Review of evidence concerning ragwort impacts, ecology and control options

Report to Defra

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EXECUTIVE SUMMARY

Introduction

- Ragwort is a widespread native plant in the UK, which occurs in a range of habitats including those used for grazing livestock and hay or silage production, and is of concern because it contains pyrrolizidine alkaloids (PAs) which are toxic to livestock. Problems have occurred particularly with poisoning of horses.
- Ragwort is a specified weed in the Weeds Act 1959, under which land owners can be required to take all reasonable steps to prevent spread on their land and onto adjoining land. Defra have issued a Code of Practice on How to Prevent the Spread of Ragwort, which was published in 2004 (revised 2007) (Defra, 2007).
- In order to ensure that guidance continues to be based on the latest and best evidence, the work reported here was commissioned by Defra with the following objectives:
    - Review and update the evidence base on the impacts of ragwort on livestock, methods of control and the cost, benefits and impacts of control;
    - Investigate experience of ragwort problems, policy and control in other countries
    - Make suggestions relating to the Code of Practice and further research needs.

Biology and ecology

Studies of Ragwort ecology and distribution have shown that:

- Ragwort is found in a wide range of habitats but requires bare ground or disturbance to establish. Ragwort plants form a rosette in their first year and typically flower, set seed and die in the second year, though in some situations they can be longer lived. Flowering occurs from mid-June to November, with seeds dispersing from August to December.

  Most seeds are shed close to the plant, with median dispersal distances ranging from around 0.5 to 2 metres, but a very small proportion disperse over a longer distance. Ragwort seeds germinate rapidly in the light, but if buried in soil can persist for a number of years, and in suitable conditions if brought to the surface could still produce fresh infestations up to ten years after burial. In a New Zealand study over 28 years, it took between 9 and 17 years (depending on the soil type and depth of burial) for the numbers of viable seeds to decline to 1% of the original sample.

  Based on the best available evidence from dispersal studies, this review estimated that at low levels of seed production, 43 seeds might be found five metres away from the source plant, but less than one at a distance of 100 m. At a very high seed production level, over 1500 seeds might be found 5 metres from the plant (though still representing less than 1% of total production) and 17 seeds might reach 100 m. However, this analysis is based on some broad assumptions as data on long-distance dispersal are very sparse, and does not consider whether any of those seeds will actually fall in a suitable site for germination.

Ragwort status

National-level surveys of plant distribution have shown that:

- Ragwort is almost ubiquitous across the country, but there is no evidence that it is invading new habitats. Countryside Survey data indicate no long term trends in occurrence in field plots in England between 1978-2007 or 1990-2007, but there was an increase in abundance (but not spread) in road verges between 1990 and 2007. Ragwort populations are believed to fluctuate markedly between years, but evidence is sparse as few data exist on the annual fluctuations in populations.

- Drought, overgrazing and presence of bare ground all increase probability of ragwort occurrence.

Impacts on livestock

- There is very little evidence from peer reviewed studies on the number of livestock that die from ragwort poisoning. Evidence from the grey literature suggests that impacts on livestock health usually take the form of chronic toxicity arising from low doses over an extended period, with few symptoms arising until the animal's health is severely affected.

- Evidence from livestock owners suggests that livestock generally avoid eating live ragwort plants, unless no alternative forage is available. However, it is more palatable when dry, e.g. in hay. The toxin content declines in silage but there is little decline in hay.

- Toxicity studies have shown that livestock vary in susceptibility to ragwort toxins as follows: pigs=1: chickens=5; cattle and horses=14; and sheep and goats=200 where low numbers indicate high susceptibility. Sheep and goats are therefore the least susceptible. Estimates suggest that consumption of between 10 and 30 kg fresh weight of ragwort over its lifetime would be a lethal dose for a horse, depending on body weight.

Risks to human health

- PAs can cause lethal liver damage to humans, but there is no evidence of illness or fatalities resulting from ragwort. Few studies of PAs in meat have been conducted, but those that have, indicate that levels of ragwort toxins decline rapidly in animal tissue after ingestion, and studies have concluded that the risk to human health from eating meat of animals that have consumed ragwort is negligible. There is limited information for risks from PAs eggs.

- PAs can be transferred to milk, however it would only constitute a risk if large amounts of milk were consumed from animals that had ingested considerable quantities of PAs. As milk is bulked before sale for consumption, such a risk is unlikely to occur in practice.

- A number of studies have considered risks from eating honey made by bees that have foraged on ragwort. There is a possibility that there may be low level chronic health risks from consuming honey containing PAs, to which ragwort may contribute along with other plants, but this is only likely to occur where high levels of honey produced in areas where a high proportion of the nectar comes from PA-producing plants. In practice, as honey made from ragwort has an unpleasant taste, it would not be sold for consumption except when heavily diluted by honey from other sources.

- In summary, current evidence suggests that risks to human health are low to negligible.

Control methods and efficacy

There have been a number of studies into the efficacy of different control options for ragwort. These have found that:

- Ragwort establishment is aided by the presence of bare ground created by trampling, poaching or overgrazing. Pasture management that encourages a tight sward with little or no bare ground will therefore aid the suppression of ragwort. Nitrogen application can also reduce the incidence of ragwort, and the concentration of PAs in the plant.

- Cutting can be used as a way of preventing the seeding of ragwort, but does not reduce the population, and can prolong the life of the plants allowing flowering and seeding in the same or subsequent years.

- The herbicides most widely used for selective control of ragwort are 2,4-D, MCPA and mixtures of the two, or 2, 4-D with dicamba. These herbicides also affect a range of other plant species if an overall spray is applied. Only a very small proportion (less than 1%) of grassland is sprayed for ragwort control.

- Pulling is frequently used as a method of control by landowners, horse enthusiasts and owners of nature reserves etc., but there is little evidence on its efficacy. Correct disposal is important as the PAs remain in the plant material after pulling.

- Seven insect species have been used as biological control agents in various countries to control non-native ragwort populations. However, they are likely to have only a limited effect within the UK as natural enemies of the biocontrol agent will also be present and limit population levels (Eilenberg, 2006). Large and frequent introductions would be necessary with a range of biological control species to achieve some level of ragwort population reduction. No evidence was found of successful use of biological control for ragwort in the UK.

- In addition sheep have been used as biocontrol agents, as they will graze on ragwort and have high tolerance of the PAs. However, this is not recommended on animal welfare grounds.

- A small number of studies have considered the potential allelopathic or autotoxic[1] effects from ragwort. However, at present evidence is too limited to conclude whether this could form the basis for a control method.

Costs of control

- Herbicide costs were estimated at around £17 per ha using list prices, and application costs (boom sprayer) at between £10 and £13 per ha.

- In recent years, between around 150 and 350 complaints forms have been received per year by Natural England. Of these, around 20-50 result in enforcement notices by the Rural Payments Agency. Very few result in clearance action by Natural England (only 3 between 2010 and 2012

- Network Rail and the Highways Agency also undertake ragwort control as part of their wider weed control programmes, although data on management costs are not recorded for individual species by either organisation. However, an example totalling £27k for treatment (pulling) of 4km of rail track with ragwort present was provided. One County Council was able to provide an estimated figure of £1500 spent on ragwort on highways but noted that most management is contracted out to Borough Councils.

Ecological impacts of changes to ragwort populations

- Ragwort is a native species and an important component of plant communities in some habitats such as sand dunes in the UK. Its removal will have impacts on other associated biodiversity. Based on the results of a number of studies, this review concludes that thirty eight species of insect are dependent on ragwort or have a limited number of alternative hosts, and therefore likely to be significantly affected by changes to ragwort populations. These include several nationally scarce species and the cinnabar moth, a Biodiversity Action Plan species whose primary host is ragwort and which has declined by 83% in the last 35 years.

- Several studies have concluded that ragwort is also an important source of nectar and pollen for a range of pollinating insects. One review reports 178 species

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[1] Allelopathy occurs when chemicals released by a plant species influence the growth, survival, and reproduction of other. **Autotoxicity** is a form of allelopathy in which a species inhibits growth or reproduction of members of that same species through the production of chemicals that are released into the environment.

(including 47 bee species and 35 hoverfly species) to have been recorded visiting ragwort flowers.

- A large number of fungi have also been found to be associated with ragwort. This review concluded that eight species were considered to be particularly susceptible to changes in ragwort populations because of their scarcity and level of dependency on ragwort. All are known to be present in 35 or fewer 10 km squares.

- Other environmental impacts may arise from the use of herbicides used to control ragwort affecting other plant species, or reaching surface or ground water. The two herbicides most commonly used, 2,4-D and MCPA, are among those that have most commonly been found in both surface and ground water through Environment Agency monitoring.

Evidence from other countries

- Key personnel were contacted in other European, North American and Australasian countries where ragwort occurs. In general, there was less concern in other European countries than in the UK, owing to ragwort being considered a natural part of the indigenous flora. Ireland however does consider it to be a problem and it is on their noxious weeds list. Ireland also has regulations relating to ragwort control.

- Ragwort is recognised as a problem in parts of the United States of America and Canada, where it is non-native. Oregon in particular has carried out a lot of work on ragwort: annual costs of $1.2M were estimated in the 1960s, since when a major biological control campaign has been carried out.

- Australia and New Zealand also consider ragwort to be a major problem and carry out control programmes. In Australia, it has been estimated that the cost of ragwort is $4M annually, but the source of this estimate could not be ascertained. A separate estimate of losses amounting to $2.1M was reported for Tasmania in 1996. Both countries have active control programmes including biological control.

- Cost-benefit analyses have been carried out in Oregon and New Zealand. In Oregon, the cost of the control programme was estimated as $1.5 million, and benefits were estimated to be $23.2M. In New Zealand, savings from biological control with ragwort flea beetle were estimated as $7M.

Data gaps and suggestions for further research

- The following areas were identified where information is lacking:
    - Seed dispersal distances;
    - Ragwort status, particularly annual fluctuations in abundance and their causes;
    - Numbers of livestock deaths caused by ragwort;

    - Transfer of PAs and metabolites into products for human consumption, and safe limits in food;
    - Effectiveness of pulling as a control method, and the possibility of using fungal pathogens as control agents
    - Status, distribution and dependence on ragwort of many associated species;
- The following areas were suggested for consideration in any revision of the Code of Practice:
    - Removal of any non-essential information, especially in appendices, to reduce length commensurate with delivery of key messages;
    - Giving more information on grazing intensity, timing and type of livestock could help refine the risk assessment;
    - Removal of references to biological control as there are currently no practical options for use in the UK;
    - Information on relative effectiveness of different herbicides, along with information on timing and conditions for use;
    - Removal of references to set-aside and updating of information on agri-environment schemes.
- A stakeholder workshop could be held to discuss the usefulness of the guide and how it could be improved. Shorter leaflets could also be produced giving advice on specific aspects. The horse passport database could be used to circulate these to horse keepers.

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1. INTRODUCTION

Common or Tansy Ragwort (*Jacobaea vulgaris*, formerly *Senecio jacobaea*) is a widespread native plant in the UK, found in a range of habitats, on free-draining calcareous soils, in sand dunes, and poorly maintained pastures (Harper & Wood, 1957; Roberts & Pullin, 2007). It is a specified weed in the Weeds Act 1959, under which land owners can be required to take all reasonable steps to prevent spread on their land and onto adjoining land. This Act was amended by the Ragwort Control Act 2003, which provides for the publication of a Code of Practice on How to Prevent the Spread of Ragwort (Defra, 2007). Control of ragwort, along with other injurious and invasive non-native weeds, can also be required on farmland under cross-compliance (RPA and Defra, 2012). Ragwort is of specific concern because it contains pyrrolizidine alkaloids (PAs) which are toxic to livestock. Problems arise particularly with horses, for which a number of fatalities ascribed to ragwort poisoning have been reported.

In order to ensure that advice and guidance was based on the most up to date and high quality evidence, the work reported here was commissioned by Defra with the following objectives:

- Review and update the evidence base on the impacts of ragwort on livestock, methods of control and the cost, benefits and impacts of control;
- Investigate experience of ragwort problems, policy and control in neighbouring EU countries;
- Make suggestions for changes to the Code of Practice for preventing the spread of ragwort, any other actions required and any further research needs.

The review of evidence presented below is based on the following sources:

- literature searches using standard bibliographical databases;
- web searches;
- extraction of information from databases including the Pesticides Usage Survey, the Biological Records Centre and the National Biodiversity Network;
- direct contact with representatives of Government Agencies and other public bodies (e.g. Natural England, the Highways Agency, local councils), private companies (e.g. Network Rail) and NGOs, (e.g. Buglife);
- direct contact with relevant individuals concerned with weed management in other countries where ragwort occurs and is, or was thought to be, a problem.

Where applicable, confidence in statements based on levels of evidence is recorded as low (L), medium (M) or high (H). This is based on LWEC Biodiversity report cards.

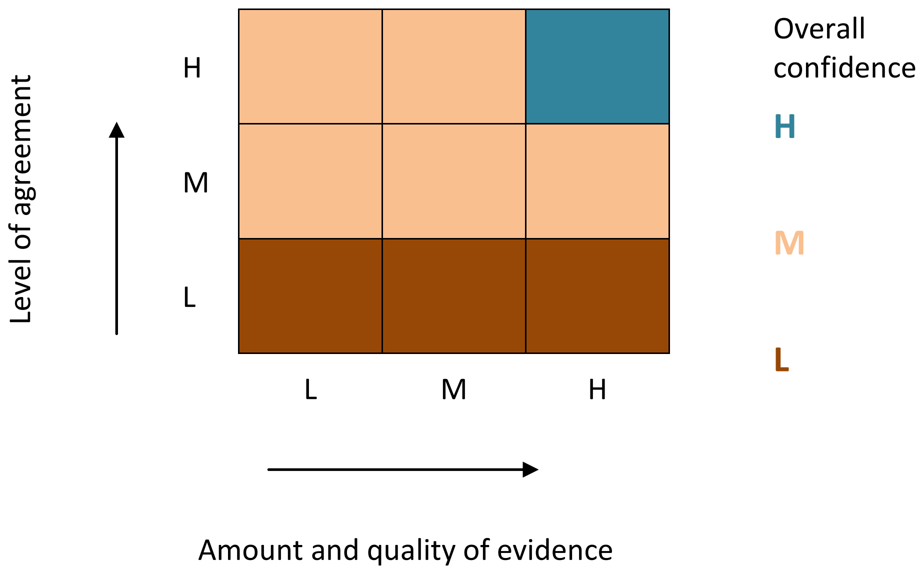

Figure 1 **diagrammatic representation of strength of evidence assignment and overall confidence (from LWEC Terrestrial Biodiversity report card 2012-3)**

2. REVIEW OF EVIDENCE

2.1. BIOLOGY AND ECOLOGY (RELEVANT TO CONTROL)

2.1.1. Habitat specificity

Ragwort is a pioneer species of open habitats (Suter *et al*, 2007), and is intermediate between a 'Ruderal' and a 'Competitive Ruderal' (Grime, 1988). It requires bare ground or disturbance to establish, but this can be relatively local disturbance. Ragwort is a biennial or monocarpic[2] perennial and is found in a range of broad habitats including boundary and linear features (e.g. hedges, roadsides, walls), neutral grassland (includes coarse *Arrhenatherum* grassland), calcareous grassland (includes lowland and montane types) and acid grassland (includes non-calcareous sandy grassland). There is little or no vegetative spread but clones form by suckering from roots.

Ragwort is widespread in grassland and especially abundant in neglected, rabbit-infested or overgrazed pastures; it also grows on sand dunes, in scrub, open woods and along woodland rides, waste ground, road verges and waysides, and on rocks, screes and walls up to 670 m above sea level. It is an important component of some sand dune communities, present as a constant in National Vegetation Classification (NVC) sub communities SD7 *Ammophila arenaria-Festuca rubra* semi-fixed dune community and SD8 *Festuca rubra-Galium verum* fixed dune grassland (Rodwell *et al*., 2000).

Horses can create ungrazed 'latrine' areas which are more fertile than the surrounding vegetation (Gibson, 1966). These may be favourable for ragwort establishment providing that other species do not outcompete it. Maskell (2012) found that ragwort was positively associated with drought. It is less susceptible than other species and outcompetes them under these conditions. Increased nitrogen status reduces the risk of ragwort occurrence (Suter *et al*, 2007).

2.1.2. Growth habit and response to defoliation

Ragwort is generally regarded as a biennial (however it can become a perennial depending on environmental factors or competition (McEvoy, 1984a). In the first year it produces a leafy, vegetative rosette 5-15 cm in diameter (McEvoy, 1984b) and in the second year it produces flowering stalks, and it is generally reported to die after flowering (McEvoy, 1984b). Roots can reach a depth of 150mm, and flowering shoots can reach up to 1.5m tall (Grime, 1988).

In common with other members of the Asteraceae (daisy) family, the flower head is known as a capitulum (plural capitula) and contains many florets tightly clustered together. On this capitulum there are two types of floret. The ones around the edge of the capitulum are the ray florets and the ones in the centre are known as the disc florets. Flowering can occur

[2] Flowers once, sets seed and then dies

over a long period from mid June until November. Seeds ripen and disperse from mid August until December (Harper, 1957).

2.1.3. Seed production and dissemination

The two types of florets produce achenes (seeds) of differing structures. The ray florets produce the heavier achenes, usually 13 in number (McEvoy, 1984a) which do not have any structure to aid in their dispersal. The achenes produced by the ray florets are usually retained by the capitulum for a longer period of time than those produced by the disc florets (McEvoy and Cox, 1987). The disc achenes are lighter and more numerous (average 58 per capitulum (McEvoy, 1984a). In addition, they have rows of trichomes and a pappus to aid animal and wind dispersal respectively. McEvoy (1984a) demonstrated experimentally that the two achenes also exhibit different germination syndromes. In disc achenes it was shown that germination time decreases as achene weight increases, with the converse in ray achenes (McEvoy, 1984a). Both achenes demonstrated an increase in germination percentage with an increase in weight. Disc achenes have a higher germination percentage than ray achenes for a given weight (McEvoy, 1984a). McEvoy (1984) reported the average germination time for a ray achene as 12 days, and 6 days for a disc achene. Ray achenes were on average 1.44 times heavier than the disc achenes (McEvoy, 1984a).

The mean number of achenes produced per capitulum is relatively similar for samples collected from different areas (Cameron, 1935) and a number of studies give similar estimates (Table 3) although van der Meijden and van der Waals-Kooi, 1979 recorded a large range for individual capitula. Records of the number of capitula per plant are, unsurprisingly, more variable (68-3375) and Cameron, (1935) reported that numbers of capitula varied with the size of plant and the quality of the soil. Van der Meijden and van der Waals-Kooi, 1979 found that the number of capitula per plant was related to the size of the rosette in the year of flowering. Similarly estimates of total seed production per plant vary enormously (4760-174,230) (Table 3) although Cameron, 1935 reported that plants growing in good soil typically produced around 40,000 seeds. Only a small number of plants produced seed at the highest estimates and these had been cut in the previous year.

A small number of studies have assessed dispersal of ragwort seed in the field. In a mark recapture study, McEvoy and Cox (1987) found that numerous factors affected the dispersal distances from the parent plant including achene type (ray versus disc achene), release height, and time of release. No achenes were found more than 14 metres from the seed source (McEvoy and Cox, 1987), however it is worth noting that no seed traps were set at more than 16 m. The study looked at 312,000 achenes. Only 17% of these fell within the trapped area (traps were set between 1 and 16 m) with the remainder dispersing less than 1 m or remaining on the parent plant. Of those that dispersed into the trapped area, 31% moved only 1 m and 89% dispersed 5 m or less.

Table 1 Estimates of seed production

Reference	Seeds per capitulum; mean and (range)	Capitula per plant; mean and (range)	Seeds per plant; mean and (range)
Van der Meijden & van der Waals-Kooi, 1979 - 4 year old plants	175 (26-476) (4 year old plants) 27 (8-105) (3 year old plants)	125 (92-476)	
McEvoy & Cox, 1987		(902-1367)	
McEvoy, 1984	71		
Poole & Cairns, 1940	55-60	3375	(50,000-150,000)
Cameron, 1935	70	(68-2489)	(4760-174,230)
Chancellor, from Harper & Wood, 1957)	(65-80)	(110-392)	(7070-28,320)

Two sites were used and those achenes at the inland site dispersed significantly further than those at the coastal site (Table 4). Sites with taller vegetation had shorter dispersal distances than those with mown vegetation. Release height of the achene only had an effect on the dispersal distances of ragwort plants on the mown sites. The range of dispersal distances for disc achenes was approximately double that of ray achenes, with the disc achenes also dispersing earlier than ray achenes. The key dispersal differences by site and achene type form this study (McEvoy and Cox, 1987) are presented below (taken directly from study).

Table 2 Median dispersal distances for early (Aug-Sept) and late (Oct-Nov) dispersing achenes for different achene types, sites and surroundings. Ranges in parentheses and sample sizes in brackets. (Reproduced from McEvoy and Cox, 1987)

	Mown			Unmown		
	Early	Late	D†	Early	Late	D
Inland						
Disk	3.2 (1–14) [6827]	0.8 (1–5) [1115]	0.46*	1.7 (1–12) [4161]	1.5 (1–11) [1914]	0.06
Ray	4.0 (3–7) [24]	0.9 (1–3) [627]	0.93	2.3 (1–3) [23]	0.8 (1–3) [129]	0.52
Coast						
Disk	2.3 (1–14) [3724]	1.6 (1–13) [4712]	0.10*	0.8 (1–11) [1515]	0.6 (1–5) [1659]	0.14*
Ray	1.5 (1–4) [67]	1.4 (1–6) [1037]	0.07	0.5 (1) [14]	0.6 (1–2) [96]	0.08

* Adjusted $P < .05$ (corresponds to unadjusted $P < .0015$). Adjustment of significance levels was according to the Dunn-Sidak Method (Sokal and Rohlf 1981).
† The maximum distance between two relative cumulative frequency distributions.

Poole, (1940) reported similar results from a study which trapped seed within an area infested by ragwort and at a radius of 5, 10, 20 and 40 yards from the source along eight transects, originating from the source area at 45° intervals. 97.7% of seeds captured were recorded in the source area and only a very small proportion of seeds were dispersed at least 5 yards. Numbers of seeds trapped at each distance were corrected for trapping effort at different distances according to McEvoy and Cox, (1987) corrected data on seed numbers for the trap area at different distances from the source using the formula $X' = (X)(\pi/4)(1/A)(2wr + w^2)$ where X = trap catch, A = trap area, r = distance from the front of the trap to the source and w = trap width. Greater dispersal was recorded from transects downwind from the prevailing wind direction (Figure 6). Across all transects, 60% of seeds captured outside the source area (when corrected for the area trapped at each distance) were found only 5 yards from the source and only 6% were recorded at 40 yards.

Sheldon and Burrows (1973) calculated maximum dispersal distances in different wind speeds based on laboratory measurements of the rate of fall. They concluded that seeds of Ragwort, from a plant 90 cm tall, would disperse a maximum of 1.8, 3.7 and 5.5 m in wind speeds of 5.5, 10.9 and 16.4 km/hour.

