contact details of all local authorities are available at www.lps.lv
Moldova	Local Authorities (City Halls)	City Halls through Department of Environmental Protection are involved in public awareness activities especially in areas where A.artemisiifolia occupy large territories (e.g. south-eastern part of Moldova).	No contact details provided.
	NGOs		No contact details provided.
The Netherlands	De Natuurkalender (Phenology Observation Network)	This network of cooperating organizations facilitates the collection and sharing of observations of ecological changes in connection to phenology and climate. A component of the network focuses on connection of observation and occurrence of hayfever, which includes specific attention to flowering of A. artemisiifolia	De Natuurkalender T.a.v. Arnold van Vliet Wageningen Universiteit Leerstoelgroep Milieusysteemanalyse Postbus 47 6700 AA Wageningen E-mail: natuurkalender@wur.nl
Poland	Allergen Research Center	Measurement of concentration of aeroallergens in majority of cities in Poland.	Tel. +48 228650800 www.obas.pl
	General Directorate (and Regional Directorates) for Environmental Protection	Provides information about common ragweed and other invasive alien species distribution/spread.	Tel.: +48 225792900 E-mail: kancelaria@gdos.gov.pl www.gdos.gov.pl/Articles/view/1889/Kontakt
Romania	Local Authorities (City Halls)	City Halls through Department of Environmental Protection are involved in public awareness activities especially in areas where A.artemisiifolia occupy large territories (e.g. western part of Romania)	No contact details provided.
	NGOs		No contact details provided.
Serbia	City of Belgrade, Municipality of New Belgrade	They manage a project on suppression and destruction of Ambrosia since 2009. Citizens volunteer to be trained and participate with the symbolic compensation. The city also handles reports from other citizens about sightings and destruction of weeds.	Tel: +38 1113106702 Email: zivotnasredina@novibeograd.rs www.beograd.rs/cms/view.php?id=1245270

Country	***Other stakeholders dealing with Common Ragweed related issues***	***Description***	***Contact Details***
	Agricultural Advisory Service of the Autonomous Province of Vojvodina	Section for Plant Protection advises farmers how to deal with problems related to ragweed, organizes lectures and trainings, and supports combat actions. In AP Vojvodina there are 12 Advisory Services in cities and municipalities.	www.polj.savetodavstvo.vojvodina.gov.rs/katt/teme/zastita-bilja?page=18
	Department of Agriculture "STIG" Požarevac	Maps and proposes suppression measures in the municipality of Pozarevac, Velika Plana and Žabari. A previous project involved determining the presence of ragweed in the Municipality of Pozarevac, mapping the presence of hot spots, carrying out prevention measures in the crops, and preventing pollination during flowering time.	arhiva.glas-javnosti.rs/arhiva/2006/07/29/srpski/IS06072806.shtml
Switzerland	Federal Council	The highest government body	www.ambrosia.ch
	Cantons	The regional government bodies	No contact data provided.
	Communes	The local government	www.ambrosia.ch
	Meteo Swiss	This organization records and forecasts pollen.	www.meteoswiss.ch
	Federal Office of Transport (ASTRA)	They are responsible for control along highways and fund part of ragweed campaigns.	www.astra.admin.ch
	Federal Office for Environment, Forests and Landscape (BAFU)	This government department deals with the environment at a federal level	www.environment-switzerland.ch
	Ambrosia groups	These multidisciplinary help coordinate and implement strategy from Agroscope.	www.ambrosia.ch
	Agroscope (AWC)	Work relates to control of all invasive plants in Switzerland. Group deals with crops in general.	www.acw.admin.ch
	AHA - asthma association	Provides information regarding pollen allergies, including symptoms, treatment, and prevention.	www.aha.ch
Ukraine	Various experts that deal with the floras of different regions	They work in different regional universities and botanical gardens and collect data on the distribution of ragweed. However, this is not the main goal of their work.	No contact details provided.

Annex 6: Overview of national databases on (invasive alien) species (Task 8)

8.3.1 DAISIE

Full name:	Delivering Alien Invasive Species Inventories for Europe
Website:	http://www.europe-aliens.org
Language:	English
Updated:	On an ad-hoc basis and only for a few organism groups since the end of the FP6 project in 2008 that formed the basis of the database.
Geographical coverage:	DAISIE covers invasive species information from the wider European area (up to 94 countries/regions). It covers all EU-27 states and Norway.
Species coverage:	The database contains 10961 alien taxa and covers vertebrates, invertebrates, marine and inland aquatic organisms as well as plants for all environments.
Data provision:	Contributors to the DAISIE system are an international group of experts, 44 institutes from 30 countries. The system also gets data from mining other databases like NOBANIS ea.
Accessibility:	The DAISIE website provides three ways to access the species information: • Search for information on one of the 10961 alien species occurring in Europe • Search for one of the 2075 experts on biological invasions in Europe • Search regions to explore the alien species threats across Europe, for 69 countries/regions (including islands) and 55 coastal and marine areas.
Reliability:	The provided information can be considered reliable based on the sources. The ad hoc character of the current maintenance and the fact that only certain organism groups are being updated diminish the reliability considerably.
Information:	The DAISIE website provides general species information including scientific name, common names in different languages and also synonyms. It also gives the user an overview of the geographical distribution of the species (indicating if they are invasive or not in the specific country), and an overview of contributors of the species information and background links.
Common Ragweed included	Yes
Note:	The DAISIE system provides the user with a list of '100 worst' invasive species in Europe.