These data suggest that dispersal distances for species with a pappus adapted for wind dispersal are very limited. However, environmental conditions may affect dispersal. Harper, (1957) reported that in humid conditions the pappus hairs cling together and become inoperative as a dispersal mechanism. Sheldon and Burrows (1973) reported experimental evidence of the effect of humidity on dispersal distance in *Senecio vulgaris* based on laboratory measurements of rates of fall at 0% and 75% relative humidity. However, Wardle (1987) notes personal communications where it has been suggested that isolated ragwort plants may have derived from seed that had been carried by the wind for many kilometres, though no evidence was presented to support this.

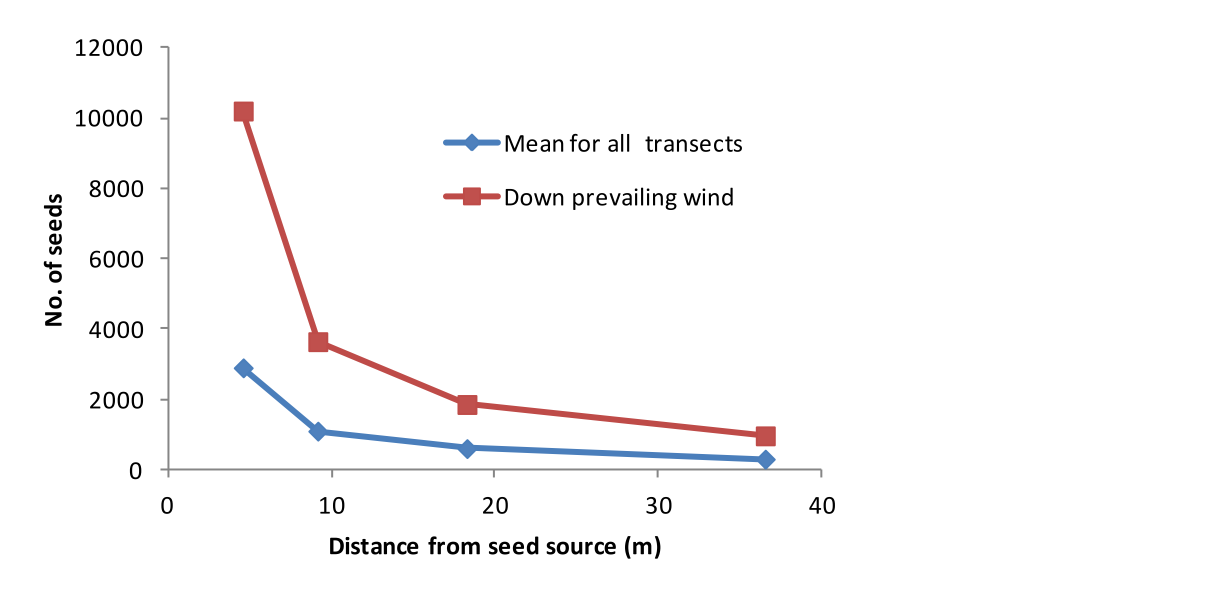

Figure 2 Dispersal distance of Ragwort seeds from a seed source in a pasture field (corrected for trap area at different distances). Data from (Poole, 1940).

Although no studies relating specifically to ragwort have been found, there is evidence that very long distance dispersal does take place for species adapted to wind dispersal (Soons *et al*., 2004); (Dauer *et al*., 2009) but that turbulence is required to facilitate very long distance dispersal by moving seeds higher into the atmosphere (Nathan *et al*., 2011). In a study of *Conyza canadensis* (another species with a wind dispersed achene) Dauer *et al*. (2009) recorded a very small number of seeds in the upper surface layer at 68 and 120 m above ground level and Shields *et al*. (2006) concluded that seeds of this species reaching these heights could travel several kilometres.

Little information is available on dispersal at distances intermediate between the relatively short distances (up to 40 m) and these very long distance dispersal events. However, Jones & Naylor (1992) reported ragwort seeds dispersing up to 72 m from a seed source on set-aside land into an adjacent arable field.

A report by Neumann *et al* (2009) as cited by Leiss (2011) suggested three levels of risk zones for the spread of ragwort onto a pasture. These were high risk if ragwort is within 50 m, Medium risk 50-100 m and low risk at over 100 m. However, it is not clear if this assessment is based on any information beyond the Defra Code of Practice. They suggest that under high risk, action to control the spread should be taken immediately. This supports the risk assessment highlighted in the Code of Practice, however the original publication has not been consulted, therefore the origin of the recommendations is uncertain. There is little field data available to support this assessment because trapping has rarely exceeded 50 m from a source population and McEvoy and Cox (1987) suggest that long range dispersal is almost impossible to measure. However Poole (1940) did observe individual achenes in the air beyond the 40 yard limit of their traps. They concluded that very little seed would disperse beyond the trapping area. However, dispersal of even a very small proportion of seeds over large distances could represent a problem, particularly since seed production can be very high. McEvoy and Cox (1987) concluded that the pappus is an inefficient dispersal mechanism and suggested that the expansion of ragwort populations may be mediated by humans, animals or water, although they did not investigate these aspects.

Seed production estimates vary widely, however this probably reflects genuine differences in seed production per plant in a species that can exhibit very plastic growth in different circumstances (M). There is a very high level of agreement from lab and field studies that dispersal distances are usually very short and that the vast majority of seed disperses only a few metres at maximum (H). There is less agreement and little data to indicate what proportion of seeds disperse beyond 50 m (L) although it is certainly very small.

2.1.4. Seed dormancy and persistence in soil

Seeds of ragwort have no innate dormancy. Grime et al. (1981) reported 94% germination in the laboratory of freshly collected seed, with 50% germinating in four days. Light is required for germination; only 8% of freshly collected seed germinated in dark conditions compared to 100% in light or shade (Grime et al., 1981). Dormancy is enforced by burial in at least 4 mm of sand (van der Meijden and van der Waals-Kooi, 1979). However the authors reported that a thin layer of sand (1-2 mm) stimulated germination compared to uncovered seed which they concluded was a result of more favourable moisture conditions. Similarly, Poole (1940) reported more rapid germination of seeds 'just covered with soil' compared to surface sown seeds and no germination was recorded over a 10 week period for seeds buried 1 inch deep.

Ragwort forms a persistent seed bank (Grime, 1988) however there are varying estimates of the time scale that ragwort seeds can persist in the soil while still retaining a level of viability. A report on Tansy Ragwort in British Columbia (Canada) suggests that seed can remain dormant in the soil for 4 to 5 years, but this can be extended to over 20 years if the seed is buried. However, work by Roberts (1986) indicated that very little seed germinated after one year (1.5% after burial for two years at 0-10 cm) when the soil was mixed three times a year to simulate cultivation. A study in New Zealand assessed seed viability in two soil types, and three soil depths over a 28 year study period (James, 2010). The two soil types were sandy loam and clay loam. Of the seeds produced by a ragwort plant, 69% of them were found to be viable. The number of seeds that germinated over the 28 year period declined. The results of this study are shown below, highlighting that seeds can remain persistent in soils for some time and this is impacted by soil type and burial depth (Table 5).

In a report of the early findings of this study, the authors conclude that due to long persistence of viable seeds in the soil, even without fresh additions of ragwort seeds it could still produce fresh infestations for more than ten years post eradication due to the persistence in the seed bank if the seed is buried (James and Rahman, 2000). This will have implications of the management of land on which ragwort has recently been eradicated.

The germination of ragwort seed has been shown experimentally to be correlated to soil temperature and soil moisture (Beskow et al., 1994). Both Roberts (1986) and van der Meijden and van der Waals-Kooi (1979) reported maximum germination in April/May with another, smaller peak in September. Conversely, Harper (1957) suggests that the majority of seed germinates in autumn with a later flush in spring.

Table 3 Extract of the results for ragwort showing the number of seeds germinating over time after burial at different depths in two soils, the coefficient of determination (R^2) of the calculated exponential decay curve and the predicted time for seed viability to decline to 1% (James, 2010).

	Horotiu sandy loam			Hamilton clay loam		
Burial time (years)	Burial depth (mm)			Burial depth (mm)		
	1-20	50	200	1-20	50	200
0	172	172	172	172	172	172
1	98	159	185	80	156	196
2	74	138	138	69	149	148
3	55	133	127	37	159	161
5	43	116	130	44	160	179
11	13	53	81	3	4	6
16	0	8	13	0	0	0
28	0	0	0	0	0	0
Time to 1%	9.8	16.6	17.2	9.0	9.9	10.1
R^2 (%)	82.6	90.2	86.6	91.3	88.2	86.5

There is some disagreement about the precise degree of persistence of ragwort seeds, but the different estimates of germination rates may reflect the different methods used. Seeds at or very close to the surface are less persistent than buried seeds (H). The maximum half life of unburied seeds is only around one year (M), whereas for buried seed, half life is a minimum of five years (M). A small percentage of seed will persist for 10-20 years (M).

2.1.5. Estimating likely risk of dispersal and persistence

This analysis is based on data from the literature, but has many assumptions and uncertainties associated with it. It can only be considered as a guide to the likely scale of the issue of dispersal and persistence in each scenario specified.

No field records are available for the proportion of seeds that disperse the maximum distance used in the risk assessment (100 m).

Two scenarios are presented in Table 4, based on number of seeds produced per square metre, likelihood of seed dispersing at least 5 m (for which data exist) and 100 m (based on assumption), and the number of seeds remaining after 9-17 years buried in the soil.

Table 4 Estimates of seed dispersal and persistence

	Seed production[1] m^{-2}	Prop at least 5 m (%)[2]	Prop at least 100 m (%)[3]	No. at least 5 m	No. at least 100 m	Proportion viable after between 9 and 17 years (%)[4]	No. viable after between 9 and 17 years at 5 m	No. viable after between 9 and 17 years at 100 m
Low	4760	0.9	0.01	43	0.48	1	0.43	0.005
High	174230	0.9	0.01	1568	17	1	15.68	0.174

[1] Based on lowest and highest estimates of seed production per plant (Cameron, 1935) However, estimates of seed density recovered from traps beneath a dense stand (most seeds are recovered from the immediate vicinity of the parent plant) represented 90,726 seeds m^{-2} (Poole, 1940) and only 1217 seeds m^{-2} (Anon, 1975 cited in (Simpson, 1993)).

[2] Data from (Poole, 1940) where of the 210,929 seeds caught in traps, 98% were caught in the source area and only 0.9% were caught more than 4.57 m from the source (data corrected for trapping effort at different distances from the source). Similarly (Jones and Naylor, 1992) recorded only 0.9% of seeds caught had dispersed at least 6 m from the source area.

[3] No data exist. (McEvoy and Cox, 1987) suggest that long range dispersal is almost impossible to measure. However the consensus of opinion is that dispersal over these distances is a very small proportion of seeds produced. Models have indicated that extremely long range dispersal can occur and other wind dispersed species have been recorded between 60 and 120 m above ground level (Dauer et al., 2009). Thus dispersal over intermediate distances is likely to occur even though it will represent only a very small proportion of seeds produced.

[4] Based on a study of seed viability when buried at 1-20 mm (9 years) and 200 mm (17 years) (James, 2010).

Other factors which influence the threat from ragwort include the likelihood of seeds dispersing to a suitable microsite for germination and, over the longer term, the likelihood of seeds becoming buried. Seeds that remain at the soil surface will lose viability quickly. Those that are buried may persist for many years but would not be stimulated to germinate without further disturbance.

Although these estimates of dispersal and persistence are largely (with the notable exception of seed dispersal beyond 100 m) based on data from the literature, they can only be considered a guide to the likely range of seed numbers under different scenarios (L).

2.2. RAGWORT STATUS

2.2.1. Current status

Plant Atlas data indicate that ragwort is almost ubiquitous across the country when recorded at the hectad scale (10 km x 10 km) (2000 – 2009). There is no evidence (Maskell et al., 2012) that it is invading new habitats.

2.2.2. Change in status

2.2.2.1. Long term changes

Recent work (Maskell *et al*., 2012) assessed changes in populations of injurious and invasive non-native species (including ragwort). They considered the value of various surveys (Countryside Survey (CS), Plant Atlas, BSBI local change data, Environmental Change Network (ECN)) in assessing change in ragwort populations.

None of the surveys assessed were entirely suitable for analysis of population change. Plant Atlas and BSBI data is not referenced at sufficient resolution to understand change, particularly of common species which occur in many hectads/tetrads. CS data, collected at the small plot scale is good for detecting change in common species which are often community dominants, whereas trends for rare species are less likely to be identified with CS because only a small area of land from within each sample square is assessed. CS and BSBI data both represent a sample rather than continuous data, although CS data can be scaled to represent GB. However, the eight year cycle of sampling in CS is good for detecting changes that occur over a period of years, but will not detect annual changes. Plant Atlas data is recorded over a period of years therefore can only be analysed by grouping years or modelling, however this minimises the impact of an individual year, which might be atypical or part of natural fluctuations (Maskell *et al*., 2012). The BSBI local change survey has only been conducted twice and not since 2003/4 (Braithwaite *et al*., 2006). Maskell *et al*., (2012) concluded that analysis of a combination of surveys gives the most accurate information on change available in the UK. Some assessment of drivers of change was possible, particularly from CS data where soil, water and land use data are available, however more detailed information on management would allow better interpretation. The periodic nature of UK surveys and data publication means that recent changes (i.e. in the last five years) cannot be identified.

A summary of the results from Maskell *et al*. (2012) is reported here. Two subsets of Countryside Survey data were analysed, one representing 260 squares across Great Britain between 1978 and 2007, and the other 500 squares between 1987 and 2007.

When changes over 20 or 30 years are considered (1978-2007 and 1990-2007) there were no changes in either frequency (+/- in plots) or abundance (% cover) for ragwort (Maskell *et al*., 2012). This included analyses of GB and England, which were applied to all plots, field plots and linear plots. Broad habitats were also analysed where possible but similarly no significant long term changes occurred. This suggests that there is no long term trend for changes in ragwort populations.

There were, however, some significant differences between individual surveys, although these might simply reflect year on year population fluctuations. For Great Britain, there were no significant differences in frequency of occurrence in field plots, however in England there was a significant increase in both datasets to 1998 and a significant decrease between 1998 and 2007 in the shorter term dataset with a larger number of plots (Figure 3).

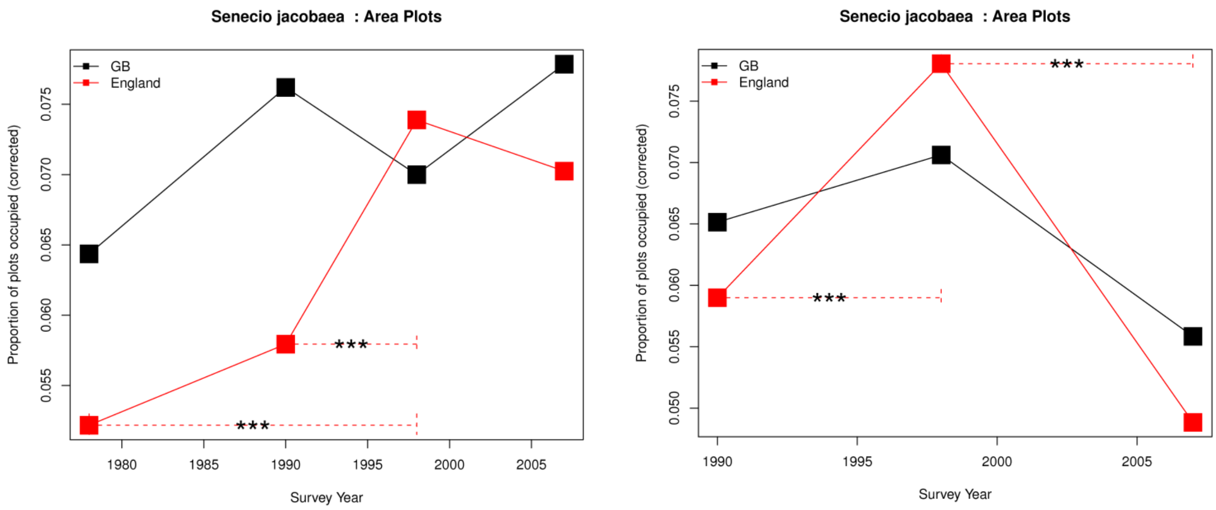

Figure 3 Changes in frequency of *Senecio jacobaea* in fields (fields, unenclosed land and small semi-natural biotope patches) a.) from repeat plots from 1978 to 2007, b.) from larger dataset of repeat plots 1990 to 2007. Reproduced from (Maskell et al., 2012).

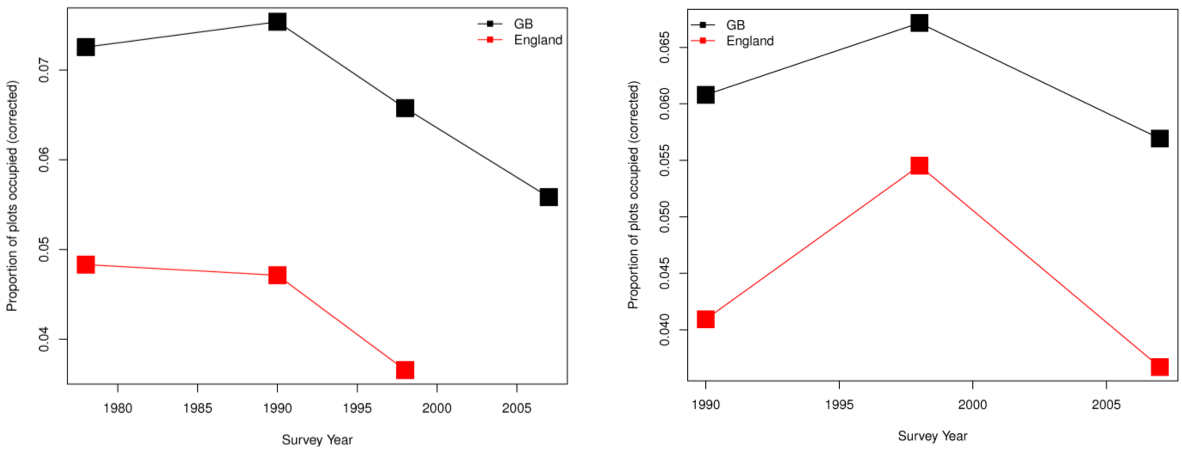

Figure 4 Changes in frequency of ragwort in linear plots (a.) from 1978 to 2007; (b.) from 1990 to 2007. Reproduced from (Maskell *et al.*, 2012)

Analysis of linear plots shows a very similar pattern to field plots for the larger dataset (shorter timescale). There were no significant differences but close to a significant increase between 1990 and 1998 (Figure 4).

Change index calculations for the plant atlas data (between 1970-1986 and 2000-2009) also indicate an increase in ragwort populations, but no subsequent data are available to substantiate the decreases recorded under Countryside Survey between 1998 and 2007. The BSBI local change data suggest an increase in populations between 1987 and 2004 (Braithwaite *et al*., 2006). The different time periods surveyed (and the potential for annual population fluctuations) makes it difficult to compare the results of the CS and BSBI local change surveys (Table 5).

Table 5 Change indices for ragwort from the BSBI, Plant Atlas and CS surveys in Great Britain. (From (Maskell et al., 2012).

No of records in CS07	CS change indices 78_07	CS change indices 90_07	BSBI Local change 1987-2004 CF*	Plant Atlas change indices
737	0.2	0.07	4	0.11

Records of abundance recorded in CS indicated that there were no long term trends in field plots in England between 1978-2007 or 1990-2007. However, a significant increase in ragwort abundance was recorded on road verges (subset of linear plots) in England between 1990 and 2007 (Maskell *et al*., 2012). It was also found that where a field/farm was in an agri-environment scheme there was less likely to be ragwort in a linear plot. However, no information on agri-environment agreements was available at the feature scale.

Similarities between CS and BSBI data reported suggest that the evidence on long term changes in populations over decades is robust (H).

2.2.2.2. Annual changes in populations

Ragwort populations are believed to fluctuate markedly between years and evidence for this is available from some studies of specific areas where annual recording has been undertaken. For example, in a study on Skokholm, Goodman (1954) observed marked changes in abundance of this species from year to year and concluded that the population fluctuations were probably associated with intense sheep grazing and the impact of high populations of the cinnabar moth. van der Meijden *et al*. (1991) monitored 100 2 x 2 m quadrats in a dune system. Ragwort disappeared in four years from one third of quadrats.

The Environmental Change Network (ECN) is an annual survey of a small number of sites. As such the sites are not a representative sample of the country, however the data are collected annually on plots which are referenced at a high spatial resolution and may have value in assessing annual changes in populations.

ECN data also suggest annual fluctuations of ragwort can be marked within a plot (although this is data from only one ECN site). If the ECN is correct, then the periodic nature of the CS makes it difficult to draw conclusions that consider the change between only two CS surveys. At the ECN site, populations apparently crashed in 2002. Unfortunately there were no assessments in 2001 and 2003. They also crashed in 2009, but this is the last year of in which ECN data are available. However this pattern does have similarities with the number of contacts/complaints concerning injurious weeds received by NE (Figure 3). These data include all injurious weeds, but almost all written complaints are regarding ragwort (Natural England, pers. comm.).

No other extensive annual surveys apparently exist which would provide data on short term changes in ragwort status. The Plantlife 'Wildflower Count' is an annual survey conducted by volunteers who record a list of 99 common plants. Unfortunately ragwort is not one of those recorded (S. Southway, pers. comm.).

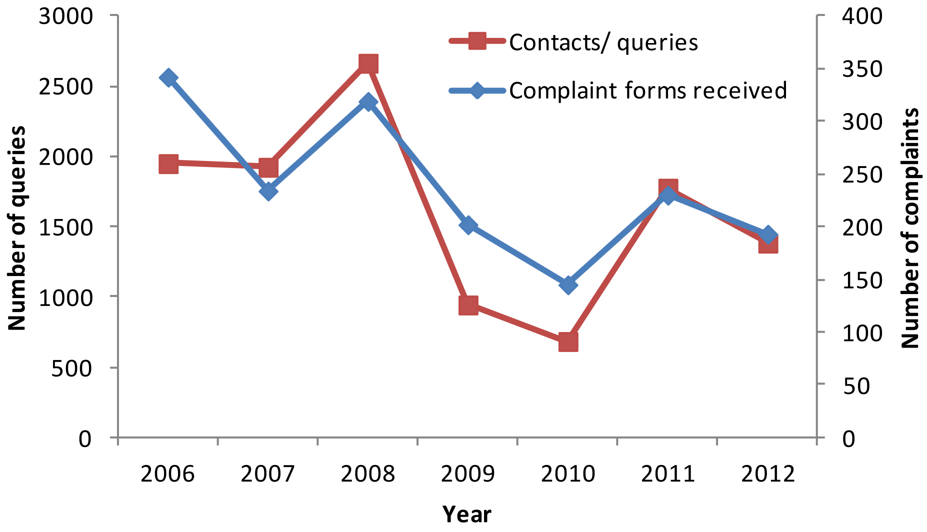

Figure 5 **Complaints and general enquiries regarding injurious weeds received by Natural England.**

In summary, few data exist on the annual fluctuations in populations, although an understanding of the biology and ecology of ragwort supports the limited information available (M).

2.3. IMPACTS ON LIVESTOCK

2.3.1. Evidence on numbers of livestock deaths

There is very little evidence on the number of livestock that die from ragwort poisoning due to consumption by choice. However, experimental studies have established doses of ragwort which produce lethal effects in sheep (Mortimer and White, 1975), goats (Goeger *et al*., 1982) horses (Craig *et al*., 1991) and cattle (Molyneux *et al*., 2011) given different dosages and duration of treatments.

Confidence in evidence:

Evidence on number of livestock deaths as a result of ragwort consumption (L)

Ragwort can cause death in animals (H)

2.3.2. Evidence on sub-lethal effects and their significance

2.3.2.1. What sub-lethal effects occur?

The low susceptibility of ruminants to pyrrolizidine alkaloid (PA) poisoning means that they rarely suffer from acute intoxication (Molyneux et al., 1988). However exposure to low doses over a long duration can lead to chronic poisoning, without causing any clinical signs. The progressive nature of chronic PA intoxication suggests that low-level PA exposure has cumulative effects. Little is known about what doses or durations are damaging (as opposed to lethal) or the effects of low level exposure on growth. Stegelmeier reports that no treatments nor diet supplements have proved effective and that poisoned animals that show clinical signs rarely recover (Stegelmeier, 2011).

2.3.2.2. What is the impact on the health of the animal?

The first symptoms observed in livestock are reported to be weight loss, depression, wandering, uncoordinated walking and diarrhoea, which has been described as “Winton disease", "Walking disease" and "Pictou Cattle Disease" (Bull et al., 1968). These behavioural symptoms are attributed to poor liver function affecting the brain. Jaundice and accumulation of fluid under the jaw and brisket may become apparent along with elevated levels of liver enzymes. Diagnosis requires liver biopsy or post-mortem examination, however liver damage may be caused by a number of factors including other toxins.

2.3.2.3. Do animals recover if further exposure to ragwort is prevented?

PAs occurring as N-oxides are water soluble and therefore can be excreted. Some oxidation of PAs occurs in the liver so can be considered as part of a detoxification process.

The metabolic pathways of PA intoxication and detoxication seem to be the same in all animals including humans (IPCS, 1988); this implies that the different rates of PA activation and detoxication determine the different susceptibilities of different species and individuals.

The microorganisms in the gut of ruminants are effective at metabolizing PAs into non-toxic derivatives; in some species (cows, sheep and goats) this process of detoxication is very efficient, reducing their susceptibility to PA poisoning (Wiedenfeld and Edgar, 2011).

2.3.2.4. Do toxins affect meat quality?

There is no evidence that the presence of PAs affects the flavour or texture of meat; the implications for human health are discussed in section 2.1.5.2

2.3.3. Risk of impacts on livestock

PAs are suspected to be present in 3% of all flowering plants (Wiedenfeld, 2011) and have been found in plants from across thirteen plant families (Wiedenfeld and Edgar, 2011). Ragwort contains six toxic PAs (Stegelmeier, 2011) and cases of ragwort poisoning in livestock reportedly date back as far as 1787 (Molyneux et al., 2011).

2.3.3.1. Levels of PA in ragwort and at different stages

The concentration of PAs in fresh ragwort flowers is reported to be 400 to 1700mg alkaloids kg^{-1} (Deinzer *et al.*, 1977 Ramsdell and Buhler, 1981, cited by Hough *et al.*, 2010). This concentration is higher than expected over the whole plant as the PAs generally accumulate in the flowers and seeds (Crews *et al.*, 2009).

Johnson *et al.*, 1985 found the PA content of ragwort to vary between 0.02% and 0.91% of the dry weight (mean 0.31% dry weight basis). Within this study they took monthly samples of ragwort plants over three years and analysed the PA content. Five sites were used in the USA, three being in Oregon, one in Washington and a final one in California. The same ragwort plant was not sampled more than once each season. The PA analyses of the leaves demonstrated large variability in PA content from month to month (Figure 6).

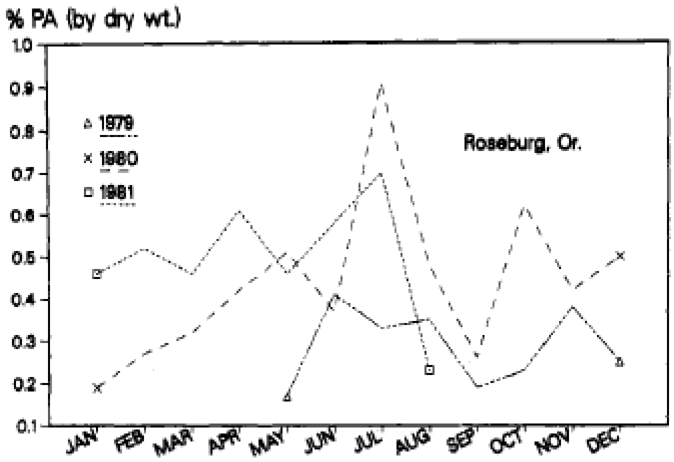

Figure 6 PA content of *S.jacobaea* leaves, reproduced from Johnson et al., 1985

A study using ragwort samples collected in Yorkshire at the flowering stage found total PA concentration to be 342mg/kg on a dry weight basis (Crews *et al.*, 2009).

Variation in concentration of PAs between ragwort plants can arise from drought and nutrient stress (Vrieling et al., 1993), with these stressed plants having on average higher PA concentrations. PA concentrations are also found to be highest in the roots of ragwort (Hol et al., 2003;Hol, 2011).

For the plant material that is above ground and poses the biggest risk to grazing livestock, analysis shows that the buds and flowers have the highest concentration of PAs (Wiedenfeld, 2011). PA content of ragwort ranged from 0.1% to 0.2% but in flowers and buds it was up to 0.8% (it is not clear if this is fresh or dry percentage but the paper implies it is a percentage of the fresh weight of ragwort). The author suggests that on this basis 2-4kg of dried plant material would be sufficient to reach the lethal level in a horse of approximately 350kg in body weight (Wiedenfeld, 2011). The variation in PA content in different areas of the plant is illustrated in Figure 7.

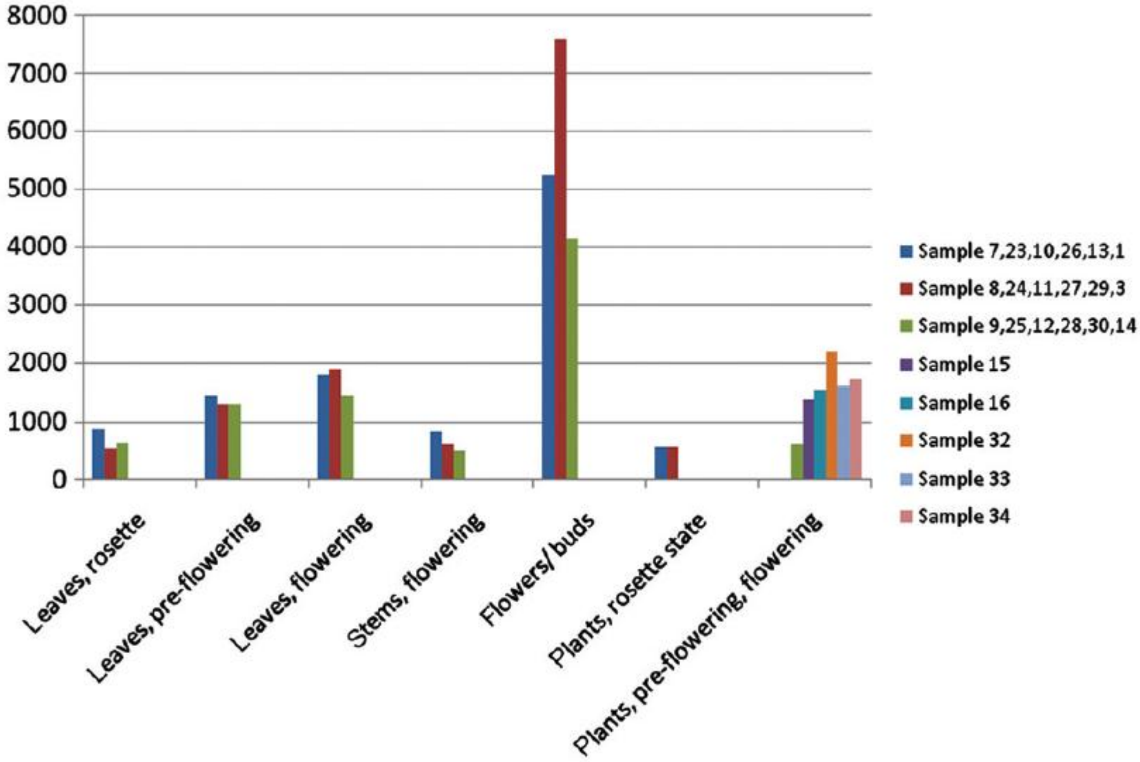

Figure 7 PAs (µg.g-1 plant material) in ragwort (reproduced from Wiedenfeld, 2011)

Confidence ratings:

- Ragwort always contains PAs (H)
- PA concentrations within ragwort plants vary with a combination of biotic and abiotic factors (H).

2.3.3.2. Do livestock eat living plants or only dead ones?

Livestock will eat both living and dead plants. Once the ragwort plant has been cut and incorporated into hay it is reported to pose more of a risk as it becomes more palatable once it is dry. Livestock (other than sheep) will not generally eat fresh ragwort in a field if other food is available. This is generally reported throughout literature from observations but there appear to be no direct feeding experiments to verify this. Stegelmeier (2011) for example states with reference to ragwort '*Although it is not very palatable and generally not eaten by livestock, poisoning occurs when plants or seeds contaminate feeds, when grazing animals cannot easily differentiate the early rosette from adjacent forage, or when no other forages are available'*

The PA content of ragwort has been shown experimentally to decline significantly, usually to undetectable levels during composting treatments, or storage in black bags (Crews *et al*., 2009;Hough *et al*., 2010). This is discussed further in section 2.5.3.3.

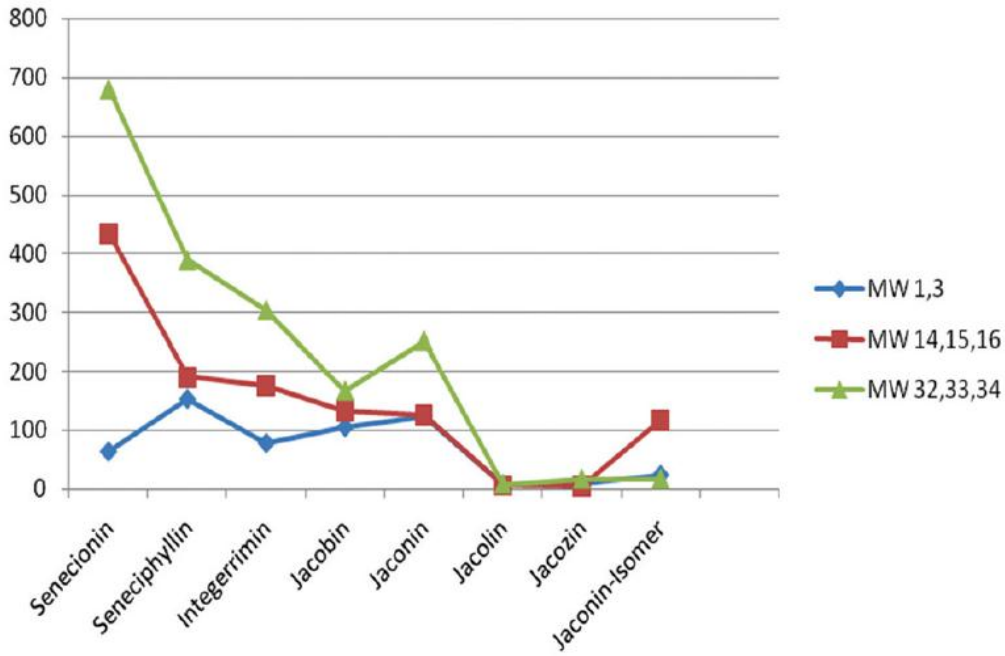

Figure 8 PAs (µg.g-1 plant material) in hay from ragwort (reproduced from Wiedenfeld, 2011)

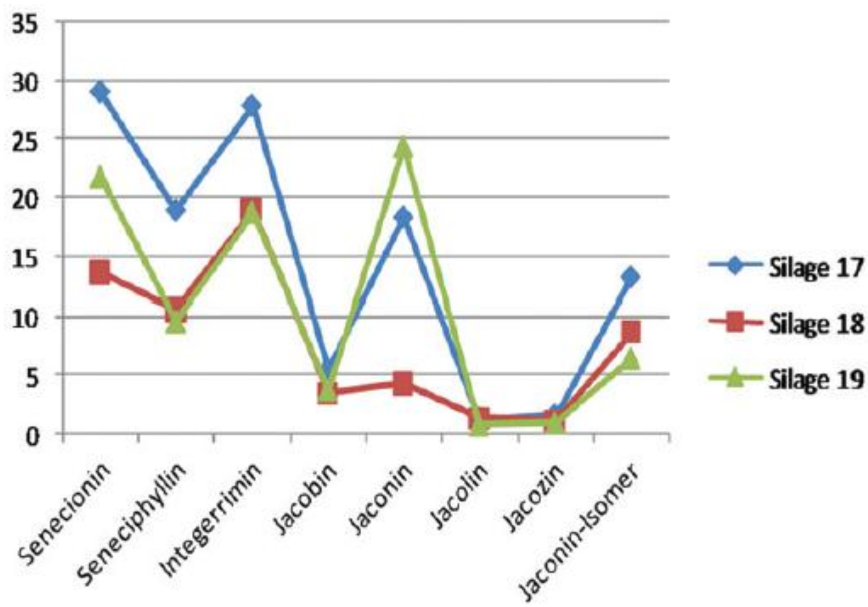

Figure 9 PAs (µg.g-1 plant material) in silage from ragwort (reproduced from Wiedenfeld, 2011)

Analysis of the PA content of both hay and silage revealed that within silage, the PA content can decrease to 10% of the original concentration. In hay there is little, if any decline in the PA content (Wiedenfeld, 2011). The PA contents in hay and silage are shown in Figures 8 and Figure 9 respectively.

Similar to PA decomposition during composting, the level of enzymatic decomposition with silage is variable depending on factors such as temperature, percent of ragwort within the original plant material and pH. An experiment comparing 100% pure dried ragwort, to 100% ragwort under silage conditions found the PA content in the pure dried ragwort to be 20% higher than the silage sample. Despite trying different conditions and starting volumes of ragwort within silage samples, ensiling never led to PA free silage (Becerra-Jiminez *et al*., 2012/3). Interestingly, the relative degradation of PAs was lower when the content of ragwort (Becerra-Jiminez *et al*., 2012/3) and a further PA containing plant, *Senecio alpinus* (Candrian *et al*., 1984) in the silage was lower.

In summary:

- Composting, storage in black bags or the incorporation of ragwort in silage reduces the concentration of PAs (H)
- PA can decline to undetectable levels in some composting treatments (M)
- There is little decline in PA concentration in ragwort that is incorporated into hay (M)
- Ragwort present in any feed, in any form will pose a risk to livestock that will vary depending upon the state of the ragwort (M)
- Hay is likely to pose more of a risk to livestock as the ragwort in dried form is more palatable yet still high in PA concentration(L)

2.3.3.3. How much needs to be eaten to cause symptoms/death?

Different species have different tolerance levels to PA toxicity. Reports suggest that the tolerance of sheep is 20 times that of cattle (Stegelmeier, 2011). The relative susceptibilities to PA poisoning have been reported to be: pigs=1: chickens=5; cattle and horses=14; rats=50 and sheep and goats=200 (Stegelmeier, 2011), where 1 indicates the highest susceptibility and 220 the lowest.

The low susceptibility of sheep explains the suggestions of their use as a possible control for ragwort (Sharrow and Mosher, 1982).

The reported chronic lethal dose for cattle is 2.5mg of total PA per kg of body weight taken for 18 consecutive days. Put into context this would amount to approximately 1.7kg of fresh ragwort each day for several weeks for the effects to be lethal (Stegelmeier, 2011). It should be noted that there is no reference within Stegelmeier (2011) as to the source of this reported lethal dose. However, a study on calves showed a similar dose of 2.8mg per kg of body weight for 20 days to be lethal (Molyneux *et al.*, 2011).

A German web page for a Working Group on ragwort, states that lethal doses to animals are as follows:[3]

Horses = 40-80 g fresh weight of ragwort per kg of body weight which equates to 14-28 kg of fresh weigh (or 2-4 kg of dry hay) for a 350 kg horse.

Beef cattle = 140 g fresh weight of ragwort per kg body weight.

NOTE; There is no indication of the time period over which this would need to be consumed to be lethal and the source is not given.

The same website also reports the following results of cattle feeding trials, source of the data not given[4]

A 180 kg animal was fed 180 g of ragwort daily for about 38 days, i.e. a total of 6.9 kg. After 54 days, the animal fell ill, and died on 55 Day.

A second 180 kg animal was fed over 128 days a total of 23 kg ragwort. This animal fell ill after 166 days and died on the 167 Day

A Swiss based webpage by the Swiss Institute of Veterinary Pharmacology and Toxicology summarises the lethal doses, and results of some feeding trials[5]. However, the original references from which this information was taken have not been obtained and the details of the studies are unclear from the web site (e.g. whether the ragwort dose was fresh or dry weight, duration of feeding).

Ruminants are reportedly able to detoxify the PAs through the presence of microorganisms in the rumen that are able to break down the PAs into non-toxic products (Wiedenfeld and Edgar, 2011). Hence ruminants exhibit lower susceptibility to PA poisoning when compared to monogastric species. In a study of the use of sheep as a bio control agent for ragwort, where ragwort plants were at a maximum density of 9.2 plants/m^2, no liver damage was seen when the sheep were slaughtered at 20 months (Betteridge *et al.*, 1994).

A feeding experiment on sheep suggests that the resistance to PAs may be induced and built up by the ingestion of continuous low levels of PA toxins. Sheep were fed seeds of *Crotalaria* that contained the PA monocrotaline at two different doses. Those on the higher dose died of acute or chronic intoxification. Those on the lower, continuous dose developed resistance to the PA toxins. When this group was fed the higher dose they did not have any clinical signs, indicating that resistance to PAs through continuous low dose feeding had been induced (Anjos *et al*., 2010). NOTE monocrotaline is not one of the PAs found in ragwort.

A study was undertaken in Oregon where 12 ponies that had no previous exposure to ragwort were fed pellets containing 5% ragwort under two feeding regimes (Craig *et al*., 1991). The mean PA content of the ragwort was 0.135% of the dry weight. In group one,

[3] Arbeitskreis Kreuzkraut (2007), Ragwort Working Group (Germany) [online] Available from <http://www.jacobskreuzkraut.de> [Accessed on 13/09/2013].
[4] Institute of Pharmacology and Toxicology (2013), *Senecio jacobaea* - Veterinary toxicology [online] University of Zurich, Switzerland. Available from <http://www.vetpharm.uzh.ch/reloader.htm?giftdb/pflanzen/0038_vet.htm?inhalt_c.htm > [Accessed on 13/09/2013].
[5] www.vetpharm.uzh.ch/reloader.htm?giftdb/pflanzen/0038_vet.htm?inhalt_c.htm

four ponies were fed continually the pellets containing ragwort (until death or euthanasia). In group two, four ponies were fed the ragwort pellets for 60 days. Both groups had two ponies receiving control pellets free of ragwort. The ponies were monitored until death.

The results of the study showing time of death are presented below in Table 6.

Table 6 PA consumption in ponies fed ragwort. Group I ponies were fed continuous 5% ragwort containing pellets until moribund. Group II ponies were fed the contaminated pellets for only 60 days.

Pony #	Mean Weight (kg)	Total Tansy Fed (kg)	Days Fed	Total PA Fed (g)	Total PA Fed mg/kg BW	Time of Death (days)
Group I						
1	159	17	173	23.0	144	173
2	168	30	296	40.5	241	296
3	150	27	296	36.5	243	296
4	164	12	119	16.2	98	119
Group II						
1	146	9	49	12.2	84	49
2	155	10	60	13.5	87	406
3	244	14	56	18.9	77	56
4	257	17	60	22.9	89	322

*Mean PA content of Senecio jacobaea was 0.135% of dry weight.

All the ponies that were fed ragwort developed terminal hepatopathy. The process of disease development in the liver was monitored in four ponies using percutaneous liver biopsies, and post-mortem analyses were also carried out. Time until death did not relate to the group the ponies were in, and in most cases the author reports there were no clinical signs until within a few days until death. It is also important to note that the animals in group two were fed ragwort for 60 days, the last dying at day 406 which is a significant length of time since the animal was last exposed to ragwort.

In summary:

- Different species exhibit differing levels of PA tolerance (M)
- Within a single species, individuals exhibit differing levels of tolerance to PAs (M)
- Symptoms of ragwort poisoning can be hard to detect and in cases may only become evident days before death despite long term exposure to ragwort (M)

2.4. RISK OF IMPACTS ON HUMAN HEALTH

2.4.1. Is there any risk to human health from consuming food stuffs that have been contaminated by ragwort?

Ragwort contains pyrrolizidine alkaloids which are known to be toxic and potentially lethal to humans, with different effects depending on dosage (Wiedenfeld and Edgar, 2011). The two main sources of pyrrolizidine alkaloid poisoning reported in human beings are the consumption of cereal grain contaminated by weeds containing the alkaloids and the use of alkaloid-containing herbs for medicinal and dietary purposes. A third form of exposure, with the potential to affect large populations is the possible low-level contamination of some foodstuffs including grains, honey, milk, liver and eggs, with PAs from ragwort, and other PA containing species such as groundsel and comfrey. In the UK, ragwort derivatives are most likely to enter the food chain in pollen and nectar in honey, or hay and silage fed to cattle and other livestock.

Liver disease caused by the contamination of cereal grains has been reported in rural populations in Afghanistan, India, South Africa, and the weed species responsible have included the Senecio genus but involve crops with an exceptionally high proportion of the alkaloid-containing weeds (World-Health-Organisation, 1980), which are unlikely to occur in the UK. Human poisoning through the medicinal use of herbs containing pyrrolizidine alkaloids, from Senecio species among others, has been reported from all parts of the world, including two from the UK, neither of which were attributed to ragwort (World-Health-Organisation, 1980). The more likely low-level contamination of honey, milk, eggs and meat are discussed below.

Pyrrolizidine alkaloids are metabolised in the human liver to derivatives which cause cirrhosis and veno-occlusive disease. Some PAs have also been shown to have mutagenic activity and genotoxic properties and to cause tumours in rodents (Fu et al., 2004). It might be assumed, therefore, that even a small dose may potentially cause tumours, however there have been no epidemiological studies to show that exposure to PAs results in increased cancer cases in humans (EFSA, 2007).

Several independent risk assessments have proposed tolerable levels of exposure for dehydroPAs and their N-oxides where the risk of disease is considered unlikely:

Committee on Toxicity (COT, 2008) suggest a limit of 0.1 µg/kg bw per day for non-cancer effects, and 0.007 µg/kg bw per day for cancer effects.