8.3.2 NOBANIS

Full name:	North European and Baltic Network on Invasive Alien Species
Website:	http://www.nobanis.org/
Language:	English
Updated:	Regularly. National focal points in each of the participating countries ensure the information is accurate and up-to-date.
Geographical coverage:	20 countries in Northern and Central Europe: Austria, Belarus, Belgium, Czech Republic, Denmark, Estonia, Finland, Faroe Islands, Germany, Greenland, Iceland, Ireland, Latvia, Lithuania, the Netherlands, Norway, Poland, European part of Russia, Slovakia and Sweden.
Species coverage:	The database contains over 6000 alien taxa and covers all organism groups and environments.
Data provision:	The data in the NOBANIS database is extracted from national databases, provided to the NOBANIS database by experts through the national focal points and from alien species projects and programmes.
Accessibility:	The data in the NOBANIS database can be accessed through a search function on the website.

	Users can search for specific species and through categorized listing on country, organism group and habitat.
Reliability:	Based on the data sources and maintenance of the NOBANIS system, the information provided by the NOBANIS database can be considered to be reliable.
Information:	The NOBANIS website provides general species information including scientific name, common names in different languages, synonyms and habitats. It also provides maps with invasiveness and frequency of the species. Furthermore, the NOBANIS system provides factsheets about the species with a wide spread of information regarding species identification, native range, alien distribution, ecology, health effects, management approaches and references.
Common Ragweed included	Yes
Note:	The NOBANIS system provides the factsheet in PDF format.

8.3.3 GISD

Full name:	Global Invasive Species Database
Website:	http://www.issg.org/database/welcome/
Language:	Main search interface is provided in English and Chinese. Species information is mainly English, but also available in other languages.
Updated:	Regularly. Managed by the Invasive Species Specialist Group (ISSG) of the Species Survival Commission of IUCN.
Geographical coverage:	Global coverage.
Species coverage:	The database currently contains 853 alien taxa and covers all organism groups and environments.
Data provision:	Data is provided to the GISD system by a network of experts.
Accessibility:	The data in the GISD database is accessible through the search engine on the website. Users can search for specific species and through categorized listing on country, habitat and organism group.
Reliability:	Based on the data sources and maintenance of the GISD system, the information provided by the GISD database can be considered to be reliable.
Information:	The GISD website provides general species information including scientific name, common names in different languages and also synonyms. It also contains information on the identification of the species, habitat descriptions, geographical range, impacts, distribution, disposal methods, management information and appropriate refrences.
Common Ragweed included	Yes
Note:	The homepage of the GISD website provides a quick link to the 100 worst invasive species.

8.3.4 GBIF

Full name:	Global Biodiversity Information Facility
Website:	http://data.gbif.org/welcome.htm
Language:	English and French

Updated:	Regularly
Geographical coverage:	Global
Species coverage:	The GBIF database covers Animalia, Archaea, Bacteria, Chromista, Fungi, incertae, Plantae, Protozoa and Viruses. It contains more than 1000 records for each kingdom except for Viruses (493).
Data provision:	Data to the GBIF system is being provided by experts through affiliated institutions that make their datasets accessible to the GBIF system.
Accessibility:	The data in GBIF can be accessed through the search engine that lets the user search on species, country or specified dataset. Also, users can explore the database based on species, country or specified dataset.
Reliability:	The data can be assumed very reliable as it is provided by experts and institutes and regularly updated.
Information:	The data sheet provides general species information regarding name, synonyms, taxonomy and links to occurrences and the specific dataset it occurs in. The information is elaborate, but the navigation on the website takes some getting used to. When exploring a country, the system provides a map specifying occurrences which can be zoomed to find specific species in specific areas.
Common Ragweed included	Yes
Note:	-

8.3.5 Q-bank

Full name:	Q-bank – Comprehensive Databases on Regulated Plant Pests
Website:	http://www.q-bank.eu/
Language:	English
Updated:	Continuously
Geographical coverage:	20 countries including The Netherlands, Belgium, United Kingdom, France, Denmark and Italy.
Species coverage:	The Q-bank database covers Bacteria, Fungi, Insects, Invasive Plants, Nematodes, Phytoplasmas and Viruses & Viroids.
Data provision:	Data is being provided by a team of curators with taxonomic, phytosanitary and diagnostic expertise from world-wide national plant protection organizations and institutes with connections to relevant phytosanitary collections.
Accessibility:	The data in the Q-bank database can be accessed through the website. Users can select a kingdom they would like to search and will be further guided through the search process by the information on the website. The database can provide the user with a factsheet about the indicated species.
Reliability:	The data can be assumed very reliable as it is provided by experts and institutes and regularly updated.
Information:	The fact sheet contains information regarding taxonomy, morphology, distribution, ecology, biochemistry and invasiveness and risk and control.
Common Ragweed included	Yes
Note:	-

8.3.6 Country Databases

Programme name	Description	CR
Belgium		
Florabank	Mapping project for the flora of Flanders Region and the Brussels Capital Region. The data is public. www.flora.inbo.be	Yes
Waarnemingen.be Observations.be	Online encoding tool for loose observations managed by Natuurpunt Studie and Natagora. The biggest environmental NGOs in Flanders and Wallonia respectively. The Walloon data is readily available; the data for Flanders is not public. www.waarnemingen.be, www.observations.be	Yes
Module d'encodage en ligne DEMNA - OFFH	Online encoding tool for biological observations managed by the Walloon government (biodiversite.wallonie.be). www.observatoire.biodiversite.wallonie.be/encodage/	No
Croatia		
Flora Croatica Database (FCD)	Floristic Database of the Faculty of Science, dpt. for Botany. It is filled in with data from researchers and a number of certified volunteers. Part of the data is publicly available.	No
Monitoring handbook of State Institute for Nature Protection	SINP prepared a handbook for monitoring which includes a section with flora. Ambrosia is one of the species suggested for monitoring. Unknown data quantity and data is not publicly available. http://www.dzzp.hr/dokumenti_upload/20100316/dzzp201003161327130.pdf http://www.dzzp.hr/dokumenti_upload/20100316/dzzp201003161328360.pdf	No, suggested
Czech Republic		
Database of the herbarium records in collections of Czech Republic	The electronic database for searching of plants by name, which are included in herbariums of the Czech republic. Result could be drawn to map or written to the table. http://www.mzm.cz/Botanika/EN/introduction.html	Yes
Flora Database of the Czech Republic	The electronic portal, which associates inventory data of plants in the Czech republic. http://florabase.cz/databanka/index.php	Yes
State Phytosanitary Administration	The administrative phytosanitary care authority with competence for the Czech Republic, that (among others) collect information and elaborates certifying methodology of control about harmful organisms. http://eagri.cz/public/web/en/srs/	No
Denmark		

Programme name	Description	CR
NOVANA	National monitoring programme on nature and water. Responsible authority is ministry of environment. There are detailed developed manuals for monitoring of nature types, single plant species etc. Common Ragweed is partly included in the system on an ad hoc basis, but not systematically reported. http://www.dmu.dk/International/Monitoring/NOVANA/ and www.mim.dk	Partly
Atlas Flora Danica	Danish Botanical Society is responsible for this Atlas Survey of all Danish plant species. The project has been ongoing since 1992. The result of the atlas survey, where hundreds of volentiers have been involved, will be published in summer 2012. Information is not available for profit reasons. www.botaniskforening.dk	Yes
"Platform invasive species"	Nature Agency, Ministry of environment, has a larger section on the homepage devoted to invasive species. Anybody can report on observations of invasive plant and animal species (from a browser list), and Danish maps with indication can be found on the homepage. http://www.naturstyrelsen.dk/Naturbeskyttelse/invasivearter/Indberetning/	Yes

Germany		
Data bank “WAtSon“	All reports about ragweed locations from the federal states are to be collected and coordinated in the Julius Kühn Institute. To this day, however, no consistent monitoring exists nor are there methodological standards. Some federal states initiated similar action programs at the state level. But the full implementation of the program (monitoring and inventory of where ragweed was found) so far exists only in Bavaria, Baden-Wuerttemburg). The Julius Kühn Institute collects all information about ragweed locations in Germany in its data bank “WAtSon“. http://watson.jki.bund.de/Start	Yes
Ragweed Atlas Berlin-Brandenburg	A systematic search for ragweed locations which occurs in several districts in Berlin carried out by ragweed scouts who are supported by the local employment agency (1-€-jobs). The Meteorological Institute (FU Berlin) is responsible for the Berlin-Brandenburg ragweed atlas. http://www.fu-berlin.de/ambrosia	Yes

Hungary		
National weed survey	It was made mainly by the specialist of Central Agricultural office. There were 5 inventory: between 1947-1953, between 1969-1971, Between 1987-1988, between 1996-1997 and between 2007-2008. Publication: Novák, R, Dancza, I. Szentey, L. and Karamán J. (2009) Arable weeds of Hungary, Fifth national weed survey (2007-2008). Ministry of Agriculture and Rural Development, Budapest	Yes
Hungarian Land Administration (Földhivatal)	This organization is responsible for the yearly monitoring and eradication of ragweed. Budget is not sufficient for yearly monitoring. www.foldhivatal.hu	Yes

Programme name	Description	CR
Aerobiological Network	National Institute of Environmental Health, This organization coordinate the national aerobiological network, which consost of 19 monitoring point in Hungary. The institute reports weekly on the pollen concentration in Hungary. http://oki.wesper.hu/	Yes

Italy		
No national programme exists so far.	However, as a follow up of the present work, a preliminary proposal to develop a dedicated databank with georeferenced data for all country has been agreed to by a number experts at the regional level. Common Ragweed is not. included in this system. Some institutions are collecting data on common ragweed (as well as other alien plant species) at the regional level, but relevant data are unpublished and such databases are not yet publicly available. Contact: Riccardo Scalera (scalera.riccardo@gmail.com)	No
PRAGMA – Progettazione di una Rete Aperta per la Gestione del Monitoraggio Ambientale (Design of an open network for the management of environmental monitoring)	In this website of the Environmental Information System of the Milano province, it is possible to report the presence of Ambrosia artemisiifolia in the territory of the Milano province (which together with Anoplophora chinensis, is one of the two species monitored by the project PRAGMA). http://ambiente.provincia.milano.it/sia/ot/pragma/pragma_1.asp?rif1=pragma&rif2=pragma&idrf=0	Yes

Netherlands		
Nederlands soortenregister	The Dutch Species Register is an extensive database containing species that inhabit the Netherlands, which is maintained by Naturalis. This register provides a list of invasive species in the Netherlands, which can be approached based on kingdoms. The list is not comprehensive and should be seen as a first version of an overview of Dutch invasive species. It only mentions species that have established themselves in the Netherlands for more than 10 years and gets its information from different (inter)national sources, likes DAISIE. http://www.nederlandsesoorten.nl/nlsr/nlsr/i000372.html	Yes
Compendium voor de leefomgeving	This online resource provides the user with a short introduction regarding invasive animal species and the developments regarding them since 1900. There is a list that can be downloaded providing a limited overview of invasive alien species in the Netherlands for a number of animal groups. http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl1375-Exoten-in-de-Nederlandse-fauna.html?i=2-41	No
Invasieve Exoten	This is a website focussing on invasive alien species in the Netherlands. It provides information about the problems regarding AIS, laws and regulations and a large amount of background information. It also contains lists of the 100 worst Dutch invasive species.	Yes