Food Standards Australia New Zealand (ANZFA, 2001) propose a limit of 1 µg/kg bw per day to avoid of veno-occlusive disease (cancer risk considered non proven).

Rijksinstituut voor Volksgezondheid en Milieu (RIVM, 2007) propose a limit of 0.1 µg/kg bw per day.

Bundesanzeiger (Bundersanzeiger, 1992) have set a limit for phytopharmaceuticals of 1 µg per day for a maximum of 6 weeks per year (zero for pregnant and lactating women) and 0.1µg per day if longer than 6 weeks per year.

Edgar in his review of PAs in food considers that low level, intermittent dietary exposure to dehydroPAs is to be expected in developed countries, leading to slowly progressing chronic diseases such as cancer, cirrhosis and pulmonary hypertension (Edgar *et al*., 2011). Ragwort is one potential source of such exposure, along with other plant species, but it is difficult to quantify the causal factors leading to such non-specific diseases.

In summary, there is good evidence to show that PAs cause liver damage in humans and can be fatal (M). There is no information to show that ragwort has been the source of fatalities. There have been attempts to identify a safe limit for PAs (L). There have been no studies that exposure to PAs leads to increased cases of cancer.

2.4.1.1. Is there any risk to human health from consuming meat from animals that have eaten ragwort?

There is a lack of information on whether hazardous residues of pyrrolizidine alkaloids, from ragwort and other plant species, remain in meat entering the human food chain. Dosing animals with radio-labelled PAs results in most being eliminated within 24 hours, suggesting that unless animals are killed soon after a large dose, PAs are not expected to be at a high level in tissues (Mattocks, 1986). However another study shows small amounts of radio-labelled PAs or derivatives remain detectable for months in edible tissues, especially the liver (Seawright, 1994). ANZFA reported PA levels of <0.010 to 0.073 µg/kg in livers and kidneys of domestic animals; this is below the level of 1 µg/kg bw per day which they determined is necessary to avoid veno-occlusive disease, but it is not clear whether these animals were representative of the population as a whole or were receiving specific diets (ANZFA, 2001).

The Committee on Toxicity of Chemicals in Food concluded that research using experimental animals suggests that levels in tissues would fall rapidly after ingestion (COT, 2008;Scotland, 2009). A more recent study concluded, 'the risk to health of persons consuming liver (or other tissues) from stock exposed to dehydroPA-producing plants is negligible ' (Fletcher *et al*., 2011).

In summary, there is limited information on the persistence of PAs in meat (L), and no studies which have considered the effects of ragwort specifically.

2.4.1.2. Is there any risk to human health from consuming eggs from animals that have eaten ragwort?

Experimental evidence for presence of PAs in eggs is lacking, but market analyses in Australia indicated the presence of certain PAs in eggs. No residues were detected in eggs from hens fed diets containing up to 4 % of *Senecio vernalis* (total PA content 0.14 %) for 210 days (Eröksüz *et al*., 2003). However, residual PA levels varying between 5 and 168 µg/kg were described on investigations from Australia (ANZFA, 2001). These results are for PAs from plants other than ragwort; no information has been found relating specifically to ragwort.

In summary, there is limited information on the transfer of PAs to eggs (L), none of which considers ragwort specifically.

2.4.1.3. Is there any risk to human health from consuming milk from animals that have eaten ragwort?

A number of studies have been carried out looking at transfer of pyrrolizidine alkaloids to milk in lactating animals.

A 1976 study in which cows were given high levels of ragwort (0.16% PAs for 2 weeks at 10 g/kg b.w./day) showed the transfer of only one (jacoline) of the several PAs found in the plants. Following correction for recovery, the highest mean concentration was 0.840 mg/L. The methodology at the time was only able to analyse a few PAs and no N-oxides. Taking into account the amount of ragwort fed to the cows, the milk yield and the PA concentrations in ragwort and milk, it was calculated that about 0.1% of the PAs was transferred to the milk (Dickinson et al., 1976). Similar studies on goats produced levels of

PAs of 7.5x10-3 mg PAs/kg dried weight (Goeger et al., 1982) and 3g per kg dry weight with a transfer to milk around 0.1% of the daily dose (Deinzer et al., 1982).

These studies are limited by the difficulties in recovering PAs from milk. An alternative approach at detecting levels of PAs is radioactive labelling. A study on cows showed that after treatment with 14C labelled PAs seneciphylline, a small amount, consisting of 0.16% of the administered dose, was excreted in the milk (Candrian et al., 1991), while in another study on mice 0.04% had been excreted into milk, 16 hours after administration (Eastman et al., 1982).

A survey carried out by MAFF in 1988 analysed 21 retail bulked samples of milk from an area which had the highest reported incidence of ragwort poisoning in cattle for the 2 years beforehand. No senecionine, seneciphylline or jacobine were detected in any sample and it was concluded that detectable levels were unlikely to be present elsewhere in the UK (Great Britain, 1994).

The European Food Safety Authority (EFSA) noted that milk can be a relevant source of PAs when obtained from a single animal which has ingested considerable amounts of PAs. However, since commercial practice in the UK is to bulk milk samples from all the cows at one farm and then also at the dairy, any PAs present are diluted, to very low levels (EFSA, 2007).

However improvement in analytical techniques and concern that N-oxides not previously detected might be responsible for part of the toxic effects (Molyneux and James, 1990) has led to further studies.

A team at the RIKILT Institute of Food Safety in the Netherlands decided to repeat the Dickinson study using much lower levels of ragwort. That study confirmed that jacoline was the major PA in ragwort transferred to milk, although it was only a minor component in the plant material itself. Practically no N-oxides were observed in milk, despite being over 80% of the pyrrolizidine alkaloids in ragwort. The overall carry-over of the PAs was estimated to be around 0.1% (similar to that in the earlier study (Dickinson et al., 1976), even though the ragwort dosages were 20–100 times lower. At the highest dosage level of 200 g day dried ragwort, the authors calculated the VSD (virtual safe dose) in consumers would be reached at a daily intake of 2–10 ml of affected milk. The authors urge the need of more research on the risk of specific PAs, like jacoline, in milk: 'since PAs can be classified as genotoxic carcinogens and since metabolites are known to be involved in these effects, further studies are needed to investigate the potential risks of ingestion of PA-containing herbs by food-producing animals and the risk of milk consumption in specific situations' (Hoogenboom et al., 2011).

In summary, there are studies which show that PAs, including those from ragwort, can be transferred to milk (M). More work is needed to ascertain the level of all possible PAs and their metabolites.

2.4.1.4. Is there any risk to human health from consuming honey made by bees that have foraged on ragwort?

The Honey International Packers Association has suggested that bees do not like foraging on ragwort or producing honey from it. They also state that the honey produced from it tastes unpleasant and therefore would not be consumed (Gormley, 2007), however there is a need for quantitative data to support this. Neither the British Bee Keepers Association nor the National Bee Unit mention ragwort on their websites; ragwort does not seem to be an issue currently among bee-keepers in the UK. There is anecdotal information that ragwort is valued as a late-season source of nectar (National Bee Unit, pers. comm.). When randomly-selected beekeepers were asked in a survey which plant species their bees were feeding on, ragwort was rarely mentioned. In 2010-2011, there were three records of bees feeding on ragwort out of 1228 returns. In 2011-2012 and 2012-2013 there were zero records for ragwort out of 1287 and 1182 returns respectively. (M. Brown, National Bee Unit, pers. comm.).

Deinzer first reported that pyrrolizidine alkaloids occurring in tansy ragwort (*Senecio jacobaea* L.) are present in honey produced from it, at levels up to 3900 µg/kg (Deinzer et al., 1977). However, accurate estimation of the level of PAs in honey is limited by extraction difficulties, and comparison of results from different studies is complicated by the use of different methods. Honey samples may contain several PAs from different plant species which have a combined effect. Different studies have sought to detect different PAs or metabolites using a variety of methods which may not specify the originating plant species (Kempf et al., 2011b).

In 1994 tests were carried out on honey samples collected from UK hives placed close to ragwort, or obtained from farmgate producers and a small independent retailer. Eight of 23 honey samples contained ragwort pollen and six of these had detectable levels of PAs. The two honey samples with the highest levels were dark, waxy samples, which were considered unpalatable and would not be used for blending with other honeys. Excluding these two samples, the highest detected level of PAs, was 0.06 µg/kg though the method used for this analysis was not reported. Using data on maximum honey consumption at any one time for adults (93 g), children (60 g) and infants (32 g), the authors concluded that PA consumption from locally produced honey was not a cause for concern (Great Britain, 1995).

A 2002 review of PAs in honey noted that the highest identified level of 3.9 µg PAs/kg was in honey reported to be from ragwort. This value was not corrected for extraction efficiency, estimated at 50-70% (Edgar et al., 2002).

In 2004, Food Standards Australia New Zealand (FSANZ) reported that Australian honey samples had levels up to 2 µg/kg PAs though it was noted that blending could substantially reduce this level. The highest levels were found in honey dominated by nectar from Paterson's Curse/Salvation Jane (*Echium plantagineum*). The FSANZ considered that 2-4 year old children of approximately 17kg with high levels of consumption at 28.6 g honey/day would be the most vulnerable subgroup of the population. To keep this subpopulation within the ANZFA provisional tolerable daily intake (PTDI) of 1 µg/kg b.w./day, the honey consumed would need to contain no more than 0.594 µg PAs/kg. As a result, the FSANZ advised that people consuming more than 2 tablespoons of honey every day (approximately 5% of the population) should not eat honey made exclusively from Paterson's Curse/Salvation Jane (FSANZ, 2004). The PAs in this case were not from ragwort but it does provide an example of what are considered to be unacceptable levels of PA in an unblended honey.

A Dutch study analysed honey samples for PA content of which 171 were retail samples of Dutch or imported origin and 8 were from hives deliberately placed in areas with high levels of groundsel, another PA-containing plant closely related to ragwort. Of the retail samples, 28% contained PAs at levels between 0.001 and 0.365 µg/kg. Four of the eight non-retail samples had detectable levels of PAs with the highest at 0.010 µg/kg. Dutch honey consumers were grouped depending on whether they consumed honey from different sources or from the same manufacturer. Each group was further subdivided into average (13 g honey/day) or high level consumers (30 g/day). The authors concluded that "only in cases of prolonged consumption of types of honey which contain high concentrations of PA is there any suggestion of a significantly increased risk of cancer and possibly acute liver damage." This was considered as rare so warning consumers of the risk was not felt to be useful (Netherlands, 2007).

The Food Standards Agency funded a project involving the collection and analysis of honey samples potentially contaminated with pyrrolizidine alkaloids from ragwort and borage. This investigated the potential for PA contamination of honey when bees foraged in areas where either borage or ragwort was growing in abundance. While the PA concentrations in honey could not be quantified due to a lack of analytical standards, they could be compared from one honey sample to another and relative to the amount of PAs in a fixed weight of plant material. Honey produced in areas with high levels of ragwort showed little difference in the PA profile compared to control sites except in honey from one site, which showed increased seneciphylline N-oxide levels. However conditions were very different at this site compared to sites for commercial honey production. The authors concluded that even where there appears to be little else to forage on, the honey produced showed no conclusive evidence of ragwort contamination in terms of PA profile and pollen contained in the honey (Canada;Gormley, 2007).

The Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment considered that there were limitations in the methods used in the above FSA study. The lack of analytical standards at the time of commissioning raised the possibility that where PAs were judged to be not present in the samples, this resulted from an inability to detect them. There was also concern that the PAs sought were the most prevalent in the plants but were not necessarily the most toxic PAs present. Overall, however, it was considered that the data from the project supported the hypothesis that honey produced in areas with a high concentration of ragwort is unlikely to be a concern for human health (COT, 2008).

The Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment sought to calculate acceptable levels of PAs in honey (COT, 2008). Using the limit of detection for honey of 1 µg/kg honey, hypothetical exposure assessments were carried out for all age groups based on the UK National Diet and Nutrition Surveys. The age group with highest PA exposure on a body weight basis in both instances would be infants. High level (97.5th percentile) infant consumers have an intake of 6.97 g honey per day (equivalent to 1.14 g/kg b.w./day), which includes honey in other foodstuffs. This is despite FSA advice for infants not to consume honey due to the very small possibility of bacterial contamination that could cause infant botulism. Following consumption of honey with a PA concentration at the limit of detection (1µg/kg honey), these high level infant consumers would receive 0.0011 µg PAs/kg b.w./day. This is 66,000 fold below the BMDL10 (Bench Mark Dose Lower Confidence Limit) and 90 fold below the dose of 0.1 µg/kg b.w./day, below which non-cancer effect would not be expected (this assumes that all the PAs present have equivalent potency to riddelliine, as no quantitative data on individual PAs present in honey are available). They concluded that the maximum PA concentration in honey, which would still maintain a Margin of Exposure of 10,000 compared to the BMDL10, for high level infant consumers, would be 6.4 µg/kg (COT, 2008).

In recent years, there have been several studies focused on getting better data on which to base an overview of the extent of PAs in honey (Kempf et al., 2011a) In order to achieve this, more samples had to be analysed and a method for the routine analysis of PA in honey and bee pollen had to be established (RIVM, 2007), (Kempf et al., 2008). They performed screenings of 171 and 216 honey samples and detected PAs in 25% and 8.8% of the samples, respectively, using very different methods, both of which are likely to give an underestimate. PA content of floral pollen ranged from 0.5 to 5 µg/g. The highest values were observed in pollen obtained from Senecio species (Kempf et al., 2010b)

A German study reported in 2011 (Dübecke et al., 2011) which aimed to provide a clearer view on PA levels in honey and bee pollen from different countries. A total of 3917 honey samples and 119 bee pollen samples from various countries were analysed regarding a range of 1,2-unsaturated (and thus potentially toxic) PAs. Raw honeys (bulk honey not yet packaged in containers for sale in retail outlets) and honeys available in supermarkets (usually blended honey) were considered separately. A total of 94% of the retail honeys contained PAs, but in 88% of the samples the concentrations were below 50 µg/kg. Thus, consumption of one hotel serving of honey (20 g) would still meet the limit for phytopharmaceuticals of 1 µg PAs per day (if not consumed for more than 6 weeks). The amounts of PAs found in some bee pollen samples could lead to negative health effects when these bee pollens are consumed, as consumption of only one teaspoon of bee pollen (about 5 g) may contain up to 189 µg of PAs, which is far beyond the existing German limit of 1 µg per day for the consumption of phytopharmaceuticals. Nevertheless, 40% of the bee pollen samples were PA negative. Only a limited number of PAs were analysed so there is the possibility that not all PAs present in honey and bee pollen were detected.

The EFSA Panel on Contaminants in the Food Chain carried out a further review in 2011 and analysis of results for 13,280 bulk honey and 1324 retail honey samples and 351 feed samples. They estimated both acute and chronic exposure to PAs through honey for three different age groups. The Panel concluded that there is a possible health concern for those toddlers and children who are high consumers of honey and for individuals who regularly eat locally produced unblended honey, whose exposure to PAs could be up to twice that of people who consume retail honey (EFSA, 2011).

It has been suggested that the dehydroPAs found in honey may have been introduced via pollen accidently dislodged into nectar, e.g. by nectar-collecting bees (Boppré, 2011), (Beales et al., 2007). Pollen from dehydroPA-producing plants contains extremely high levels of the N-oxides (Boppré et al., 2008), (Kempf et al., 2010a). These are very soluble in water and rapidly transfer into the nectar and thus end up in the honey.

It has been calculated, based on a 30% probability of dehydroPA occurrence, that consumption of the recommended daily amount of 10 g of bee pollen would expose an average consumer to 15 µg of dehydroPAs (Kempf et al., 2010b). At this level of exposure, the authors suggest that regular or intermittent ingestion of pollen-based food supplements by susceptible individuals could lead to chronic diseases such as pulmonary hypertension, cirrhosis and cancers. However, as with honey and perhaps for the same reasons, no cases of toxicity have yet been reported from the consumption of bee pollen food supplements.

Ragwort is one of several plant species which may contribute PAs to honey. The levels of PAs in honey are very variable, but clearly will be highest in honeys which are produced from a single source in an area which a high proportion of PA-producing plants, rather than commercial brands which are made from honey from many sources. There is insufficient data to establish whether low-level exposure to PAs in commercial honey contributes to chronic diseases such as liver cirrhosis, pulmonary hypertension and cancer. That no cases of dehydroPA-related toxicity have been attributed to the consumption of honey or bee pollen products, is maybe due to the intrinsic difficulties in associating slowly developing chronic diseases with dietary exposures to dehydroPAs or their N-oxides.

In summary, many studies have shown that PAs and their metabolites are found in honey (H). The levels of PAs reported have differed, due to differences in methodology and depending which PAs are investigated (M). A few studies have sought to investigate the impact of ragwort in particular, by analysing honey from hives in areas with abundant ragwort (L).

To conclude, there is a possibility that there may be low level chronic health risks from consuming honey containing PAs, to which ragwort may contribute along with other plants, but this is only likely to occur where high levels of honey produced in areas where a high proportion of the nectar comes from PA-producing plants.

2.5. CONTROL METHODS, THEIR EFFICACY, POTENTIAL FOR IMPROVEMENT (INCLUDING ANY NOVEL APPROACHES) AND COSTS

2.5.1. Pasture management to prevent establishment

The presence of bare ground increases the germination of ragwort seeds (Phung and Popay, 1981). It has been shown experimentally under greenhouse conditions that 35 days post sowing, 30.8% of seeds will germinate on bare ground as opposed to 14.4% on short pasture and 15.2% on long pasture (Phung and Popay, 1981). Field experiments have shown that grazing and trampling increases the germination of ragwort seedling (Beskow et al., 1994). In this experiment there were three treatments; grazed, treading (animal treading) and the removal of pasture to leave bare ground. All three treatments resulted in an increase in seedling emergence, with the complete removal of pasture resulting in the greatest increase in seedling emergence (Beskow et al., 1994).

A study by McEvoy (1984) looked at the theory of self replacement within habitats where ragwort already persisted. Along with being able to induce a perennial habit and seeds that can remain dormant for some years, self replacement was proposed as the third method in which ragwort can maintain a population once it becomes established. The field study mapped the dispersal of seeds from 26 adult ragwort plants and found that the number of seedlings declined sharply with distance from the average adult. Seedling density was 4.3 times higher inside the estimated perimeter of the rosette than outside the perimeter with the conclusion that higher densities were found at the base of the rosette (McEvoy, 1984b). As reported earlier ragwort, produces two types of achene with different dispersal patterns and germination patterns (McEvoy, 1984a), which McEvoy suggests may be related to self replacement. The non dispersing ray achenes ensure the population remains at the current site whilst the disc achenes with both a pappus and trichromes have a chance to disperse and colonize a new site if the conditions are conducive (McEvoy, 1984b).

2.5.1.1. Can establishment be prevented by appropriate management of pastures?

Bare ground appears to be one of the key aspects in the establishment of ragwort populations.

Rabbits have been noted to not eat ragwort (Harper and Wood, 1957) and therefore rabbits may exacerbate ragwort populations by removing the competition through grazing and creating bare patches of soil.

A study looking at the development of ragwort populations in fields that had been previously extensively grazed and cultivated showed a peak in percentage cover of ragwort at about 5 years after cessation of agricultural practices (van de Voorde et al., 2012). An interesting study by Bezemer *et al.* looked into the impact of sowing mid-successional plant species on ex-arable land on ragwort colonisation and biomass (Bezemer et al., 2006). Percent cover of ragwort was higher on the plots with zero sown species, but in this study ragwort abundance did not vary between plots sown with 4 or 15 species (the authors report this is in contrast to the majority of studies that conclude that increasing the plant diversity increases the resistance to colonisation). There is also suggestion within this paper of the impact of the soil community on the success of establishment (Bezemer et al., 2006).

Nitrogen application can reduce the incidence of ragwort, and also affect the concentration of PAs with the ragwort plant (Vrieling et al., 1993). Whilst an application of nitrogen has been shown to decrease the likelihood of establishment of ragwort due to competition (Suter et al., 2007) the concentration of PAs in plants under nutrient stress has been experimentally shown to have higher concentrations of PAs (Vrieling et al., 1993). Ragwort plants appear to allocate nitrogen to the production of PAs, to the detriment of fresh weight of the plant when nitrogen is limiting (Vrieling and van Wijk, 1994). In correlation to this, increasing nutrient levels has been shown to significantly decrease the concentrations of PAs while the total amount of PA produced in the plant remained constant (Hol et al., 2003). The concentrations of all PAs all decreased with the exception of jacobine. In conclusion, nutrient levels can affect the biomass of the plant but it do not seem to affect the amount of PA produced. Larger plants should therefore have a lower concentration of PAs. The main results of the Hol *et al* study are presented in Table 7, highlighting the points made above (Hol et al., 2003).

Table 7 The effect of nutrients on mean (+/- SE) biomass, pyrrolizidine alkaloid (PA) concentration, total PA concentration, total PA and relative allocation of PAs to the shoot in *Senecio jacobaea* (reproduced from Hol et al., 2003).

		N0	N1	N2	N3	*F*	d.f.	*P*
Biomass	Start (g f. wt)	0.95 ± 0.24a	0.79 ± 0.10a	0.90 ± 0.17a	1.01 ± 0.11a	0.34	3,35	0.796
(g d. wt)	Shoot	0.24 ± 0.03a	0.45 ± 0.07ab	0.63 ± 0.05b	0.94 ± 0.10c	17.49	3,35	0.000
	Main roots	0.18 ± 0.02a	0.20 ± 0.04a	0.20 ± 0.02a	0.26 ± 0.02a		3,35	0.203*
	Minor roots	0.32 ± 0.05a	0.36 ± 0.07a	0.37 ± 0.05a	0.45 ± 0.03a	0.90	3,35	0.450
	Whole plant	0.74 ± 0.10a	1.00 ± 0.17a	1.20 ± 0.12ab	1.68 ± 0.17b	6.767	3,35	0.001
	Shoot/root	0.51 ± 0.03a	0.89 ± 0.08b	1.16 ± 0.10bc	1.32 ± 0.06c	21.49	3,35	0.000
Nitrogen	Shoot	3.01 ± 0.22a	3.98 ± 0.19b	3.84 ± 0.16b	4.02 ± 0.17b	6.36	3,35	0.001
%N d. wt	Main root	0.71 ± 0.10a	1.16 ± 0.18ab	1.11 ± 0.14a	1.80 ± 0.21b	7.30	3,35	0.001
	Minor roots	2.01 ± 0.43a	1.79 ± 0.23a	1.73 ± 0.17a	2.12 ± 0.13a		3,35	0.523*
PA conc	Shoot	6.18 ± 0.07b	5.54 ± 0.41b	4.77 ± 0.35ab	3.30 ± 0.39a	8.38	3,35	0.000
(mg g^{-1} d. wt)	Main roots	6.68 ± 0.38cd	7.64 ± 0.44d	5.98 ± 0.32ac	4.61 ± 0.42a	10.98	3,35	0.000
	Minor roots	4.77 ± 0.34b	5.20 ± 0.32b	4.03 ± 0.37b	2.60 ± 0.39a	10.46	3,35	0.000
PA (mg)	Whole plant	4.19 ± 0.61a	5.78 ± 1.01a	5.84 ± 0.76a	5.45 ± 0.72a	0.88	3,35	0.461
PA production	mg g^{-1} root	8.69 ± 0.45ab	10.98 ± 0.61b	10.10 ± 0.71b	7.68 ± 0.60a	5.90	3,35	0.002
PA allocation	Shoot/total	0.36 ± 0.03a	0.44 ± 0.03ab	0.53 ± 0.01b	0.55 ± 0.06b		3,35	0.001*

N0: control: 0 mg Steiner wk^{-1}; N1: 20 ml Steiner wk^{-1}; N2: 40 ml Steiner wk^{-1}; N3: 60 ml Steiner wk^{-1}. *Kruskal–Wallis test.

Under intensively fertilised grassland management, increasing the application of nitrogen from 50 to 100kg $ha^{-1}yr^{-1}$ has been shown to reduce the risk of ragwort occurrence approximately five fold (Suter et al., 2007).

2.5.1.2. What are the key management practices that need to be followed and how effective are they?

The establishment of ragwort has been shown experimentally to be affected by the length of the vegetation, with percentage germination decreasing from 30.8% on bare ground to 15.2% on long pasture, which is thought to be a result of the lower light levels at the soil surface. This finding is supported by Beskow *et al* (1994) who found three treatments of grazing, treading and removal of pasture all increased the germination of ragwort (Beskow *et al*., 1994). A study by van de Voorde *et al* also highlighted a positive relationship between bare ground and ragwort establishment (van de Voorde et al., 2012). Experimental evidence collected by McEvoy and Rudd also showed that disturbance consistently increased the abundance of ragwort (McEvoy and Rudd, 1993). Within this study, the average seedling emergence rates per $0.06m^2$ were 78.9 on the tilled plots, 8.7 in clipped plots and 1.1 in dense unaltered vegetation.

The conclusion to a study by Dauer *et al,* that looked at bio control methods along with various levels of plant competition, was that overall the maximisation of plant competition was the fastest way to control ragwort. Hence their recommendation to landowners was to encourage interspecific plant competition early in the ragwort life cycle (Dauer *et al.*, 2012). If this was not an option then biocontrol by the ragwort flea beetle was the second choice (note this was a study in the USA).

Experimental evidence suggests that the optimum time for cutting of ragwort (in order to minimise regrowth, reduce the number of newly formed capitula and minimise the viability of achenes) appears to be when 10% of the capitula are open, and the florets are opening and yellow (Eisele *et al*., 2009). Cutting at this stage resulted in no germinable achenes in the floret that had been cut, however it is suggested that a second cut later in the year (at the same stage in flower development) may be needed to prevent germinable achenes being produced later in the year (Eisele *et al.*, 2009). This method of control is suggested only as a way to prevent spread of ragwort, not to reduce the population. This study was conducted in Germany and here the optimum cutting date in the given year fell on the 3rd July (Eisele et al., 2009).

Risk of ragwort occurrence is also related to low levels of nitrogen fertilisation, extensive overgrazing and open swards (Suter et al., 2007). In this study, a total 62 land parcels were looked at to see which combinations of factors increased or reduced the risk of ragwort. The hypotheses tested were;

- Frequent moving and fertilisation of grassland will favour fast growing species and produce dense ragwort free swards
- Pastures of low intensity, continuously and unevenly grazed with bare patches will be favourable for ragwort and provide an area where it may complete its lifecycle ad be abundant
- If ragwort occurs in high abundance on ruderal sites in the local vicinity of agriculturally managed grassland it will continuously colonise the managed parcel. But under regular cutting it will be prevented from seed formation, will occur in the vegetative state and will not increase in abundance

The findings of the study revealed that doubling the application of nitrogen (from 50 to 100kg ha^{-1} yr^{-1} led to an approximately five fold reduction in the occurrence of ragwort. This is thought to be due to the promotion of fast growing species which inhibit the growth of ragwort, and supports the first hypothesis.

A sward with in excess of 25% uncovered soil had a 40 times higher risk of ragwort occurrence than those with less than 25% bare ground. The study also showed that risk of ragwort was 11 times higher under continuous stocking compared to mown grassland, and

12 times higher under continuous stocking compared to rotational grazing. Within the study ragwort was never found in grassland that was mown more than twice per year and steeper sites were more at risk of ragwort establishment than relatively flat sites.

Ragwort was found in four intensively managed pastures. These fell into two categories. They were either highly fertilised, prone hillsides with bare ground and low maintenance, or adjacent to motorway verges that had high abundances of ragwort. This supports the third hypothesis.

The results of this study (Suter et al., 2007) undertaken in Switzerland demonstrate that many factors interact to affect the likelihood of ragwort establishing on pasture, and that it may be possible to identify sites that are at a higher risk than others.

In summary:

- Bare ground increases the potential for ragwort establishment (H)
- Increasing plant diversity can reduce the risk of colonisation by ragwort (L)
- Increase in the levels of nitrogen application can reduce the risk of ragwort occurrence (M) and reduce the concentration of PAs within ragwort (M)
- Disturbance increases the risk of ragwort establishment (M)
- Cutting at the correct time of year can help decrease the spread of ragwort (L)
- Overgrazing causes an increased risk of bare ground and disturbance and therefor an increased risk of ragwort establishment (M)

2.5.2. Herbicide use and application

2.5.2.1. What herbicides are available and how effective are they?

Herbicide data were extracted from the database of the 2009 Pesticide Usage Survey for grassland and fodder crops (Garthwaite *et al*., 2009), which was carried out by Fera. This survey is carried out every four years, and this is the most recent version available. The survey is being repeated in 2013. Glyphosate was excluded as this is used for total destruction of pastures rather than selective control.

A wide range of herbicides is used on grassland. However, survey respondents are asked what the reason was for spraying, so it is possible to identify which products were used where ragwort was identified as the target species. The areas treated with different active ingredients where ragwort was identified as a target are shown in Table 8. By far the most widely used was 2,4-D. 2,4-D mixtures with dicamba or MCPA were also frequently used, as was MCPA alone. All these are among the first herbicides that were available, indicating that little has changed in the last half a century.

Products containing 2,4-D, 2,4-D/dicamba/triclopyr and Dicamba/MCPA/mecoprop-P, among others, are approved for use on amenity grassland. These may therefore be available for use to control ragwort on non-agricultural grassland.

Table 8 **Area sprayed (ha) with different active ingredients where ragwort was identified as a target (from 2009 pesticide usage survey)**

Herbicide active ingredient(s)	reason for spraying			total
	ragwort	**docks/ ragwort**	**ragwort/ thistles**	
2,4-D	15,893	139	2,092	17,862
2,4-D/MCPA	2,334		42	2,375
MCPA	2,077	139	2,092	4,307
Metsulfuron-methyl	421	654		1,076
2,4-D/dicamba	5,139			5,139
Clopyralid/fluroxypyr/triclopyr			41	41

In a systematic review of management interventions to control ragwort, Roberts and Pullin (2007) carried out a meta-analysis for the effectiveness of control by various herbicides, which confirmed the efficacy of both 2, 4-D and MCPA in reducing densities of ragwort plants. Young rosettes are easier to control than older plants (Leiss, 2011).

2.5.2.2. What application methods are used in different situations and land use types?

Only around 6% of grassland is sprayed with herbicide, though the percentage is considerably higher for new leys. Of this, around 5% is sprayed for ragwort[6], which amounts to 0.35% of the total area of grassland. Most spraying for ragwort takes place in permanent pasture or grassland that is 2-5 years old.

Data from the 2009 Pesticide Usage Survey for grassland and fodder crops indicate that most spraying was by tractor mounted boom sprayer. Of 30,801 hectares sprayed where ragwort was identified as a target, only 108 ha (0.35%) were sprayed with a knapsack sprayer, the rest were sprayed with a tractor mounted boom sprayer.

2.5.2.3. What are their effects on other plant species?

Herbicides that are used for ragwort control are effective on a range of other broadleaved plant species. Species which may be found in or adjacent to grassland and listed as susceptible or moderately susceptible to 2, 4-D and MCPA are listed in Table 9. These are species for which information is available; other species may also be susceptible but information is insufficient or lacking. Black (1976, quoted by Leiss, 2011) noted that red and white clovers are also susceptible to herbicides used for ragwort control.

Table 9 **Species listed as susceptible or moderately susceptible to 2,4-D or mecoprop (from Flint, 1987)**

[6] Calculated from area where ragwort identified as a target species, plus an estimate of the proportion of grassland sprayed for general broad-leaved weed control that is likely to contain ragwort, derived from the proportion of land sprayed for specific species that includes ragwort.

Species	Susceptibility*	
	2,4-D	Mecoprop
Branched bur-reed	S	
Buttercup, Creeping	M	S
Buttercup, Meadow		S
Campion, Bladder		S
Campion, Red		S
Campion, White		S
Cat's Ear	M	M
Chickweed, Common		S
Daisy	M	S
Dandelion	M	
Dock (broad-leaved + Curled)	M	S
Knapweed, Common	M	
Knapweed, Greater	M	
Mint, Water	S	
Mouse-ear, Common	M	S
Nettle, Common		S
Plantain spp.	M	S
Ragwort, Common	M	
Rush, soft	M	M
Sorrel, Common	M	
Sorrel, Sheep's	M	
Star-thistle, Red	M	
Thistle, Creeping	M	S
Thistle, Spear	M	S
Vetch, Common		S
Water-cress	S	
Willow-herb, Great	S	

*S = susceptible; M = moderately susceptible

2.5.2.4. When are they most appropriately used?

Guidance for 2,4-D application is to spray when growing vigorously in the spring when plants are in the rosette stage, before flower spikes start to grow. Spraying should be carried out in two successive years, in May or June (Flint, 1987).

Records from the 2009 Pesticide Usage Survey for grassland and fodder crops indicate that most spraying for ragwort occurred in April and May (Table 10).

Table 10 Area sprayed for ragwort by month (from the 2009 Pesticide Usage Survey for grassland and fodder crops)

Month	Area (ha)
March	61
April	20,590
May	7,938
June	646
July	903
October	452

2.5.2.5. Are there circumstances where herbicide application could exacerbate the problem, e.g. by creating more bare ground?

Inappropriate herbicide use could exacerbate a ragwort infestation by creating more bare ground in which ragwort seedlings can establish. Hence broad-spectrum herbicides should be avoided and grassland managed to encourage colonisation of gaps created by spraying as rapidly as possible. Where a significant amount of bare ground is present, partial or complete re-seeding should be considered.

2.5.3. Physical methods (e.g. pulling, cutting etc.)

2.5.3.1. What methods are available and how effective are they?

Cutting and pulling are both used but there is limited reference to the effectiveness of physical control methods with the literature. Roberts & Pullin (2007), who carried out a systematic review of the effectiveness of management interventions used to control ragwort species, stated that their searches had revealed no high quality evidence on manual and mechanical control methods, and recommended further research.

Pulling and cutting may help prevent the spread of ragwort via the prevention of seeding but it is unlikely to reduce a population of ragwort unless the roots can be removed. As mentioned previously (section 2.5.1.2) cutting may be effective to control a population if cut at an appropriate time to prevent seed production. Additionally plants that are cut, or pulled with large root mass remaining have a tendency to re-grow forming multiple crowns (Leiss, 2011). Cutting of ragwort plants promotes the formation of multiple rosettes which can form new capitula just 26 days after cutting (Eisele et al., 2009). McLaren, 2004 reports that plants can regenerate from root fragments less than 2.5cm long with 2 months (however, there is no reference for the original source of this information). Similarly, Harper and Wood (1957), reported that regeneration can occur from roots of 1.5cm in length.

Poole (1940)reported that a trial involving flame throwers successfully killed 93% of seeding ragwort. The seeds on the burnt plants did not retain their viability.

Advice published by the State of Victoria (Australia) suggests that ploughing to a minimum of 15cm depth in spring, followed by summer and autumn cultivations will also help to manage ragwort by killing plants, regrowth and seedlings. The advice does recommend that the cultivation needs to be carried out systematically and needs to be followed by an improved pasture or cropping programme to suppress ragwort that will germinate form the seed bank (McLaren, 2004).

The extent of ragwort removal via pulling in the UK is unclear, although it is known to be undertaken by landowners. Various articles on the Horse and Hound Website[7][8] were found which encouraged the pulling of ragwort through the promotion of 'ragwort pulling parties' and 'Ragwort awareness weeks' run by the British Horse Society (BHS). The BHS Ragwort Awareness Weeks for 2013 ran from 17-23rd September[9], and it promoted the organisation of pulling parties to remove ragwort.

Similarly, web-page references have been found to the pulling of ragwort by volunteers helping the National Trust[10] and Wildlife Trusts[11], with the Yorkshire Wildlife Trust stating that '*Pulling ragwort is a really important part of managing our reserves*'.

There is a specialist tool that has been developed for removing ragwort, the 'Rag-Fork', which claims it has 'been specifically designed to remove ragwort and other common field weeds by their roots, preventing re-growth'[12] although there is no evidence on the effectiveness of this method of removal.

In summary:

- Cutting and pulling can promote the formation of plants with multiple crowns (M)
- Ragwort can regenerate from roots that remain in the soil after pulling (M)

2.5.3.2. Disposal after physical removal

The PAs in ragwort will remain present once the plant has been pulled and so one of the main considerations if using this method as control has to be the disposal of the plant in order to prevent animals gaining access to the dried ragwort. In addition given the large number of achenes that a single plant may produce its important if a plant is pulled when seed has set, the achenes are prevented from dispersal.

Composting of ragwort, and then the application of the compost was highlighted as an area of concern for livestock produces (Hough *et al*., 2010) due to the possible persistence of the PAs. The degradation of toxins in ragwort were monitored in a pilot scale compost heap over a three month period (Hough *et al*., 2010). Results suggest that the PA as in

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7 http://www.horseandhound.co.uk/news/volunteers-needed-to-help-control-the-deadly-yellow-weed-ragwort/#SdwU5RkgHXZX7D2y.99
8 http://www.horseandhound.co.uk/news/bhs-throws-ragwort-pulling-party/#19V3oPhJqeSYGLuP.99
9 http://www.horseandhound.co.uk/news/pulling-parties-organised-for-ragwort-awareness-week/#EwTFZtYUEYCzWP1z.99

10 http://ntlargeblue.wordpress.com/2013/07/25/a-ragwort-here-and-a-ragwort-there/

11 http://www.ywt.org.uk/news/2013/07/30/ragwort-ahoy
12 http://www.livingthelifeofriley.co.uk/acatalog/about-rag-fork.html

compositing are degraded fully after a cumulative temperature of 200dc, and reached undetectable levels within 4 weeks(Hough *et al*., 2010)

A similar study looked at the degradation of PAs when stored in waste bags (Crews *et al*., 2009). Ragwort was harvested in flower but before seed set, and placed in loosely sealed black polythene bin bags, 20 plants per bag. The bags were left in the sunlight. Two plants were removed every 2 weeks and analysis of their PAs was undertaken. At the onset of the experiment the total PA concentration was 342 mg/kg dry weight basis, and at week 8 this had decreased to 6mg/kg (Crews *et al*., 2009).

In summary:

- Ragwort remains a threat to animals once it has been cut or pulled (H)
- Ragwort need to be disposed of appropriately to minimise the levels of PAs in the plant material, and prevent livestock gaining access to it (H)

2.5.4. Biological control

Biological control, as defined by Eilenberg and co-authors (2001), is the use of living organisms to suppress the population density of a specific pest organism making it less abundant or damaging. These authors determine classical biological control as the intentional introduction of an exotic biological control agent for permanent establishment and long term control. This type is most effective as the control organism is in an area outside its native range. Therefore the biotic factors limiting the insect biological control species' population growth have been left behind. A good example of this would be the control of water hyacinth, *Eichhornia crassipes*, from the Amazon by two weevils and two moths, all from South America, on Lake Victoria (Dagno *et al*., 2007).

Worldwide there have been seven biological control agents that have been used against ragwort (Ireson, 2012). These are:

- *Tyria jacobaeae* (Cinnabar moth-foliage feeder)
- *Botanophila jacobaeae* (Seed fly)
- *Botanophila seneciella* (Seed fly)
- *Longitars uragworte* (Root-feeding flea beetle)
- *Longitarsus flavicornis* (Root-feeding flea beetle)
- *Cochylis atricapitana* (Crown boring moth larva)
- *Platyptilia isodactyla* (Ragwort Crown-Boring Plume Moth)

These biological control agents have been successful in countries where they have been imported to control non-native ragwort populations. The same biological control agents are unlikely to have any considerable impact within the UK as other species that parasitize and predate the bio control species will also be present and limit population levels. Biological control is most effective when the organism used for control is in an area outside its native range. This is because biotic factors limiting the population growth of the insect biological control species are not present . All the insect biological control agents for ragwort in Australia, USA and Canada are native to this country and therefore there are no potential 'foreign' agents that can be used at the moment. The known candidates that are present in the UK are clearly being affected in their distribution by factors other than their host plant as most have limited distributions or are declining and this is not the case for ragwort. Therefore the only other option would be augmented introductions where large numbers of individuals of a species would be released over areas with high ragwort populations. This would mean that the chosen species would have to be bred under artificial conditions in large numbers and then transported to the target area for release. However, they would not be expected to establish permanently at a sufficiently high population density for continuous control (Eilenberg, 2006). It is therefore likely that further releases would be required annually as the introduced populations would rapidly decline to a 'normal' density as natural limiting factors came into operation. Even in Oregon USA, where ragwort populations are successfully suppressed by biological control, (though 2011 saw the return of ragwort due to environmental factors[13]), there have been more than 3500 releases of the Cinnabar moth in 17 counties between 1960 and 1991 and more than 300 releases of the ragwort seedfly (*Botanophila seneciella*) between 1966 and 1991 (McEvoy *et al.,* 1991).

In addition sheep have been used as biocontrol agents, as they will graze on ragwort and have high tolerance of the PAs.

*2.5.4.1. Ragwort flea beetle (***Longitarsus flavicornis** *and* **Longitarsus jacobaeae)**

The ragwort flea beetle is commonly used, successfully, in areas where ragwort is an invasive species. It is considered to be more successful than the cinnabar moth because the flea adults are pit feeders and rasp holes in mainly juvenile plants, while the larvae develop by feeding on leaves, petioles, stems and root. In contrast the larvae of the cinnabar moth feed on the leaf and flower (Dauer et al., 2012).

There are two species of flea beetle that have been use for biological control, these are *Longitarsus flavicornis* and *Longitarsus jacobaeae.* Within more general reports on the effectiveness of the flea beetle it is often just referred to as 'the ragwort flea beetle' so it is hard to determine which of the species is being referring to. The implication from the review by Leiss, 2011, is that *L. jacobaeae* was introduced in the USA, Australia and New Zealand. The species introduced into Australia was later identified as *Longitarus flavicornis L. jacobaeae* and is now established in Australia.

A French strain of the flea beetle was released in Tasmania, Australia as a biological control in 1979 (Ireson *et al.*, 1991; Ireson *et al.*, 2000). This was originally thought to be *L. jacobaeae* but it was later identified as *L. flavicornis* (Ireson *et al*., 1991;Ireson, 2012). Ragwort populations at two of the release sites were monitored. It was noted that the ragwort density at these two sites was reduced. At one site the population declined from 55.2 plants/m^2 to 6.4 plants /m^2. The initial population at the two sites consisted of plants with single and multi-crowns, and shoots of various sizes and development stages. The flea beetle was seen to change the population of ragwort plants to one of plants consisting of small rosettes and small single crowns (Ireson et al., 1991).

A programme to redistribute the flea beetle population in Tasmania commenced in 1986, with an average of 2000 adults being released at 879 sites. Surveys were undertaken in 1999

[13] http://westernfarmpress.com/management/invasive-tansy-ragwort-once-again-threatening-oregon (accessed 17/12/2013)

that showed the flea beetle had dispersed well and was present in 90% of the sites in which it was released. Reductions of ragwort densities of up to 95% were recorded at one of the sites. The beetle was not successful at all sites, however and successful establishment of a population varied. This variation is thought in part to be due to flooding, incompatible management practices such as the use of boom spraying (Ireson et al., 2000) and in very dry areas, the desiccation of eggs. General implications from literature are that *L. jacobaeae* is considered to be better adapted to drier, low altitude areas where *L. flavicornis* is unable to establish (Ireson, 2012).

In a controlled experiment the survival of *L. flavicornis* larvae was monitored while it was inundated with water. At 24 hours of inundation 35.6% of the larvae had died, with 50.4% mortality at 72 hours (Potter *et al.*, 2007). This finding supports the proposal that lower levels of successful bio control with the ragwort flea beetle are exhibited where the land is prone to flooding.

A study by Potter *et al*, (2004b), in a study on the variation in success of the *L. flavicornis* populations in Australia, indicated that a high level of salinity and a low abundance of plant roots also reduced the success of the ragwort flea beetle.

Reported recommendations in 2004 in Tasmania for the control of ragwort were for wick-wiping of herbicides in summer to kill flowering ragwort and aid in the reduction of seed production (Potter *et al.*, 2004a). This was recommended as a way to integrate bio control and chemical control and is supported by evidence collected in a study by Potter *et al* (2004). This study found 80% of adult *L. flavicornis* occurred on the rosette rather than the flowering plant, and that 95% of eggs were laid around the rosette rather than on the flowering plant (Potter et al., 2004a). Wick-wiping of ragwort with herbicides should therefore have minimal impact on the ragwort flea beetle.

Experimental work undertaken in Oregon found that *L. jacobaeae* were able to reduce vegetative ragwort densities by 95% and flower production by 39%. In combination with defoliation (undertaken to replicate the effect of cinnabar moths), the damage caused by *L. jacobaeae* reduced the ragwort plants' ability to compensate for defoliation and defloration, resulting in a reduction of 98% in capitulum production and the production of no viable achenes (James *et al.*, 1992).

L. jacobaeae was released in New Zealand in 1981 (Suckling, 2013). There are variations in the levels of success *L. jacobaeae* has had on ragwort populations, with some sites seeing a reduction of 90-100%, but others where *L. jacobaeae* has not been as successful.

In New Zealand less success has been seen in the areas where the insect appears to be limited by high rainfall (Gourlay *et al* 2005, as cited by Suckling, 2013).

2.5.4.2. Cinnabar moth (Tyria jacobaeae)

Cinnabar moth larvae feed on the leaves and flowers of ragwort, and have been show to aid in the reduction of ragwort populations but not as effectively as the flea beetle (Dauer *et al*., 2012). Releases and the success of ragwort control of the moth in America are known at some locations to have been limited by predation of the moth larvae by carpenter ants (Crider, 2011). Exclusion of ants from an experimental site increased the consumption of ragwort flowers by the larvae from 18% to 81% (Crider, 2011).

A study in Oregon that artificially replicated the mode of bio control offered by the moth (defoliation) found a reduction in capitulum production of 77% and a reduction of 15% in the number of achenes produced (James et al., 1992). The cinnabar moth was found to be most effective when used in combination with the flea beetle *L. jacobaeae*, resulting in the production of no viable achenes (James et al., 1992).