Programme name	Description	CR
	http://www.invasieve-exoten.nl/index.html	

Poland		
"Alien Plant species in Poland"	In 1999, the database on species introduced into Poland was developed at the Institute of Nature Conservation, Polish Academy of Sciences in Krakow for the Ministry of the Environment. In 2003, thanks to a grant from the US State Department, part of the data was translated and made accessible on the Internet. http://www.iop.krakow.pl/ias/default.aspx	Yes
"Distribution Atlas of Vascular Plants in Poland - ATPOL" (including ALPOL - KENO - details in Data Holder List final July 2011.xls)	The distribution is presented using dot maps based on squares (the details of the grid of squares avalible on http://www.ib.uj.edu.pl/chronpol/geo/geo.html ;) The detailed description of the method used available on http://www.ib.uj.edu.pl/chronpol/intro.html; Botanists from the whole Poland (usually university staffs) provide data to this base. Prof. Adam Zając is the manager of ATPOL-project. The first and the most important data base of vascular plants distribution in Poland (probably each data concerning common ragweed distribution is/will be in ATPOL). There are two key publications: Zając, A. (1978) Atlas of distribution of vascular plants in Poland (ATPOL). Taxon, 27(56), 481-484; Zając, A. & Zając, M. eds. (2001) Distribution Atlas of Vascular Plants in Poland, pp: 715. Laboratory of Computer Chorology, Institute of Botany, Jagiellonian University, Kraków. http://www.ib.uj.edu.pl/en/	Yes
"Catalogues of alien plant species for Poland: implication for conservation, management and legislation"	The aim of the present study is to gather current knowledge on alien plant species for Poland and to identify actual and potential highly invasive species. To achieve this, it is necessary to develop and achieve acceptance of a robust system based on solid science, with a clear invasion terminology and transparent risk assessments which is also understandable by a wider public. Alien plants contribute 29 % of species, i.e. 1017 taxa, to the flora of Poland. This includes ca. 160 archaeophytes, over 300 neophytes and 511 ephemerophytes. The members of all these groups require cyclical assessment of their current distribution and requirements for management. We are producing selected and up-to-data catalogues of alien species for Poland, which might be a base for developing the black and grey lists and could be used to help to develop regulatory measures to prevent the introduction, establishment, spread and negative effects of invasive alien species. We also advocate testing the prioritisation process for invasive alien plants proposed by the EPPO and make recommendations for preparation of a framework of organizational and legal solutions. Eds.: Barbara Tokarska-Guzik1, Maria Zając2, Adam Zając2, Zygmunt Dajdok3, Alina Urbisz1, Władysław Danielewicz4 1 Department of Plant Systematics, University of Silesia, Katowice, Poland; barbara.tokarska-guzik@us.edu.pl; alina.urbisz@us.edu.pl	Yes

Programme name	Description	CR
	2 Institute of Botany, Jagiellonian University, Kraków, Poland; Maria.Zajac@ib.uj.edu.pl; Adam.Zajac@ib.uj.edu.pl 3 Institute of Plant Biology, University of Wrocław, Poland; dajdokz@biol.uni.wroc.pl 4 Department of Forestry Natural Foundation, University of Life Sciences, Poznań, Poland; danw@up.poznan .pl	
Polish Biodiversity Information Network	Polish Biodiversity Information Network was founded by the Ministery of Science in 2003 and was financed by ministerial grant from 2005 to 2008. Until 2008 it was working as a network of international cooperation with the basic task being the cooperation with GBIF. Its main goal was to open national resources of biodiversity information and to implement standards for storage and exchange of data. Based on technologies used in GBIF, the system was launched for exchange of data with the global network. During several years majority of technical solutions for exchange of data with GBIF were tested. The current system, approved by all the PolBIN members, uses TAPIR protocol, replacing formerly used DiGIR i BioCASE as a tool for publishing data in the GBIF system. http://www.gbif.pl/index.php?id=db&st=al&l=en	Yes
Polish Aerobiology Network	The Krakow Monitoring Station is the Coordinator of the Polish Aerobiology Network joining 7 University Centres. PAN is organized by the small, but very active team of scientists. The Polish Network came into being to help to develop aerobiology as a scientific discipline in Poland and to co-ordinate the activity of aeropalynological monitoring centers. Aerobiological monitoring was performed using a the volumetric method. http://www.aero.cm-uj.krakow.pl/metod.html	Yes

Serbia		
National project (No. 312-01-747/2004-11/4): "Mapping of quarantine, invasive and economically harmful weeds in Serbia and propose measures for their suppression, 2004-2006"	Project leader was Faculty of Agriculture University of Belgrade, team members were: Institute for Pesticides and the Environmental Protection, Institute for Plant Protection and Environment, Institute of Field and Vegetable Crops of Novi Sad, The Maize Research Institute at Zemun Polje. Project was funded by the Ministry of Agriculture, Trade, Forestry and Water Management of Republic of Serbia. The project sampled at about 149129 points, they studied 25 species, among them *Ambrosia artemisifolia*. The database is available in the Ministry of Agriculture, Trade, Forestry and Water Management of Republic of Serbia.	Yes
National project : "Identification and monitoring of alien invasive weeds (AIW) in Serbia and	Project leader was Faculty of Agriculture University of Belgrade, team members were: Institute for Pesticides and the Environmental Protection, Institute for Plant Protection and Environment, Institute of Field and Vegetable Crops of Novi Sad. Project was funded by the Ministry of Agriculture, Trade, Forestry and Water Management of Republic of Serbia. Sampled 145875 points for all alien species (19 species), among them *Ambrosia artemisifolia*. The main	

Programme name	Description	CR
proposed measures for control, 2007-2009	project result is huge data base and the intersection of the real situation is done. The weaknesses of this project are lack of controlling data and mechanisms and lack of education which should be based on the results. Common Ragweed is included in this system. Data base available in the Ministry of Agriculture, Trade, Forestry and Water Management of Republic of Serbia. The main project result is huge data base and the intersection of the real situation is done. The weaknesses of this project are lack of controlling data and mechanisms and lack of education which should be based on the results.	

ANNEX 7: Details of measures used for controlling ragweed summarised from the national expert reports

Awareness Raising

	Measure taken	Country/ region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
Germany	Action Program Ragweed	Germany	Not compulsory	Federal Ministry for Food, Agriculture and Consumer Protection (BMELV)	Prevent further spread	This program is charged with stemming the spread of ragweed. It conducts countrywide monitoring, provides information for stakeholders, researches measures to prevent the import/spread of ragweed seeds, fights against existing ragweed plants/seeds.
	Bavarian Action Program Ragweed	Bavaria	Not compulsory	Bavarian State Ministry for Environment and Public Health (StMUG)	Prevent further spread	Each person finding ragweed is expected to weed single plants/clusters, up to 100 plants. Reports of more than 100 plants go to the local county agencies. The agencies register confirmed amounts with the Bavarian State Institute for Agriculture.
	Public information/ training of employees	Bavaria	Not compulsory	Bavarian State Ministry for environment and Public Health (StMUG)	Prevent further spread	Carry out intensive information and advisory activities through print, television, radio, internet, professional events, consulting, training courses, lectures, and information material.
	Execution of a broadbased information campaign	Hesse	Not compulsory	Hesse Ministry for Work, Family and Health	Prevent further spread	Disseminate information about avoiding the spread of ragweed.
	Internet pages for information about ragweed	Allmost all federal states	Not compulsory	Different Ministries	Prevent further spread	Most federal states have websites that describe the problem and call for the abatement of ragweed. They include suggestions for recognizing the plant and guidance on how to deal it.
Switzerland	Campaign in 2006 involving public, gardening magazines etc.	Switzerland	Based on regulation	National Ambrosia Working Group	n/a	n/a

Prevention

	Measure taken	Country/region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
Austria	Prevent the use of contaminated agricultural seed and bird seed (from States with ragweed)	n/a	No. The existing laws are not ragweed specific.	n/a	Prevent introduction	This includes some legal regulations and awareness raising campaigns.
	Cleaning of farm machinery and vehicles	n/a	No	n/a	Prevent further spread	Machinery and vehicles must be washed after work in a ragweed area.
	Cleaning of machinery and vehicles used for mowing of roadsides etc.	n/a	No	n/a	Prevent further spread	Machinery and vehicles must be washed after work in a ragweed area.
	Creation of unfavorable constructional conditions (especially of roadsides)	n/a	No	n/a	Prevent further spread	Highways and motorway verges, often consisting of gravel, are colonised by ragweed
	Prevention of the transport of contaminated soil etc.	n/a	No	n/a	Prevent further spread	This measure requires someone to examine the soil but affords some kind of a quarantine management.
	Reduce the existing populations	n/a	No	n/a	Reduce or mitigate harmful effects	Contaminated soil has to be transported only to areas already with ragweed.
	Medical treatment	n/a	No	n/a	Reduce or mitigate harmful effects	n/a
	Crop rotation	n/a	No	n/a	n/a	Alternation of maize and other thermophytic crops with cereal.

	Measure taken	Country/region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
Bulgaria	Border control of imported materials	Bulgaria, including border control points. Specifically border control point "Vrashka chuka" with Serbia.	Plant Protection Law; Law on Bulgarian Food Safety Agency; Regulation 54/2002 of Ministry of Agriculture.	Bulgarian Food Safety Agency (www.babh.government.bg); National Plant Protection Service	n/a	Border control of imported material, observation of the distribution, identification of the threats, and indication of required measures.
Cratia	Order of the Ministry to remove/combat ragweed	Territory of Croatia	Compulsory: Order of the Ministry of Agriculture, Forestry and Water Management (national); Official Gazette 72/07.	Croatian Institute for Agricultural Advice Service; relevant county and local authorities offices.	Prevent further spread	Landowners and land users are obliged to implement the measures to remove ragweed. Agro-technical: cultivation, crop rotation, etc; mechanical: cultivation, weeding, regular (multiple)mowing, preventing the plant to produce pollen and seeds; chemical: by applying the legally approved pesticides.
	Order of the regional/local governments to remove/combat ragweed	Various municipalities/cities in Croatia	Compulsory: Orders/decisions by the local governments.	Relevant local offices.	Prevent introduction	Landowners and land users are obliged to implement the measures to remove ragweed; mostly by mechanical means (uprooting, mowing, etc).
	Repeated mowing	Rhône-Alpes	n/a	n/a	n/a	n/a
	Plant cover	Rhône-Alpes	Not compulsory	n/a	Prevent further spread	Sowing to avoid bare ground (revegetation or plant cover)