A review by Roberts and Pullin (2007) on methods for the control of ragwort found that the cinnabar moth does not significantly reduce the population of ragwort, but it does affect the reproductive capability of the plant. Numbers of capitula per plant, seed per capitulum, viability of seed and dry weight of the plant were all significantly reduced (Roberts and Pullin, 2007). This is supported by an original study in Oregon by McEvoy and Rudd who concluded that '*reduction in ragwort fecundity by the cinnabar moth had little effect on the dynamics of ragwort populations on local scales of space and time'* (McEvoy and Rudd, 1993)

The effectiveness of the cinnabar moth in most situations as a biocontrol agent is likely to be limited. It may reduce capitulum production, and the number of achenes but this will be irrelevant in area where there is a large viable seed bank (McEvoy *et al.*, 1993). Furthermore in Britain there is such a long interval between its feeding in June and July and the onset of frost that the moth has little effect as the plants have sufficient time to recover from any defoliation (Simpson, 1993).

The cinnabar moth has been found to be more effective when the ragwort plants suffer from moisture stress, and it has been proposed in areas that receive high levels of rainfall a second bio control agent would be required to achieve satisfactory levels of control of ragwort populations (Cox and McEvoy, 1983). Ragwort plants were able to recover from defoliation in areas where water was sufficient.

2.5.4.3. Ragwort seed fly

The life cycle of the ragwort seed-fly is closely synchronised with ragwort. It has one generation per year (Cameron, 1935). Adult emergence coincides with the appearance of buds of ragwort in the spring (Frick and Andres, 1967) and the eggs are laid in the in the buds of the plant. The larvae feed on the developing seeds of the plant and are fully developed in one month. They enter the soil and overwinter as diapausing prepupae (Frick and Andres, 1967).

Two species of ragwort seed-fly, *Batanophila seneciella* and *Batanophila jacobaeae*, have been used for the control of ragwort (Dymock 1998), the larvae of both species feeding exclusively on the developing seed heads of *S. jacobaea* (Frick and Andres, 1967). Their use for biological control has occurred in countries beyond the native range of *S. jacobaea*, where the plant is now established as an introduced pest species. Control attempts have taken place in New Zealand (1928), Australia (1930), Canada (1968) and the USA (1966) (Dymock, 1988; Harris *et al.*, 1971; Field, 1989; Frick, 1969) with ragwort seed-fly stocks sourced from European countries such as England, France, Spain, Italy, Switzerland and Austria (McLaren, 2000; Harris *et al*., 1971; Field, 1989). These releases had varying rates of success, set back by the difficulties with rearing flies under laboratory conditions and establishment in the field (Harris *et al*., 1971; McLaren, 2000). In Canada, from a stock of 2000 puparia received from the USA (originating from collections made in Italy), only 105 flies were eventually released on Prince Edward Island and 80 in British Columbia; neither population is believed to have established (Harris *et al*., 1971). In Australia, no releases from the first introduction were made because of difficulties with rearing the flies (McLaren, 2000), as they would not oviposit in captivity (Harris *et al*., 1971). It was not until 1958 that a release of *B. jacobaeae* was made in Victoria and Tasmania (Field, 1989). There has been no subsequent evidence of the insect establishing in either state (Field, 1989).

In New Zealand, both *B. seniciella* and *B. jacobaeae* were released between 1928 and 1939 (Miller 1970) in an effort to control ragwort. By 1954 the insect had established itself (Frick and Andres, 1967) and was reported to have infested 98% of the early blooming flower heads within a range of about 10 square miles. The late blooming flower heads however, were not attacked. Studies by Dymock (1987) have since shown that the effectiveness of the seed-fly as a biological control agent is reduced by poor synchronisation of damage and competition for ovipostion sites. In his study, the adult seed-fly emerged up to six weeks before ragwort flowered. When oviposition sites became available, high levels of multiple oviposition, caused by competing adults, were a significant mortality factor. Together with a long flowering period, this resulted in 80-90% of ragwort seeds escaping predation with 28-43% of the uneaten seeds germinating (Dymock, 1987). The impact of ragwort seed-fly as a biocontrol agent at this site was considered negligible. To date, only *B. jacobaeae* has survived and established in New Zealand. It has been hypothesised by Dymock (1988) that a short pre-oviposition period for *P. seneciella* (Frick, 1969) would be expected to be even further out of synchrony with flowering ragwort and may explain why the species failed to establish. It is not known how accurately seed-fly damage is synchronised with ragwort flowering in its native range (Dymock, 1987), but in countries outside this range it has been used only as part of an integrated biological control programme, in combination with other biocontrol agents.

2.5.4.4. Crown boring moth (Cochylis atricapitana)

Larvae of *Cochylis atricapitana* are monophagous borers of *Senecio jacobaea* (McLaren, 1992). Each female moth lays on average up to 158 eggs on the underside of ragwort leaves (McLaren, 1992). The larvae mine into the plant tissue, boring into the leaf, crown, stem or bud, which can cause severe damage to the ragwort plant (McLaren, 1992; Ireson and McLaren, 2012). The insect overwinters as a diapausing larva or pupa, depending on which larval instar was reached before the winter [14]. Adults emerge as delicate, fragile moths towards the end of spring or beginning of summer (McLaren, 1992).

The Commonwealth Institute of Biological Control (CIBC) identified *Cochylis atricapitana* as a potential biocontrol agent of *S. jacobaea*, as it appeared to be host specific and had a high damage potential (McLaren, 1992). The moth was selected to be released in Victoria, Australia, to help control the spread of *S. jacobaea*. Prior to its release, McLaren (1992) states that the CIBC and the Victorian Department of Conservation and Environment carried out extensive host specificity tests to ensure that the larvae of the moth fed exclusively on ragwort. *C. atricapitana* was first introduced from Spain in 1986 (Ireson and McLaren, 2012). It was then released in Victoria in 1987 (Field, 1989) and Tasmania in 1995 (Ireson and McLaren, 2012) as part of an integrated biological control programme to complement the damaging effects of *Longitarsus flavicornis* and *L. jacobaeae*, root feeding beetles of *S. jacobaea* (McLaren, 1992). *C. atricapitana* established well in both states and continues to spread naturally (Ireson and McLaren, 2012). In Victoria, efficacy studies have shown that *C. atricapitana* can significantly reduce ragwort plant size and survival, and though no such studies have occurred in Tasmania, the agent has been observed to cause significant damage at sites in both the north and south of the state (Ireson, unpub. data, as cited by Ireson and McLaren, 2012) and so is assumed to be having the same impact as populations in Victoria (Ireson and McLaren, 2012).

*C. atricapitana*is has established well in Australia. In conjunction with other biological agents, it is considered to provide a significant and widespread impact on ragwort as populations continue to increase and spread naturally (McLaren *et al*., 2000; Ireson and McLaren, 2012). However, no literature has been found on the efficacy of *C. atricapitana*is as a biological agent of *S. jacobaea* in the plant's native range.

2.5.4.5. Ragwort plume moth (Platyptilia isodactyla)

The ragwort plume moth *Platyptilia isodactyla* is bivoltine[15] with young larvae overwintering within ragwort plants. Like *C. atricapitana,* the larvae can cause severe damage to ragwort by tunnelling in the petioles, crowns and stems (McLaren, 1992). The moth is the most recent biocontrol agent introduced into Australia (McLaren et al., 2000), released in Victoria at 53 sites between 1999 and 2004, and in Tasmania at 29 sites between 2000 and 2007

[14] British Columbia Ministry of Forest, Land and Resource Operations <http://www.for.gov.bc.ca>
[15] Two generations a year

(Ireson, unpub. data, as cited by Ireson and McLaren, 2012). Field efficacy studies in Victoria showed that annual capitulum production was 48-67% lower in plants attacked by *P. isodactyla* (McLaren, 1992).

2.5.4.6. Fungal pathogens

There are rust fungi and other pathogens that infect ragwort but do not cause serious injury and are unlikely to provide an effective means of control[16]. However the suitability of a rust *Puccinia expansa* has been tested under glasshouse conditions with favourable results (Bain, 1991). Ragwort had been shown to be more susceptible to infection by this species than other S*enecio* species in a previous study by Alber and co-workers (Alber *et al.*, 1986).

Puccinia lagenophorae, a rust originating from Australasia, which has spread throughout the world (Scholler *et al.*, 2011) and is now found throughout England, has been used against groundsel *Senecio vulgaris* (Müller-Schärer and H. and Rieger, 1998) and ragwort (Paul *et al.*, 1993). The necrotrophic *Botrytis cinerea* is also another possible candidate (Paul *et al*., 1993) Moreover Paul *et al*. (1993) found that a better outcome was achieved if application of this species occurred after infection by *P. lagenophorae*, as this led to a high rate of secondary infection and a subsequent reduction in leaf area.

2.5.4.7. Sheep

One of the earlier methods investigated to manage outbreaks of ragwort on pasture was the use of sheep (often in combination with cattle) to graze the ragwort, and so control the population of the weed. Evidence from two studies Sharrow and Mosher, 1982; Betteridge *et al*., 1994 does suggest that this is an effective way to reduce and manage ragwort on land where it has already become established.

Sharrow and Mosher monitored 200 ragwort plants, split equally between cattle only grazing and a second treatment of cattle and sheep grazing. In the cattle only treatment 43 plants had been defoliated, and 40% of plants flowered and produced seed Sharrow and Mosher, 1982. On the cattle and sheep plot, all ragwort plants were defoliated and only 2% flowered and produced seed. It was also noted that although mortality of ragwort was similar on both treatments, the causes were very different. On the cattle only plot the ragwort died due to the completion of the ragwort life cycle and seed production, while on the sheep and cattle plot the ragwort died due to mainly grazing before seed production had occurred.

Similar finding were observed by Betteridge *et al* (1994). Here, in a cattle only grazing system, 72% of ragwort died after seeding. In contrast, where cattle were integrated with ‘mob-stocking’ of ewes (3 sheep per ha for 4 days, for four periods of time) 72% of ragwort died within 12 months without flowering Betteridge et al., 1994. The results of the study are shown below Betteridge *et al*., 1994

[16] Bond, W., Davies, G. and Turner, R. (2007) The Biology and non-chemical control of Common Ragwort (*Senecio jacobaea* L.). organic Weed Management Project, OF 0315, Defra funded. http://www.gardenorganic.org.uk/organicweeds/downloads/senecio%20jacobaea.pdf (Accessed 26/09/2013)

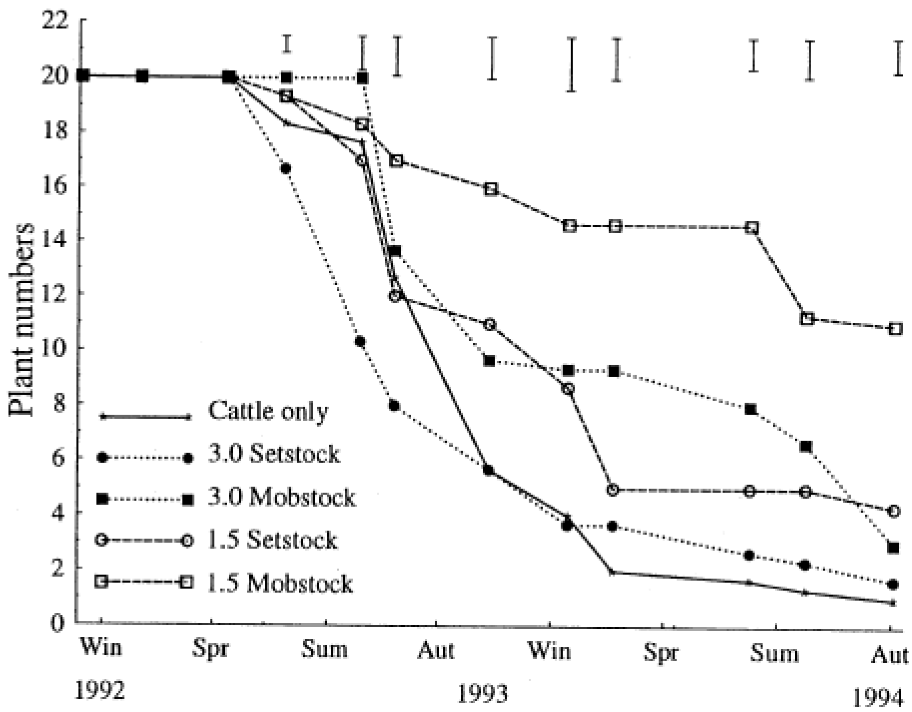

Figure 8 **Number of surviving ragwort plants over 21 months following imposition of one cattle-only and four sheep-with-cattle treatments (reproduced from Betteridge, Costall et al. 1994).**

2.5.5. Chemical inhibition

A small number of studies have considered the potential allelopathic or autotoxic effects from ragwort. Bioassays based on ragwort shoot and root leachates demonstrated slight allelopathic effects against four pasture legumes (red clover, white clover, subterranean clover and lucerne) and to a lesser extent against perennial ryegrass. No difference between extracts from different growth stages of ragwort (rosette vs flowering) (Ahmed and Wardle, 1994; abstract only).

Studies of the potential effects on germination and growth of ragwort itself have been undertaken in The Netherlands (van de Voorde et al., 2012; van de Voorde et al., 2012; Bezemer et al., 2006). In a laboratory study using shoot and root extracts high strength shoot extracts reduced germination rates in Petri dishes by approximately 50%. Low strength shoot extracts and root extracts had no significant effect on germination (van de Voorde et al., 2012). Similarly seedling growth was affected by shoot extracts, but effects of root extracts were also observed at high concentrations. Effects were greater for root length than total biomass particularly at high strengths. However, when extracts were applied to soil in which seedlings were grown, no autotoxic effects were recorded. The authors suggest that the chemicals may have been absorbed to the soil particles, reducing their mobility. This was supported by observations that extracts from soil did not reduce seedling performance.

The same research group found that ragwort biomass was reduced when plants were grown in soil from fields with ragwort (van de Voorde et al., 2012) and there was evidence for a positive relationship between ragwort density and the degree of effect on seedling growth. The authors concluded that these effects were important in ragwort population dynamics but that many other factors were also important.

In summary:

- Insects as bioconrol agents can be highly successful in countries where ragwort is a non-native (H)
- Biocontrol agents will have limited effect in countries where ragwort is native, and the biocontrol agent is native due to the present of parasites and predators of the biocontrol agent (M)

2.5.6. Costs of ragwort control

2.5.6.1. Cost of control in different situations (e.g. farmland, road verges, railways etc.)

Herbicide application on farmland

The average cost of herbicide products sprayed on grassland, as recorded in the 2009 Pesticide Usage Survey, was estimated as £17.38/ha using 2013 published prices for common products containing the active ingredients used. This is likely to be a maximum price, as many farmers obtain pesticides at lower than the advertised price through bulk-buying discounts or by buying generic products containing the same active ingredients.

Costs of herbicide application are not readily obtained, because so little grassland is sprayed. Nix (2012) gives contractors costs for crop spraying at 200 l/ha with a 24 m boom sprayer as £13.10/ha and farmers' costs as £12/ha, at an average work rate of 5 ha/hour. The only other figure given is for spraying with an ATV at £30/hour, but no work rate is given. In view of the lack of published information, a local agricultural contractor who does a lot of grassland spraying was consulted. He estimated a work rate of 4-8 ha/hour for grassland, at a cost of £10.25/ha, using a 24 m boom sprayer.

Weeds Act enforcement by Natural England

Natural England currently enforces the Weeds Act 1959, which requires that landowners take reasonable steps to prevent the spread of five species of injurious weeds, one of which is ragwort. Table 11 below shows the number of complaints by members of the public for all the weeds in the Act. It was not possible to obtain numbers for ragwort separately, but advice from Natural England is that almost all complaints from this Act are regarding ragwort (Natural England pers comm.).

When a complaint is made against a land-owner, Natural England will pass the complaint information on to the Rural Payments Agency who are contracted to carry out the inspection work. In Table 11 it can be seen that not all complaints need to go on to the Rural Payments Agency, but once they do an inspector will look over the site and decide if action is required. In most years it appears only around half of inspections lead onto enforcements. An enforcement notice is issued/sent by the RPA inspector to the land owner when an inspection shows that weeds are spreading from their land on to others, where they are a threat to grazing animals, livestock, the production of forage and other agricultural practices. If no action results, it is taken up further by Natural England. As can be seen from the table very few enforcements reach the stage where Natural England will clear the land and ask for cost recovery.

Table 11 Natural England Weeds Act

Year	Complaint Forms received	Rural Payment Agency Inspections	Rural Payment Agency Enforcements	Natural England Clearances	Natural England Technical Visits
2006	342	67	19	5	Unknown
2007	234	117	52	2	Unknown
2008	319	136	39	3	Unknown
2009	202	73	40	0	Unknown
2010	145	41	24	2	Unknown
2011	230	86	46	0	21
2012	193	72	36	1	45

Information from Weeds Act 1959 – Statistics 2012 (received from Natural England)

Costs of enacting the act include the costs of the Natural England helpline, administration and handling complaints. It should be noted that not all of these complaints are valid and some time may be spent dealing with unwarranted complaints. The estimated cost of these aspects is £80,000 per year, based on the detailed NE Customer Services resource model.

An approximate figure for advice enforcement by the Natural England technical advisors, based on an average two working days per visit including preparation and writing up of the visit and the visit report forms, would be £40,000 per year. Each valid complaint if not resolved through initial contact with land owners triggers a visit from an RPA inspector with again an estimated resource of £40,000k per year.

In 2012, the cost of the single clearance was £1,080, unfortunately the contractor asked to provide this service did not give a breakdown of costs. There are details of a clearance conducted in 2010, which cost £946. The contractor which was chosen for the work invoiced £40 p/a for chemical spraying and £24 p/a for topping/cutting on this 12 acre site. Further costs were related to removing obstacles blocking entry to the field. Some land-owners create difficulties for contractors clearing the field, such as grazing animals and physical barriers. Natural England has also had difficulties with contractors not wishing to take on enforcement contracts against local businesses with whom they may already have a vested business interest, which can make a local selection more difficult.

Recovering the costs of the clearance is delegated to the Shared Services Directorate (SSD), but it is not always possible to recover the debt.

Costs to local authorities and transport network operators

The costs of clearing ragwort are also borne by local authorities. In 2011 Natural England received 17 complaints, 20 in 2012 and 16 so far in 2013 (personal correspondence from customer services at Natural England). One County Council suggested that their Property Services Department had spent around £3,200 in the last year on work indirectly related to ragwort on the surplus land portfolio (land owned by the council but no longer required for operational purposes). A quote for spraying a wide range of broad-leaved weeds but mainly ragwort on a farm, for which the Council was responsible, was given at £2,850 before VAT for 30 ha.

Network Rail was contacted to ascertain their costs in respect to ragwort control but national data were not available.

The Highways Agency (HA) is responsible for weed control on trunk roads and motorways in England. Their policy is to treat ragwort according to the Code of Practice but they do not have any readily available data on the costs of controlling ragwort. Under new contracts the policy for ragwort management states: 'manage the soft estate to control the spread or increase of instances of injurious and invasive weeds. Where control is required, the preferred approach is to spot treat the weed with a selective herbicide at the rosette stage before flower spikes develop. This may be backed up by much more expensive hand pulling in July and August. Occasionally plants will be mown prior to the flowering stage but this is only a holding measure until herbicide can be applied.'

County councils are responsible for all other highways. One County Council estimated that around £1,500 was spent controlling ragwort on highways, but most of the management is contracted out to borough councils (County Council, pers. comm.). Two boroughs were able to supply estimates of annual costs of weed control. However, these data related to weed control in general and no specific figures for ragwort could be provided.

2.6. ENVIRONMENTAL IMPACTS OF RAGWORT CONTROL

2.6.1. Ecological impacts of ragwort

The impact of an invasion of ragwort was monitored on a *Lolium perenne/Trifolium repens* pasture on the North Island of New Zealand, under different management practices to reflect the conventional dairy farming in the area (Wardle et al., 1995). Soil samples, vegetation samples and pitfall traps were used to monitor any changes to the local environment, taken at five time periods over a ten month period. The results of the vegetation samples showed that ragwort did not inhibit net primary production and in many cases increased it compared to the control. For example *Lomium perenne* was enhanced in the 10 cm zone that lay outside the rosette on the first three sampling dates, when compared to the control. *Trifolium repens* was inhibited by flowering ragwort. The overall plant productivity is highlighted in Figure 8.

This apparent productivity increase needs to be taken into context as if ragwort was growing in a field it would result in areas of the pasture being ungrazable by livestock so overall may have a negative impact on availability of grazing productivity across the whole area. The authors suggest that ragwort can affect the pasture composition, possibly by the protection that the senescent plant offers weed seedling.

Other findings suggest the soil microbial biomass and saprophytic microarthropods were both reduced in the area immediately adjacent to flowering ragwort. Ragwort was also found to affect the microfaunal groups collected by the pitfall traps (Wardle et al., 1995).

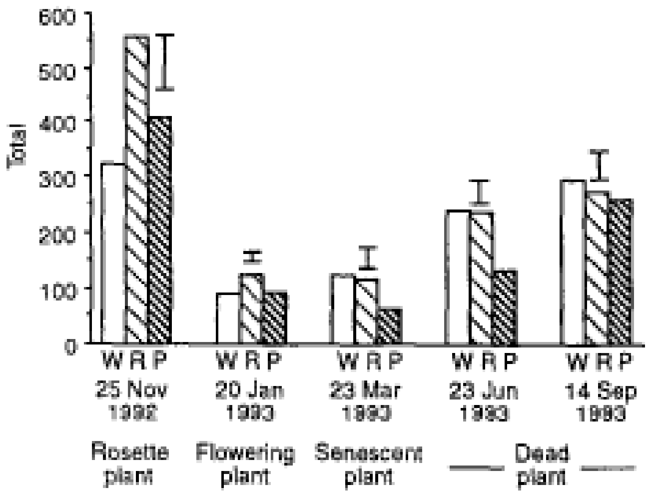

Figure 11 Above ground primary productivity in areas occupied (or previously occupied) by ragwort rosette (W), in 10 cm wide rings surrounding the rosette ® and in 0.5 m x 0.5 m areas of control pasture (P). Vertical bars represent Tukey's honestly significant difference (P = 0.05) for each sampling time (reproduced from (Wardle et al., 1995).

2.6.2. Species associated with ragwort

2.6.2.1. Invertebrates

A number of invertebrate species are associated with ragwort. To determine their degree of dependence, conservation status and distribution, the following sources were consulted:

1) Harper, J.L. & Wood, W.A. 1957 Biological Flora of the British Isles: *Senecio jacobaea.*

   This publication listed 60 species with a further 23 species of Thysanoptera (Thrips).

2) Biological Records Centre: Database of Insects and their Food Plants – Ragwort and its associated invertebrates[17].

   This produced a list of 88 species and the associated references for the evidence of the relationship between plant and invertebrate. It also provided references for other species of associated with those invertebrates.

3) 'Insect Fauna in detail', Buglife publication[18] recording the best available current knowledge of the insects associated with ragwort.

   61 insects were reported associated with *Senecio* sp. and of these 30 were ragwort specific, for a further ten having ragwort was the major food source and for another 12 species ragwort was a significant food plant.

4) The Ecological Flora of the British Isles database: The phytophagous insects for *Senecio jacobaea*[19].

   This gave a list of 23 species recorded for this association.

In total, these sources revealed combined list of 122 different invertebrate species to be considered with respect to the potential impact of any change in the distribution of ragwort within England. Each of the species was assessed for its status within England via the National Biodiversity Network Gateway. This provided its distribution in England and also its frequency at the 10 km level. This information was combined with its level of dependency on ragwort at the larval stage, the crucial period of the life cycle. Habitat dependency was also taken into consideration. Note was also taken of Biodiversity Action Plan (BAP) species and those with scarcity and conservation designations. However these latter were only used as criteria if there was a dependency on ragwort.

This selection produced a list of 38 species and these are found in Table 12. These are generally widespread species, however they tend to have very local populations within the areas that they are found. Their distributions are far more restricted than their food plant ragwort. Their restricted ranges mean that they are encountered infrequently and specialist expertise is required for identification.

The most notable species in conservation terms is the cinnabar moth, *Tyria jacobaeae,* as it is the only BAP species on the shortlist. This designation was applied in 2007 as its

[17] http://www.brc.ac.uk/dbif/hostsresults.aspx?hostid=5110 (Accessed 25/09/2013)
[18] http://www.buglife.org.uk/sites/default/files/Ragwort%20-%20Insect%20Fauna%20in%20detail_1.pdf (Accessed 26/09/2013)
[19] http://www.ecoflora.co.uk/search_phytinsect.php?plant_no=1690960440 (accessed 25/09/2013)

population has declined by 83% a 35-year period (1968-2002), even though it has a widespread distribution (Fox *et al*., 2006). This trend for the Cinnabar has ameliorated using the latest 40-year trends (from 1968 to 2007) to the extent that this species is now in the declining category as it shows a 67% in population decline (Fox *et al.,* 2013). This publication notes that habitat changes, especially those related to agricultural intensification, changing woodland management and urbanisation, appear to have had substantial, largely negative impacts on moths. There is no strong evidence for the causes of the decline of the Cinnabar (*Tyria jacobaeae*), though some European long-term studies have suggested that monophagous species were more likely to have declined than less-specialised species (Franzen & Johannesson, 2007; Mattila *et al*., 2008). Studies of moth declines in both Britain and the Netherlands found significant relationships between overwintering life-cycle stage and species trends; species overwintering as larvae or pupae (such as the Cinnabar) have decreased (Conrad *et al.,* 2004; Groenendijk & Ellis, 2011).

The Cinnabar moth has also been designated as a species "of principal importance for the purpose of conserving biodiversity" in 2008[20]. It is therefore covered under section 41 (England) of the NERC Act (2006) and needs to be taken into consideration by a public body when performing any of its functions with a view to conserving biodiversity (JNCC 2010). Ragwort is its primary host plant though it is also found on other ragworts, groundsels and occasionally Colt's-foot (Waring & Townsend, 2009).

Five other BAP species were assessed in the original list. These were excluded as they had large plant host ranges that may include ragwort such as *Aporophyla lutulenta, Arctia caja* and *Xylena exsoleta* (Appendix 1). For *Coleophora tricolor* there was no evidence of a ragwort association. For *Thalera fimbrialis,* the main host was probably wild carrot (Waring & Townsend, 2009), as the evidence for yarrow[21] may be erroneous, and ragwort was only a minor host (Appendix 1).

Distribution data for the other ragwort-dependent species, show that 16 of the species are present in 15 or fewer 10 km squares, the equivalent of Red Data Book status though that is a Great Britain designation as are all other rarity classifications such as 'Nationally notable A'. Four species, *Campiglossa malaris, Heriades truncorum, Homoeosoma nimbella* and *Stelis breviuscula,* have this designation, and *Ophiomyia senecionina* is presumed to have this designation as well[18]. *Longitarsus ganglbaueri* and *Pilemostoma fastuosa* are classified as Nationally Notable A that includes species occupying 16-30 10 km squares. A further five species, *Commophila aeneana, Homoeosoma nebulella, Icterica westermanni, Longitarsus dorsalis* and *Longitarsus ochroleucus*, are considered Nationally Notable B, occupying 30-100 10 km squares. One species *Trypeta zoe* has an International Union for Conservation of Nature (IUCN) (pre 1994) designation of Endangered[22] that was applied in 1987. For two species, *Contarinia aequalis* and *Haplothrips senecionis,* there is no location information on the NBN gateway.

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[20] http://data.nbn.org.uk/speciesInfo/taxonomy.jsp?searchTerm=tyria&spKey=NBNSYS0000006155 (accessed 04/10/2013)
[21] http://ukmoths.org.uk/show.php?id=5628 (accessed 04/10/2013)
[22] http://data.nbn.org.uk/speciesInfo/taxonomy.jsp?searchTerm=Trypeta%20zoe&spKey=NBNSYS0000012868 (Accessed 04/10/2013)

Habitat requirements were also important considerations when assessing the risks to these species. Remarkably for 22 species, from the Coleoptera, Diptera, Thysanoptera and micro-moths, no habitat information was found. Nine species do seem to have coastal distributions and eight are associated with dry/heathland habitats. Only one species, *Phytomyza alpine,* has an upland distribution. This is probably at the southern end of its range in Yorkshire, as it is a boreal/alpine species with a wider distribution in Scotland.

The amount and quality of the evidence supporting the ragwort dependency was variable. Sixteen of the species had a low score for overall confidence as the amount of evidence was small. A further sixteen had medium scores as the amount and quality was adequate but there was some doubt over the level of agreement. Three species, *Sphenella marginata, Trypeta zoe* and *Tyria jacobaea*, scored a high overall confidence level as they had four or more publications supporting the association and the level of agreement between them was high.

Ragwort also provides nectar and pollen resources for invertebrates and Harper and Wood (1957) reported 178 had been recorded visiting ragwort flowers. The largest numbers of species were bees with 47 species recorded, and hoverflies with 35 species recorded. Ragwort often provides a valuable resource for pollinators, particularly within specialist habitats such as heaths and coastal sites but also on rough ground and brownfield sites. Its extended flowering season is also important in this context as it provides resources for those insect species that survive the winter as adults and also those that have two generations in the year such as *Cheilosia bergenstammi,* a hoverfly dependent on ragwort.

The species that were not dependent on ragwort have been placed in Appendix 1.

Table 12 Invertebrate species that are solely dependent on ragwort or have a limited number of alternate hosts

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W [23] 1957 (80)	BRC ragwort hosts[24]	Buglife list[18]	Status in England[25]	No. 10 km^2 England [26]	Other hosts for larva (reliable)	References	Ecology/Range
Hemiptera (Sternorrhyncha -aphids)	Aphididae	*Aphis jacobaeae*		Y	Y	not in NBN under this name	0	None recorded	Stroyan (1984), [27], [28]	Sandy and gravelly soils, Thames, Ouse [28]
Diptera	Tephritidae	*Campiglossa malaris*			Y	RDBK: no NBN desig info; IUCN: not yet assessed	10	*Senecio erucifolius* mainly,[18 29]	[29]	Very local, chalk grassland, coastal shingle and other dry sites. It is believed to breed in the flower heads. Gloucs, Kent, Essex, Shropshire, Sussex, Surrey
Diptera	Syrphidae	*Cheilosia bergenstammi*		Y	Y	no NBN desig info; IUCN: not yet assessed	>100	*Senecio erucifolius* (Stubbs & Falk, 2002) (European record of oviposition)	Stubbs & Falk (2002), Ball & Morris (2000), Smith (1979)	Widespread throughout England but very local within areas that they are found (Stubbs & Falk, 2002); favour ragwort-rich, warm sheltered locations; two generations per year
Lepidoptera (micro-moths)	Tortricidae	*Cochylis atricapitana*		Y		no NBN desig info; IUCN: not yet assessed	>50	None recorded	Emmet (1979), Emmet & Heath (1992), [28]	Commoner around the coast and on chalky ground throughout England.

[23] Harper & Wood 1957
[24] Biological Records Centre: Database of Insects and their Food Plants http://www.brc.ac.uk/dbif/hostsresults.aspx?hostid=5110 Accessed 25/09/2013
[25] NBN/IUCN designation status
[26] Approx number of 10km squares in England from 1970 (from NBN Gateway https://data.nbn.org.uk/)
[27] http://www.aphidsonworldsplants.info/d_APHIDS_A.htm#Aphis (accessed 17/12/2013)
[28] Ecological Flora of the British Isles http://www.ecoflora.co.uk/search_phytinsect.php?plant_no=1690960440 (Accessed 18/09/2013)
[29] http://www.essexfieldclub.org.uk/portal/p/Species+Account/s/Campiglossa+malaris (Accessed 26/09/2013)

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W [23] 1957 (80)	BRC ragwort hosts[24]	Buglife list[18]	Status in England[25]	No. 10 km^2 England [26]	Other hosts for larva (reliable)	References	Ecology/Range
Lepidoptera (micro-moths)	Tortricidae: Tortricinae	*Commophila aeneana*		Y		no NBN desig info; IUCN: not yet assessed; Nationally scarce (Nb) [30]	15	None recorded	Emmet (1979), Emmet & Heath (1992), [28], [31]	Rough meadows and waste ground in scattered localities; occurring locally in the southern half of England; Beds, Bucks, Gloucs, Suffolk, Essex, Kent, Hants, Sussex [31]
Diptera	Cecidomyiidae	*Contarinia aequalis*		Y	Y	no NBN desig info; IUCN: not yet assessed	0	None recorded	Buhr (1965), Bagnall & Heslop-Harrison (1921)	No location data on NBN
Diptera	Cecidomyiidae	*Contarinia jacobaeae*	Y	Y	Y	no NBN desig info; IUCN: not yet assessed	14	*Senecio aquaticus*; *S. erucifolius* (Niblett, 1942)	Buhr (1965), Nijveldt (1969), Niblett (1942)	Location Yorks (Most records), Devon, Gloucs, Surrey, Norfolk.
Lepidoptera (micro-moths)	Tortricidae: Olethreutinae	*Epiblema costipunctana*		Y	Y	no NBN desig info; IUCN: not yet assessed	30-100	None recorded	Emmet (1979), Emmet & Heath (1992), [32]	Open uncultivated and waste ground and similar habitats [32]; Gloucs, Beds, Norfolk, Suffolk, Kent, West Midlands, Yorks, Lincs, Hants
Lepidoptera (micro-moths)	Tortricidae: Olethreutinae	*Eucosma campoliliana*		Y	Y	no NBN desig info; IUCN: not yet assessed	30-100	None recorded	Emmet (1979), Emmet & Heath (1992), [28], [33],	Dry locations, distributed widely; Gloucs, West Midlands, Surrey, Sussex, Beds, Suffolk, Norfolk, Yorks, Lincs, Lancs, Cumbria
Lepidoptera (macro-moths)	Geometridae	*Eupithecia virgaureata*	Y	Y		no NBN desig info; IUCN: not yet	>100	oligophagous, principal host plant; other host *Solidago*	Noble (1975), Allan (1949), Riley & Prior (2003), [34]	Mainly northern and western species, with few recent records south of a line from the Severn to

[30] http://www.hantsmoths.org.uk/species/0952.php (Accessed 26/09/2013)
[31] http://ukmoths.org.uk/show.php?id=3952 (Accessed 17/09/2013)
[32] http://ukmoths.org.uk/show.php?id=5800 17/09/2013
[33] http://ukmoths.org.uk/show.php?id=5460 17/09/2013

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[23] 1957 (80)	BRC ragwort hosts[24]	Buglife list[18]	Status in England[25]	No. 10 km[2] England[26]	Other hosts for larva (reliable)	References	Ecology/Range
						assessed		*virgaurea*[34]		the Wash There are two generations in the south with adults flying in May and June, and again from July to August.
Thysanoptera	Phlaeothripidae	*Haplothrips senecionis*		Y	Y	no NBN desig info; IUCN: not yet assessed	0	*S.aquaticus* only alternative host	Mound *et al.* (1976), Morison (1949)	No location data on NBN
Lepidoptera (micro-moths)	Pterophoridae: Pterophorinae	*Hellinsia osteodactylus*			Y	no NBN desig info; IUCN: not yet assessed	24	Oligophagous; only other host *Solidago virgaurea*[28, 35]	[28], [35]	Open woodland areas, and some coastal habitats; local species, Devon, Gloucs, Suffolk, Staffs, Derbys, Yorks, Lancs, Cumbria
Hymenoptera	Apidae: Megachilidae	*Heriades truncorum*			Y	Rare (RDB 3) (Shirt, 1987); RDB K (Insufficiently known) (Falk, 1991b)	30-100	Oliogolectic on the pollen of yellow-flowered Asteraceae. Univoltine, June to September[36]	[36]	Commons/heaths of Hants, Surrey, West Sussex (Thorney Island), Essex, Suffolk[36]
Lepidoptera (micro-moths)	Pyralidae: Phycitinae	*Homoeosoma nebulella*	Y	Y	Y	Nationally Scarce B, Nationally Notable B (Parsons, 1993), applied 1993)	65	Oligophagous[24] (Six host species)	Emmet (1979), Emmet & Heath (1972),[28]	Dry, chalky or sandy habitats, mainly Norfolk (Breckland)

[34] http://ukmoths.org.uk/show.php?bf=1851 Accessed 17/09/2013
[35] http://ukmoths.org.uk/show.php?bf=1520 17/09/2013
[36] http://www.bwars.com/index.php?q=bee/megachilidae/heriades-truncorum (Accessed 19/09/2013)

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W [23] 1957 (80)	BRC ragwort hosts[24]	Buglife list[18]	Status in England[25]	No. 10 km^2 England [26]	Other hosts for larva (reliable)	References	Ecology/Range
Lepidoptera (micro-moths)	Pyralidae: Phycitinae	*Homoeosoma nimbella*	Y	Y	Y	RDBK insufficient known (Parsons, 1993)	6	Oligophagous [28], *Achillea millefolium, Anthemis tinctoria* only	Emmet (1979), [28]	Coastal - Norfolk, Suffolk, Devon, Cornwall, Northumberland
Diptera	Tephritidae	*Icterica westermanni*		Y	Y	Nationally scarce B, Nationally notable (Falk 1991a) applied 1991	41	*Senecio erucifolius* (Uffen & Chandler, 1978), [18]	Uffen & Chandler (1978), [18]	Dorset, Hants, Surrey, Sussex, West Midlands, Cambs, Norfolk, Yorks
Diptera	Agromyzidae	*Liriomyza erucifolii*		Y	Y	no NBN desig info; IUCN: not yet assessed	6	*Senecio erucifolius* (leaf mines) Spencer (1972)	Spencer (1972), [28], Robbins (1984), [37]	Uncommon. Middlesex (Scratch Wood), Hants (Southwood), Warwicks (Binley, Combrook and Ufton); Buckinghamshire, Cambs, Middlesex, North Somerset, South Wilts and Surrey (Robbins, 1984)
Coleoptera	Chrysomelidae: Galerucinae	*Longitarsus dorsalis*	Y	Y	Y	Nationally scarce B, Nationally notable B (Hyman,1992) applied 1992)	100+	*Senecio aquaticus; S. erucifolius; S. sylvaticus; S. vulgaris* (Cox, 2007; Newton, 1933)	Cox (2007), Newton (1933), [38]	Generally on chalky or sandy soils including coastal areas; Widespread but very local in England south of the Humber

[37] www.ukflymines.co.uk/Flies/Liromyza_erucifolii.php
[38] http://www.coleoptera.org.uk/chrysomelidae/longitarsus-dorsalis (Accessed 09/09/2013)

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W [23] 1957 (80)	BRC ragwort hosts[24]	Buglife list[18]	Status in England[25]	No. 10 km^2 England [26]	Other hosts for larva (reliable)	References	Ecology/Range
Coleoptera	Chrysomelidae: Galerucinae	*Longitarsus ganglbaueri*	Y	Y	Y	Nationally scarce A, Nationally notable A (Hyman, 1992) applied 1992)	80	*Senecio inaequidens; S. sylvaticus;S. viscosus; S. vulgaris* (Cox, 2007)	Cox (2007), Newton (1933), Shute (1979), [39]	Widespread but scattered, central southern England, Hants, Surrey, Sussex, Essex, Hants, coastal Yorks and Northumberland
Coleoptera	Chrysomelidae: Galerucinae	*Longitarsus gracilis*	Y	Y	Y	no NBN desig info; IUCN: not yet assessed	100+	*Tussilago farfara* (Newton, 1933)	Cox (2007), Newton (1933), [40]	Widespread and locally common. central and southern England
Coleoptera	Chrysomelidae: Galerucinae	*Longitarsus jacobaeae*	Y	Y	Y	no NBN desig info; IUCN: not yet assessed	100+	*Senecio aquaticus; S. erucifolius; S. sylvaticus; S. vulgaris* (Cox, 2007)	Cox (2007), Newton (1933), Shute (1979), [41]	Widespread and locally common. Coastal nearly all counties, plus central from Gloucs north to Yorks and inland Norfolk/Suffolk
Coleoptera	Chrysomelidae: Galerucinae	*Longitarsus ochroleucus*	Y	Y	Y	Nationally scarce B, Nationally notable B (Hyman, 1992) applied 1992)	30-100	*Senecio squalidus* (Cox, 2007)*;* Ragworts (*Senecio* spp.), sometimes other Asteraceae [42]	[24], [42]	Grassland, commons, woodland, sand & chalk pits, beaches (around high-water mark); Herts, Bucks, Hants, Surrey, Sussex, Essex, Suffolk, Norfolk, Yorks, Gloucs, Cumbria
Coleoptera	Chrysomelidae: Galerucinae	*Longitarsus succineus*		Y	Y	no NBN desig info; IUCN: not yet assessed	100+	None recorded [43]	Newton (1933), [43]	Widespread and common; Coastal nearly all counties, plus central from Gloucs north to Northumberland/Cumbria and

[39] http://www.coleoptera.org.uk/chrysomelidae/longitarsus-ganglbaueri (Accessed 09/09/2013)
[40] http://www.coleoptera.org.uk/chrysomelidae/longitarsus-gracilis (Accessed 09/09/2013)
[41] http://www.coleoptera.org.uk/chrysomelidae/longitarsus-jacobaeae (Accessed 09/09/2013)
[42] http://www.coleoptera.org.uk/chrysomelidae/longitarsus-ochroleucus (Accessed 09/09/2013)
[43] http://www.coleoptera.org.uk/chrysomelidae/longitarsus-succineus (Accessed 09/09/2013)

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W [23] 1957 (80)	BRC ragwort hosts[24]	Buglife list[18]	Status in England[25]	No. 10 km^2 England [26]	Other hosts for larva (reliable)	References	Ecology/Range
										inland Norfolk/Suffolk
Diptera	Agromyzidae	*Melanagromyza aeneoventris*	Y	Y	Y		9	*Cirsium palustre; C. vulgare (*Spencer, 1972)	Spencer (1972), [28], [44]	London (Hampstead), Surrey (Bookham, Selsdon), Middlesex. (Scratch Wood), Hampshire (Isle of Wight, Branscombe), Devon (Studland), Cambridgeshire (Woodwalton Fen), East Kent, Surrey, West Kent and West Norfolk (Spencer, 1972)
Diptera	Agromyzidae	*Melanagromyza eupatorii*		Y	Y		0 (extinct)	*Inula conyza; Leucanthemum vulgare; Eupatorium cannabinum (*Spencer, 1972)	Spencer (1972), [28], [45]	Cambs
Diptera	Tephritidae	*Merzomyia westermanni*		Y			12	*Senecio erucifolius* (Niblett, 1939; White, 1988)	Niblett (1939), White (1988)	Gloucs, Surrey, Sussex, Suffolk, Cambs, Staffs
Diptera	Agromyzidae	*Ophiomyia senecionina*		Y	Y	Red Data book status? (Only at Wicken Fen NBN), no NBN desig info; IUCN: not yet assessed	1	*Senecio erucifolius* (Spencer, 1972)	Spencer (1972), [28]	Cambs, Surrey (Box Hill) (Spencer, 1972)

[44] www.ukflymines.co.uk/Flies/Melanagromyza_aeneoventris.php

[45] www.ukflymines.co.uk/Flies/Melanagromyza_eupatorii.php

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W [23] 1957 (80)	BRC ragwort hosts[24]	Buglife list[18]	Status in England[25]	No. 10 km^2 England [26]	Other hosts for larva (reliable)	References	Ecology/Range
Diptera	Anthomyiidae	*Pegohylemyia jacobaeae* (Synonyms *Botanophila jacobaeae, Anthomyia jacobaeae*) 19	Y	Y	Y	no NBN desig info; IUCN: not yet assessed	5	*Senecio erucifolius* (Uffen & Chandler, 1978)	Uffen & Chandler (1978)	Kent, Surrey, Berks, Oxford, Warks, Herefs, Yorks
Diptera	Anthomyiidae	*Pegohylemyia seneciella* (Synonyms *Botanophila seneciella, , Phorbia seneciella*) 19	Y	Y	Y	no NBN desig info; IUCN: not yet assessed	12	None recorded	Uffen & Chandler (1978)	Cornwall, Devon, Gloucs, Kent, Surrey, Oxford, Staffs, Notts, Yorks
Lepidoptera (micro-moths)	Pyralidae: Phycitinae	*Phycitodes maritima*		Y	Y	no NBN desig info; IUCN: not yet assessed	48	Oligophagous [288], *Achillea millefolium* [23], *Chrysanthemum vulgare*	Emmet (1979), Emmet & Heath (1992), [28] [46]	Mainly coastal Cornwall, Devon, Gloucs, Kent, Essex, Lincs, Norfolk, Suffolk, Cambs
Lepidoptera (micro-moths)	Pyralidae: Phycitinae	*Phycitodes saxicola*		Y	Y	no NBN desig info; IUCN: not yet assessed	32	Asteraceae flower heads, including *Anthemis* species [24]	Kunin (1999), [47]	Coastal habitats, walls, dry banks, old sand dunes [477]. Cornwall, Devon, Gloucs, Hants, Kent, Suffolk, Yorks, Lancs, Cumbria
Diptera	Agromyzidae	*Phytomyza alpina*		Y	Y	no NBN desig info; IUCN:	0	None recorded [28]	Spencer (1972), Griffiths (1972), [8]	Yorkshire only, boreal-alpine

[46] http://ukmoths.org.uk/show.php?id=5901 accessed 25/09/2013
[47] http://ukmoths.org.uk/show.php?id=6605 accessed 25/09/2013

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W [23] 1957 (80)	BRC ragwort hosts [24]	Buglife list [18]	Status in England [25]	No. 10 km^2 England [26]	Other hosts for larva (reliable)	References	Ecology/Range
						not yet assessed				
Coleoptera	Chrysomeli-dae	*Pilemostoma fastuosa*		Y		Nationally notable A (Hyman, 1992) applied 1992)	14	Oligophagous, Asteraceae, especially *Inula conyzae* and *Pulicaria dysenterica*, also ragwort and *Mentha* spp. [48]	Cox (2007), [48]	Devon, Dorset, Hants, Surrey, Sussex, Kent, Essex, Berks, Lancs
Diptera	Tephritidae	*Sphenella marginata*	Y	Y	Y	no NBN desig info; IUCN: not yet assessed	30-100	*Senecio aquaticus; S. erucifolius; S. viscosus; S. vulgaris*	Uffen & Chandler 1978, Buhr (1965), [188], Niblett (1939), White (1988), Saunt (1947), Niblett (1940), Hincks (1946)	Cornwall, Devon, Dorset, Hants, Surrey, Sussex, Kent, Essex, London, Berks, Lancs, Cheshire, Yorks, Norfolk, Suffolk, Cambs
Hymenoptera	Apidae: Megachilidae	*Stelis breviuscula*			Y	Endangered (RDB1) by Shirt (1987); Insufficiently Known (RDBK) by Falk (1991)	23	*Pulicaria dysenterica*, *Hieracium* sp. and *Senecio jacobaea* [49]	Dependent on *Heriades truncorum,* its host [49]	Heaths with host *Heriades truncorum* Hants, Surrey, Sussex, Kent
Thysanoptera	Thripidae	*Thrips pillichi*		Y	Y	no NBN desig info; IUCN: not yet	1	*Achillea millefolium*, *Matricaria* sp.	Mound *et al*., (1976)	Cambs, Suffolk

[48] http://www.coleoptera.org.uk/chrysomelidae/pilemostoma-fastuosa accessed 25/09/2013
[49] http://www.bwars.com/index.php?q=bee/megachilidae/stelis-breviuscula (Accessed 19/09/2013)

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W [23] 1957 (80)	BRC ragwort hosts[24]	Buglife list[18]	Status in England[25]	No. 10 km^2 England [26]	Other hosts for larva (reliable)	References	Ecology/Range
						assessed				
Diptera	Tephritidae	*Trypeta zoe*		Y	Y	IUCN pre 1994: Endangered (applied 1987)	30-100	Three *Senecio* spp. and five other Asteraceae spp.[50]	Niblett (1939), White (1988), Saunt (1947), Hincks (1946), Niblett (1954), Niblett (1957), [18]	Surrey, London, Gloucs, Norfolk, Cambs, Essex, Staffs, Shrop, Cumbria, Yorks
Lepidoptera (macro-moths)	Arctiidae	*Tyria jacobaeae* (*Hypocrita jacobaea*)	Y	Y	Y	BAP (applied 2007); Species of principal importance in England (applied 2008)	>100	Eleven other species including *Senecio aquaticus, S. erucifolius, S. squalidus, S.vulgaris, S.sylvaticus* [24]	Noble (1975), Allan (1949), Heath & Emmet (1979), [288] Waring and Townsend (2009)	Prefers well-drained, rabbit-grazed grassland, including mature san-dunes and Heathland, also many open habitats (Waring and Townsend, 2009); Fairly common in much of England.