Monitoring

	Measure taken	Country/ region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
Germany	Monitoring / Evaluation	Bavaria; Baden-Württ-emberg	Not compulsory	Bavarian State Ministry for Environment and Public Health (StMUG); Landesamt für Umwelt, Messungen und Naturschutz	Prevent further spread	Includes multi-year site visits of the known ragweed stock and documentation of its development. Two site visits—before and after abatement measures—in the year of the measure allows an evaluation of success.
	Berlin Action Programm	Berlin	Not compulsory	Senatsverwaltung für Gesundheit, Umwelt und Verbraucheschutz; Senatsverwaltung für Stadtentwicklung mit dem Pflanzenschutzamt	Reduce or mitigate harmful effects	Multiple city districts are systematically searched for ragweed. The incidence and amount is registered, mapped, and eliminated, if possible. The information is compiled in a data bank and is made available through the ragweed atlas.
	Brandenburg Working group ragweed	Branden-burg	Not compulsory	Ministry of Environment, Health and Consumer Protection of the Federal State of Brandenburg	Reduce or mitigate harmful effects	The action program for Brandenburg aims to control ragweed and to eliminate it. The key goals are to contain health risks, avoid agricultural production losses, and avoid biodiversity loss. The administrative agencies and other state offices collaborate.
	Identified occurrences and held roundtable discussions	Hesse	Compulsory	City of Griesheim, Hesse (with support from the Hesse Environment Ministerium)	n/a	In 2006 and 2007 the city area was searched for ragweed occurrences by scientific experts, with these experts providing recommendations regarding abatement measures. In the following years, the ragweed stock was monitored by the environment office and municipal construction regulatory office. During 2006-2007, the lower-level nature protection office, nature protection associations, public health office, forresty office, section species protection and scientific experts jointly decided the procedure for ragweed abatement.

	Measure taken	Country/ region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
Hungary	Staff of Land Administration manages local control and monitoring of ragweed.	Hungary	Year 2004. XXIX. Law 141. § (4)(5) paragraphs	Hungarian Land Administration (Földhivatal)	Prevent further spread	n/a
Italy	Surveillance activities	Milano 1 Province	Decree Lombardy Region no. 25522 of 29/3/99, and related communication of the Lombardy Region no. H1.2008.0018694 of 9/5/2008, H1.2009.0016369 of 5/5/2009, H1.2010.0015650 of 28/4/ 2010.	Public Health and Hygene Service - Servizio di Igiene e Sanità Pubblica (SISP) and Unità Operativa Complessa di Sanità Pubblica (UOC SP)	Reduce or mitigate harmful effects	Includes surveys and mapping.

Eradication: Biological

	Measure taken	Country/region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
Austria	Cultivation of competing vegetation	n/a	n/a	No	n/a	The measure is combinated with the mowing experiments.
	Grazing	n/a	n/a	No	n/a	A smale-scale test on grazing with sheep has been performed, but is not finished. Preliminary results indicate that sheep will eat ragweed unhesitantingly and they showed no negative effects.
	Controll by other animals which eat or harm ragweed.	n/a	n/a	No	n/a	No research on this topic has been performed in Austria.
Germany	Competition Culture	Bavaria	n/a	Compulsory	Bavarian State Ministry for Environment and Public Health (StMUG)	This aims to prevent the development of ragweed through a competitive vegetation that would crowd out the ragweed plants. Ragweed is a pioneer plant dependent on bare soil. If the vegetation is too dense, ragweed generally cannot develop. One can achieve a vegetation that is capable to compete with ragweed through seeding, planting, or it generates itself in the course of succession.
Hungary	Crop rotation	Hungary	n/a	Year 2004. XXIX. law 141. § (4)(5)	Local owner of arable land	n/a
	Grass establishment, sowing	Hungary	n/a	Year 2004. XXIX. law 141. § (4)(5)	Local owner of arable land	n/a

Eradication: physical

	Measure taken	Country/ region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
Austria	Manual tearing (and hoeing)	n/a	n/a	No	n/a	n/a
	Mowing of roadsides	Lower Austria	Sabine Auer, Klaus Krickl (Government of Lower Austria)	No	Government of Lower Austria	There are tests being conducted regarding the effectivity of different mowing methods, as well as the number and optimal time of cuttings.
Croati	Mechanical removal of ragweed	Croatia	n/a	Prescribed by law	Regional and local authorities; public utility services.	citizens are pulling out the ragweed plants prior to flowering and they are being collected and destroyed
Germany	Weeding	Bavaria	n/a	Compulsory	Initiator was the landscape preservation association Kehlheim. Bavarian State Ministry for Environment and Public Health (StMUG)	In a nature protection area in Lower Bavaria the stock of ragweed had increased to about 10,000 plants in the early 2000s and covered 200-300 m^2. Ragweed was eradicated by weeding. Through 2004, ragweed plants were pulled which reduced the stock by 25% in 2005. The same procedure was repeated in 2005. In order to find all plants on a plot, sufficient time should be allowed for a careful search of the area following a scheme. All ragweed plants from July on should be placed in bags and incinerated.
	Mowing/ Mulching	Bavaria	n/a	Compulsory	Bavarian State Ministry for Environment and Public Health (StMUG)	Flail mowers/muchers are used most frequently. Flails attached to a rotating drum chop the plants. The mulched mass remains on the surface and decomposts. The depth of cut ranges from 5 to 10 cm. The effectiveness of mulching depends largely on the stage of development and the height of the ragweed plants.

	Measure taken	Country/ region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
	Milling and plowing	Bavaria	n/a	Compulsory	Bavarian State Ministry for Environment and Public Health (StMUG)	Soil layers on the surface are shifted to deeper layers.
	Singeing	Bavaria	n/a	Compulsory	Bavarian State Ministry for Environment and Public Health (StMUG)	This does not actually involve an incineration of plant parts but rather their short-term heating to a temperature of 50 to 70 degrees Celsius. With this method, larger ragweed stock can be combated prior to blooming without the use of herbicides. This technique has only been applied once when it was used to eradicate ragweed along the sides of the freeway A3East (BY 18).
Hungary	Mowing	Hungary	n/a	Year 2004. XXIX. law 141. § (4)(5)	Local owner or trustee of the area	Once, twice or more mowing per year
	Disking	Hungary	n/a	Year 2004. XXIX. law 141. § (4)(5)	Local owner or trustee of the area	-
Serbia	Combination of weeding, mechanical, chemical	AP Vojvodina (northern part of Serbia)	Dr Slobodan Puzovic, Deputy Secretary of the Province Secretariat for Urban Planning, Construction and Environmental Protection of the Autonomous Province of Vojvodina	The Serbian government adopted a Decree on measures to combat ragweed published in the Official Gazette No. 69/06.	Provincial Secretariat for Urban Planning, Construction and Environmental Protection of the Autonomous Province of Vojvodina established a council for the integrated control of harmful organisms in the environment in the territory of Vojvodina	A plan and program for integrated eradication of ragweed will be implemented in the whole territory of the Autonomous Province of Vojvodina, which means in all 45 municipalities. The most effective way of combating ragweed is pulling directly from the roots, in areas where individual plants occur.

	Measure taken	Country/ region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
	Mowing, cutting and transportation of biomass	City of Belgrade, 8 municipalities, in total 60 ha where the measure is applied	Dr Vladan Jovanovic, Institute for pesticides and environmental protection, Belgrade, vladan.jovanovic@pesting.org.rs	Decree on measures to combat ragweed published in the Official Gazette No. 69/06. The decision is taken by the Mayor.	City of Belgrade, Secretariat for Utilities and Housing Services	This is important in areas where human settlements have been developed, and areas around residential and commercial facilities, maternity wards, schools, kindergartens. The plant is mowing at least 5 cm above the ground, before flowering. If it is not treating in this way, it will grow again in 20 days.
Switzerland	Trials held on timing of cutting and combination of cutting/herbicides	All communes	As above	Practical eradication	Department of Agriculture	Mowing on its own is recommended for road verges, gravel pits, nature reserves, river banks, other area where herbicides are not allowed
	Unroot plants by householders or by commune.	All communes	As above	Regulation	Communes	Conduct regular inspection during maintenance work and send reminders to households.

Eradication: Chemical

	Measure taken	Country/ region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
Austria	Tribenuron-methyl herbicide used with tribenuronmethyl-tolerant sunflowers.	n/a	n/a	No	n/a	n/a
	Metribuzin, Imazamox, Bentazon herbicides used with soy.	n/a	n/a	No	n/a	n/a
	Tribenuron-methyl (a sunflower-herbicide) used with soy.	n/a	n/a	No	n/a	n/a
	Bifenox (a sunflower-herbicide) used with soy.	n/a	n/a	No	n/a	n/a
	Imazanox (a soy-herbicide) used with soy.	n/a	n/a	No	n/a	n/a
	Sulcotrione + Terbuthylazin (a maize-herbicide) used with soy.	n/a	n/a	No	n/a	n/a
	Pre-emergence herbicides used with maize.	n/a	n/a	No	n/a	n/a
	Triketone (Callisto, Clio, Mikado, Laudis, a post-emergence herbicide) used with maize.	n/a	n/a	No	n/a	n/a
	Sulfonyl-urea (a post-emergent herbicide) used with maize.	n/a	n/a	No	n/a	n/a

	Measure taken	Country/ region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
	Bromoxynil (a post-emergent herbicide) used with maize.	n/a	n/a	No	n/a	n/a
	Terbuthylazin-containing herbicides (a post-emergent herbicide) used with maize.	n/a	n/a	No	n/a	n/a
	Total herbicides like Roundup used outside farmland.	n/a	n/a	No	n/a	n/a
Croatia	Chemical control in sunflower fields	Eastern Croatia	Sanda Rasic	Prescribed by law	Croatian Institute for Agricultural Advice Service; relevant county and local authorities.	Spraying with a sprinkler attached to a tractor (mostlu pre-emergence of the crop).
	Chemical control along the roads, canals and stubble fields	Eastern Croatia	Sanda Rasic	Prescribed by law	Ditto	Spraying with glyphosate and gluphosinate based pesticides.
Germany	Herbicides	Bavaria	n/a	Compulsory	Bavarian State Ministry for Environment and Public Health (StMUG)	Effectiveness of herbicides against ragweed depends on the compound and active agent used and on the development stage of the ragweed plant. In general, compounds are available that effectively eradicate ragweed in corn and grain fields. Since ragweed plants have a long germination period, a combination of leaf and soil active compounds might have to be utilized to achieve a lasting abatement during the growing season.

	Measure taken	Country/ region	Prescribed by law/regulation	Implementing body	Purpose of the measure	Description of the measures/method
Hungary	Herbicide application, sunflower, pre-emergence or pre-sowing	Hungary	László, Szentey, pest control specialist	Year 2004. XXIX. law 141. § (4)(5)	Local owner of arable land	It has to be applied 2 weeks before sunflower germination. Name of the active subtance: flurochloridon (’Racer’), or oxyfluorfen (’Goal’, ’Galigan’, ’Global’, ’Oxi’, stb.), or these with terbutylazin+s-metholachlor.
	Herbicide application, sunflower, post-emergence	Hungary	László, Szentey	Year 2004. XXIX. law 141. § (4)(5)	Local owner of arable land	Flumioxazin ('Pledge')
	Herbicide application in herbicide-resistant sunflower	Hungary	László, Szentey	Year 2004. XXIX. law 141. § (4)(5)	Local owner of arable land	In IMI-sunflower: imazamox ('Pulsar'), in Express: tribenuron-metil ('Express').
	Herbicide application, maize	Hungary	n/a	Year 2004. XXIX. law 141. § (4)(5)	Local owner of arable land	There are several prossible herbicides, eg. dimetenamid-P and terbutilazin ('Akris SE ').
	Herbicide application, wheat and stubble after wheat	Hungary	n/a	Year 2004. XXIX. law 141. § (4)(5)	Local owner of arable land	n/a
	Herbicide application, other annual crops	Hungary	n/a	Year 2004. XXIX. law 141. § (4)(5)	Local owner of arable land	Detailed description for several types of crops: Kádár A. (2010) Vegyszeres gyomirtás és termésszabályozás. Kádár, ISBN: 978-963-08-0013-6. pp382.
Serbia	Treatment with herbicides based on glyphosate	City of Belgrade, 8 municipalities.	Dr Vladan Jovanovic, Institute for pesticides and environmental protection, Belgrade,	Decree on measures to combat ragweed published in the Official Gazette No. 69/06.	City of Belgrade, Secretariat for Utilities and Housing Services	The use of chemicals to combat ragweed in urban areas is kept to a minimum. Only smaller areas that are impossible to mow are treated by environmentally safe medicines, with monitoring of changes to the surrounding wildlife. Treated areas have marking and placing of warning tape for at least 24 h after application.

Annex 8: Workshop feedback form

Ambrosia Workshop

Brussels 24th July 2012

Name (optional): ....

On a scale of 1 – 5 (with 1 being the lowest and 5 being the highest) please rate the following: -

	1	2	3	4	5
Organisation of workshop (including pre workshop communication)					
Facilities (buildings, location, etc)					
Overall content of presentations					
Relevance of workshop to your interests					
Usefulness of focus group discussions					
Networking opportunities					
Overall experience					

1. Were you aware of the issues relating to *Ambrosia artemisiifolia* prior to this workshop?

2. After this workshop, do you now have a better understanding of *A.artemiisfolia* issues, its management and control?

3. What further information would you like to have about *A.artemiisfolia* , its management and control?

4. Are there other invasive species you think this projects methodology could be applied to?

5. What did you gain most from this workshop?

6. Would you do anything differently to make the workshop more effective?

Other comments:

Annex 9: Example costs calculation for Italy

This gives a detailed description of the calculation approach for current costs for one country in order to describe the modelling for Task 5 in more detail. It deals with both the impacts of ragweed on human health, crop yields and workforce capacity, and the control of ragweed in agriculture and urban areas. Note that there is some rounding in the figures for ease of presentation.

Impacts of Ragweed

Health treatment

This is based on data taken from the spatial modelling (in Task 6) of the estimated percentage of the population exposed to ragweed pollen sufficiently to stimulate allergic responses. The percentage was then applied to the national population (estimated for 2010 at 60.88m) to give 1.43m people.

It is estimated that 2% (28,693), 5% (71,732) or 10% (143,463) of this population have additional allergenic symptoms as a result of this exposure such that they require health treatment.

For this population, medication and medical treatment costs are calculated.

Medication costs are estimated at €3,030 over ten years, or €303 per year, giving estimated medication costs of €8.70m, €21.73m or €43.47m per year.

Other treatment costs are estimated based on 1 hour of doctors and nurses time, valued at relevant wage rates. The average of these groups wages rates for Italy is estimated at €23.4 per hour, based on average data from across the study area. This cost is doubled to reflect overhead costs, giving treatment costs of €1.34m, €3.36m or €6.71m per year.

Total health costs are treatment costs plus medication costs: €10.04m, €25.09m or €50.18m.

Crop yields

Loss of crop yield is estimated at a residual (after herbicide controls) loss of 25% of the value of crops affected by ragweed. The crop area affected is taken from the spatial modelling (in Task 6) of agricultural land in affected areas. For Italy this is 4.5% of the total crop area (324,657ha). Of this, 193,144 ha is assumed to be crop types vulnerable to ragweed infestation.

For this area, it is assumed to be cropped with the same pattern as national average crop types. For example, in Italy, 25.9% of cropland is wheat, so an estimated 84,051 ha impacted by ragweed are assumed to be wheat. Average yield per ha of wheat is 3.69 tonnes, so yield loss of 25% is 0.92 tonnes per ha, giving a total lost wheat yield of 77,741 tonnes.

This loss is valued through the price of wheat in Italy estimated at €230.0 per tonne, giving a total value of lost wheat yield of €17.8m.

This crop calculation is repeated for all the crops grown in Italy that are vulnerable to ragweed, and gives a total estimated lost yield worth €190m per year.

Workforce capacity

The loss of workforce capacity is estimated by multiplying the exposed population experiencing additional health impacts, as described above, by the percentage of the national population that is the workforce, at 11,832 to 28,579 people. For these people, work productivity loss is estimated at between 1.5% (3.375 of a 225 day working year) and 5% (11.25 days) per year.

This work time is valued in two ways:

- Based on GVA per worker (of €53,609 per year in Italy), giving estimated losses of €8.92m to €74.3m per year.

- Based on average wage rates (of €28,625 per year in Italy), giving estimated losses of €5.3m to €39.7m.

Control of Ragweed

Agricultural controls

The costs of agricultural controls are based on one additional application of herbicide for the crop area estimated to be impacted by Ragweed (losses of crop yields are estimated above) (193,144 ha).

One additional herbicide application is estimated to cost €13.70 per ha for chemicals, labour and machinery, based on average EU data. For some crop types in the study area, crop-specific herbicide data is used. This gives estimated agricultural control costs of €4.3m.

Urban controls

The urban area requiring controls for the 'control on' modelling approach is estimated from the Task 6 spatial modelling work. Firstly the area of vulnerable urban land is estiamted at 83ha in Italy. Between 0.03% (0.025 ha) and 1.2% (1 ha) of this land is assumed to be colonised by Ragweed and requires controls.

Urban controls are costed at between €300 and €800 per ha, based on average EU data for hand weeding, spraying and mowing costs. This gives estimated urban control costs of between €300 and €800 for Italy...