[50] *Senecio erucifolius* Niblett (1939), White (1988)*; Senecio squalidus* White (1988), Niblett (1954)*; Senecio vulgaris* Niblett (1939), White (1988) *also Artemisia* Niblett (1939), White (1988)*; Eupatorium* Niblett (1939), White (1988)*; Tussilago, Petasites* (White (1988)*;; Cirsium vulgare* Hincks (1946),

2.6.2.2. Fungi

Records of fungi associated with ragwort were compiled from four sources:

1) British Mycological Society database: The Fungal Records Database of Britain and Ireland (FRDBI)[51], which records 79 species of fungi as being associated with ragwort. This database holds all the records for each species of fungus together with associated plant, location and collection details.
2) The Ecological Flora of the British Isles database[52] holds information on eight species of fungi associated with ragwort, with records of a further six species linked to ragwort.
3) The Systematic Mycology and Microbiology Laboratory Fungus-host Database of the USDA[53] holds records for 24 species associated with ragwort in the U.K.
4) Harper and Wood (1957) in an ecological study of ragwort list 14 species associated the plant.

Fourteen species of fungi associated with ragwort are also quoted by Buglife.[54] Buglife obtained this information from Plantlife (Buglife, pers comm.), however Plantlife were unable to provide the source of this information (Plantlife, pers. comm.).

When the four lists were combined, there were 97 different fungi to assess. Eight of these were at genus level and were not investigated if there were species within the genus included in the list, as the relationship between host and fungus would be more accurately represented at species level. Each of the species was assessed for its status within England via the National Biodiversity Network Gateway[55] and the FRDBI, and for its host range via the FRDBI. Certain names were synonyms of other species either within or outside the list which resulted in the addition of three additional species, with the final list totalling 89 species.

Host specificity is one of the key determinants of the population size of any given fungal species. Any changes in the population of a host species will have a much greater effect on the population size if the dependent species is totally reliant upon it for survival. The level of host plant dependency was combined with the scarcity of the species to select the fungal species that would be most affected by any change in the population of ragwort. The eight species that are most critical are shown in Table 12. None of these species have any conservation designation. All have limited ranges with a presence in 35 or fewer 10 km squares. There are two species that are particularly host-dependent. *Puccinia dioicae var. schoeleriana* requires two hosts, ragwort and the sedge *Carex arenaria*, at different stages to complete its life cycle and is found on coastal dunes of Norfolk and Northumberland in

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[51] FRDBI http://www.fieldmycology.net/FRDBI/assoc.asp (Accessed 16/09/2013)
[52] (http://www.ecoflora.co.uk, based on Ellis & Ellis, 1985)
[53] Farr, D. F., & Rossman, A. Y. Fungal Databases, Systematic Mycology and Microbiology Laboratory, Agricultural Research Service, United States Department of Agriculture. Retrieved September 10, 2013, from http://nt.ars-grin.gov/fungaldatabases/
[54] http://www.buglife.org.uk/Resources/Buglife/Documents/Ragwort%20-%20Insect%20Fauna%20in%20detail.pdf (Accessed 06/09/2013)
[55] http://data.nbn.org.uk/ (Accessed 16/09/2013)

particular. *Ramularia pruinosa,* for which ragwort is the sole host, has been found in Shropshire and Yorkshire only.

The remaining species, including twelve that may be non-native, are found in Appendix 2.

The strength of evidence assignment and overall confidence in the relationship between the fungi and ragwort is based mainly on the records that have been filed with the FRDBI and there are few other sources for the association (Table 13). Therefore for five of the species, *Diaporthe orthoceras, Podosphaera xanthi,i Puccinia dioicae var. dioicae, Ramularia filaris var. filaris* and *Ramularia pruinosa,* the overall evidence is low. For the others the amount and quality of evidence together with the level of agreement means that they should be considered as medium level overall.

Table 13 Species of fungi that are solely dependent on ragwort or have a limited number of alternate hosts

Species	Synonym	Phylum: Order	Plant Part	Alternate Hosts	No. Hosts	Reference	Distribution
Diaporthe orthoceras	*Phomopsis achilleae var. senecionis*	Ascomycota: Diaporthales	Stem	*Achillea millefolium*	Oligophagous	FRDBI, Harper &Wood (1957)	NBN 3 10km records, 2 in Norfolk and 1 in Mid-west Yorkshire (VC: 64); FRDBI: 6 records, one record *S. jacobaea* (1 of 3 records from Scotland on *S. jacobaea*)
Leptosphaeria derasa	*Nodulosphaeria derasa*	Ascomycota: Pleosporales	Stem	*Senecio aquaticus, Senecio* spp	Oligophagous *Senecio jacobaea* (Main)	Dennis (1978), FRDBI, Harper & Wood (1957), Farr & Rossman (2013), Braun &Cook (2012)	NBN 16 10km records mainly Yorkshire; FRDBI 28 records, 20 records *S. jacobaea*
Podosphaera xanthii		Ascomycota: Erysiphales	Leaves, stems	*Matricaria discoidea, Pulicaria dysenterica, Taraxacum officinale*	Oligophagous	FRDBI, Ellis & Ellis (1985)	NBN 23 10km records widespread; FRDBI 39 records; 10 records *S. jacobaea*
Puccinia dioicae var. dioicae		Basidiomycota: Pucciniales	Leaves, flower stems	*Carex ovalis, C. pendula, C. rostrata*	Oligophagus *Cirsium palustre, S. jacobaea* broad-leaved hosts	FRDBI	NBN 13 10km records; FRDBI 27 records Devon, Norfolk, Oxford, Worcs, Yorks; 5 records *S. jacobaea*
Puccinia dioicae var. schoeleriana	*Puccinia schoeleriana*	Basidiomycota: Pucciniales	Leaves	*Carex arenaria*	Oligophagous *S. jacobaea* sole broad-leaved host	FRDBI, Ellis & Ellis (1985), Jones & Baker (2007), Francis & Waterhouse (1988), Harper & Wood (1957), Farr & Rossman (2013)	NBN 13 10km records; FRDBI 33 records; 18 records *S. jacobaea* Devon, Lincs, Norfolk, Northumberland, Suffolk, Yorks
Puccinia glomerata	*Puccinia expansa Link*	Basidiomycota: Pucciniales	Leaves	*S. aquaticus, Tephroseris palustris*	Oligophagous	FRDBI, Ellis and Ellis (1985), Jones and Baker (2007), Harper and Wood (1957), Farr and Rossman (2013)	NBN 35 10km records widespread; FRDBI 65 records; 30 records *S. jacobaea*
Ramularia filaris var. filaris		Ascomycota: Capnodiales	Leaves		Oligophagous *Arctium* spp., *Picris echioides*	FRDBI	NBN 6 10km records; FRDBI 16 records; 1 *S. jacobaea* record
Ramularia pruinosa		Ascomycota: Capnodiales	Leaves	-	Monophagous	FRDBI, Ellis and Ellis (1985)	NBN 5 10km records; FRDBI 7 records; 6 *S. jacobaea* records Shropshire, Yorks

2.6.3. Other environmental impacts

Environmental impacts other than impacts on biodiversity are mainly likely to arise from the use of herbicides. All of the herbicides used for ragwort control also affect other plant species (see section 2.5.2.3). Other environmental risks will be similar to those arising from herbicide use on crops etc. These are assessed during the pesticides approvals process, and the sale and use of pesticides are governed by legislation[56], LERAP[57] requirements, cross compliance Statutory Management Requirements 9 and 11, and the Code of Practice for Using Plant Protection Products. Particular care should be taken when herbicides are used near water or in situations where leaching to ground water is likely, as the main herbicides used for ragwort control are among those most frequently found in ground and surface waters (Table 14).

Table 14 Occurrence of herbicides commonly used for ragwort control in samples of surface and ground water (source: Environment Agency).

Herbicide	Percentage of samples over 0.1 µg/l[2] (or the limit of detection)							
	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Surface water								
MCPA	10.7	7.8	7.0	7.4	8.7	8.2	12.9	
2,4-D	10.0	6.3	6.8	6.3	7.7	4.4	6.5	
Ground water								
2,4-D	-	1.56	0.18	0.27	0.18	0.24	0.09	0.07
dicamba	-	2.89	0.16	-	-	0.38	0.08	0.19
MCPA		0.20	2.34	-	-	0.83	0.24	0.07

2.7. RAGWORT IN HAY

2.7.1. Analysis of hay/silage

2.7.1.1. Visual detection

In some cases ragwort is very obvious and can be visually detected, but it is not always possible.

[56] The Food and Environment Protection Act 1985, Control of Pesticides Regulations 19686 as amended by the Plant Protection Products (Basic Conditions) Regulations 1997, and the Health and Safety at Work Act 1974.
[57] Local Environmental Risk Assessments for Pesticides http://www.pesticides.gov.uk/guidance/industries/pesticides/topics/using-pesticides/spray-drift/leraps

2.7.1.2. Chemical analysis

An Analytical Chemist at Fera has had requests to sample hay in the past (C. Crews, pers. comm.). Five samples have been sent in by vets after a horse died of suspected ragwort poisoning. The cost of testing each sample was £250, with no profit made. This test is not commonly conducted, so this price is a special case because of low demand. Testing for ragwort in hay is not thought to be carried out anywhere else in the UK. It should also be noted that unlike seed or grain, a hay sample cannot be mixed into a representative sample, therefore a test would be more suited to a customer looking for a positive result, i.e. after the death of an animal to find the cause of death, rather than to ensure hay is ragwort free before feeding it to livestock.

2.7.1.3. Quality assurance

There are many claims from sellers that their hay is ragwort-free. From our research we have yet to find any sellers to claim this other than on local selling sites. It appears that the claims are founded in an assurance that the hay is gathered from ragwort-free fields. There is no official scheme to ensure hay is ragwort-free or that efforts are made to reduce ragwort presence in hay.

2.8. EVIDENCE FROM OTHER COUNTRIES

2.8.1. Status in Europe

2.8.1.1. Is ragwort a problem?

A selection of countries in Europe were contacted regarding ragwort. These were Belgium, France, Germany, Ireland and the Netherlands.

Belgium: In Belgium it is recognised that ragwort can be a problem to livestock, but believe that in the majority of locations where ragwort can be found, there are no issues (information obtained through personal correspondence with Research Institute of Nature and Forest, Brussels (L[58])).

France: Ragwort is not believed to be a problem. It is not in France's plant health regulation, which has the power to control some native weeds (information obtained through personal correspondence, Entomology and Invasive Plants Unit at the Plant Health Laboratory and Scientific Officer for Invasive Alien Species at the French National Plant Protection Organisation (L).

Germany: Nothing known to be documented about the impacts, however it is recognised as a threat to livestock (Personal communication from the Federal Research Centre for Cultivated Plants Institute for Plant Protection in Field Crops and Grassland) (L). It may be

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[58] This is marked as low on the confidence scale as the information has only came from one source, but the correspondent is in a position whereby they should know if ragwort is a large threat or not. This applies to all personal communication entries.

possible that further work is conducted at a state level rather than national, further research will be required.

Ireland: Ragwort is perceived as a problem and is on Ireland's noxious weeds list. It is commented that the main difficulty in enforcing legislation is the abundance of ragwort in public areas and roadside margins (personal communication from an Agriculture Inspector at the Department of Agriculture, Food and Marine, Feedingstuffs, Fertilisers, Grain and Poultry Division) (L).

The Netherlands: It was recognised that ragwort may be on the increase in the country, but it was considered that this was due to bad land management. It is not a large concern for the Netherlands Government (personal communication from Ministry of Agriculture, Nature and Food) (L).

2.8.1.2. Control regimes

Belgium: Belgium considers ragwort to be a management issue and has campaigns to inform horse owners of the dangers of ragwort.

France: Not applicable to France.

Germany: Similar to Belgium, a campaign to educate those with livestock on how to manage their fields, particularly emphasising the importance of eradicating the plant at the earliest possible stage. There also is an act under the civil code of Germany whereby removal of ragwort can be enforced due a complaint by a neighbour, similar to the UK system.

Ireland: An annual public notice campaign is carried out every summer. Ragwort is listed as a noxious weed as in the UK. Enforcement is a written notice to clear the land in two weeks; if this is not done there is a €1000 fine and penalties on farm payments.

The Netherlands: Good land management is recommended.

2.8.1.3. Cost-benefit analyses

None of the European countries contacted appear to have carried out cost-benefit analyses.

2.8.2. Status in countries where ragwort is non-native

2.8.2.1. Is ragwort a problem?

United States, Oregon: A considerable amount of work has been carried out in Oregon. Ragwort was first detected in Oregon in the 1922s (Isaacson, 1973) in (Coombs, 1996)(H) and by the 1960s it was estimated to cause an annual loss of $1.2 million by poisoning of livestock ((United States of America, 1972) in (Coombs, 1996)). Coombs estimated that there was a higher ratio of horses poisoned than cattle, and in 1974 horse losses were estimated at $29,000 at $500 replacement value; this estimate was arrived at using a diagnosis-to-real-loss ratio of 50%. See Table 15 below for impact on cattle.

Canada, British Columbia: Ragwort is a recognised problem that Canada is trying to control, but figures on the extent of this problem were not found.

Canada, Alberta: Alberta has a high livestock to person ratio and is keeping alert to ragwort presence as it borders the highly infested British Columbia, but as yet there is no perceived problem with ragwort. (Personal communication with a Weeds Specialist at Alberta Agriculture and Rural Development).

Canada, Nova Scotia: Ragwort is common in this province, but not a perceived risk due to less agricultural impact. Cinnabar moth is present, but it was unknown if this was due to deliberate release in the area (Personal communication with Botany Risk Assessor in the Plant and Biotechnology Risk Assessment department in the Canadian Food Inspection Agency).

Australia: Australia has an extensive ragwort problem, especially in Victoria and Tasmania. Roberts & Pullin (2006) quote an estimate by the Australian Dairy Industry of $4 million annual cost of ragwort to Australian agricultural production; included in this is $2,428,211 lost in milk production and $434,327 in beef production. However, no reference was given for this estimate.

McLaren & Mickan (1994) estimated that ragwort cost $2,495 per dairy in the Yarram region of Victoria. In 1990, the Department of Conservation and Natural Resources spent approximately $90,000 on ragwort control annually. For the whole state, the estimate was between $1.5 and 2 million. Additionally, ragwort was estimated to cost Australian paper manufacturers approximately $200,000 per annum. The total annual cost of ragwort to the state of Victoria at the time was considered to be $3-5 million annually.

A state-wide survey was conducted by Ireson *et al*. in Tasmania on rural landholders with regard to the most important pasture and cropping weeds in the state. The results are based on a 19.4% response rate. The results of this study indicated that there has been a decline in ragwort in the past ten years and that currently only 31.8% of respondents consider ragwort to have an economic impact on their farm, and of these 56.9% were beef farmers, 22.9% dairy, 10.1% crops, 7.3% sheep and 2.8% other. It is not clear if horse only farms were included in this survey.

In 1996 it was estimated that Tasmania had annual production losses in dairy and beef production at $2.1 million due to ragwort (Ireson *et al*. (2000) in Ireson *et al*. (2006) (M)[59]

2.8.2.2. Control regime

United States, Oregon: Ragwort was declared a noxious weed and a programme was set up in 1975 involving the Oregon Department of Agriculture (ODA) and the Oregon State University (OSU), where various control practices were tested. Three insects were then released in the 1960s and 1970s: the cinnabar moth, ragwort flea beetle and the ragwort seed fly.

A hay-quarantine was also enacted in one county (Wallowa) in 1983, whereby ragwort contaminated hay was prevented from entering the county; no further details were given as

[59] There is a high level of agreement about the success of biological control within Tasmania, but little evidence other than this study as to current degree of impact ragwort still has in the area and with such a low response rate it is difficult to be clear whether this is representative of farming and livestock in the region.

to how hay could be declared ragwort free. It is believed to have worked well with biological control to reduce the number of new infestations (Coombs, 1996).

Canada, British Columbia: Ragwort is on the British Columbia noxious weed act. The province emphasises good land management and public awareness. Biological control is being used in British Columbia, and it is believed that the Ministry of Agriculture and Food are distributing flea beetle in the province.

New Zealand: Ragwort has been controlled on a regional basis in New Zealand since the 1993 Biosecurity Act; previous to this it was listed under the now defunct Noxious Plants Act and was targeted for eradication. Eradication proved unsuccessful and the current method of control requires creating zones for targeted action.

Landcare Research looked into the most effective methods of control, as grazing and chemical means had proved expensive to the land owner and their work showed that biological control should prove successful. Five insects were released, but the ragwort flea beetle (*Longitarus jacobea)* proved to be the most successful (Personal communication from Land Management Officer at Northland regional Council) (L).

Australia:

Provisions in Australia are similar to those in England. Under the Vermin and Noxious Weeds Act 1958, it is the duty of the owner/occupier of private land to “take sufficient reasonable action to destroy and suppress noxious weeds and to keep the land and any adjoining half width of road free of noxious weeds”. There are penalties for failure to comply with a notice to destroy ragwort, and the Department of Conservation and Natural Resources can enter private land to carry out such work and charge the land owner (McLaren & Mickan, 1994). A Ragwort Management Handbook has been produced in the state of Victoria, but much of the detailed information included is also of relevance elsewhere (McLaren & Mickan, 1994).

Ragwort is now routinely controlled using brushoff herbicide. Ragwort biological control has also been very successful in Victoria and Tasmania. Five insect predators of ragwort have been released in Australia for biocontrol, but only three have established. The flea beetle has in some localities of Tasmania reduced infestations by 95% and is dispersed across all of southern Tasmania and 90% of Northern Tasmania. In Victoria, the ragwort crown boring moths, *Cocylyis atricapitana* and *Platyptilia isodactyla* are now well established and are controlling ragwort infestations (Dr David McLaren, pers.comm.). The crown boring moth is having more success in Victoria than the flea beetle, with recoveries at 35% in Victoria and 67% in Tasmania (Pullin, 2006).

2.8.2.3. Cost-benefit analyses

United States, Oregon: Biological control for ragwort has reportedly reduced the loss of livestock by $3.7 million a year with additional savings of $1.27 million from improved pastures and $850,000 from a reduction in herbicide use. The cost of controlling ragwort was estimated at approximately $5/ha. It was estimated that cattle deaths attributed to PAs were reduced by 90% (Coombs, 1996). Table 15 shows the herd size in Oregon in 1974 and the costs due to ragwort and was taken from a more detailed report produced by the Oregon Department of Agriculture in 1993.

Table 15 Estimated cattle revenue losses in western Oregon due to ragwort poisoning in 1974 at 2% herd loss per year.

Class	Cattle numbers		Costs	
	Herd size	Deaths due to ragwort	Replacement value (cost/head)	Lost revenue
Calves	202813	4056	$305	$1237156
Cows	230469	4609	$500	$2304688
Bulls	9219	194	$1000	$184375
Total	442500	184		$3726219

Table taken from Coombs *et a*l. (1996).

The 1974-1992 biocontrol programme was estimated at $23.2 million in benefit and $1.5 million in costs. By 1989 there was a decline in requests for biocontrol agents for ragwort, suggesting fewer large ragwort infestations (Coombs 1996).

New Zealand: A report was commissioned by the Sustainable Farming Fund to find out what the average cost of controlling ragwort was. This work was undertaken by the West Coast Ragwort Control Group who surveyed farms on the West Coast of New Zealand's south island. They calculated an average cost of control without biocontrol agents in this area with 12,000 farms to be $980 per farm. Following an assessment on areas which do currently use the flea beetle with success, there is a potential net saving of $7 million per year. It was also estimated that the ragwort plume moth may provide benefits as high as $5 million per year in those areas which are wetter than is suitable for the flea beetle to be effective (Landcare Research, New Zealand).

A very conservative estimate for the cost of ragwort control in 2000 was $17 million per year, however this did not take into account production losses, animal health and environmental losses. The plume moth was introduced in 2003. An economic evaluation of ragwort biocontrol is in the progress and is expected to be published in 2015 (personal correspondence from a senior researcher in Landcare Research).

Canada: A cost-benefit analysis is not known to exist.

3. DATA GAPS IDENTIFIED AND SUGGESTED FUTURE ACTIONS

3.1. DATA GAPS AND SUGGESTIONS FOR FURTHER RESEARCH

Biology and ecology

- Further evidence is needed on the proportion of seeds that disperse, particularly beyond 40 m (but also between 15 and 40 m) to support risk assessments.

Ragwort status

- Annual vegetation surveys at a number of sites are required to monitor ragwort populations. Collection of management and environmental data would allow analysis of factors that influence populations and this information could be used to highlight potential risks based on, for example, weather conditions in the previous year.

Impacts on livestock

- Evidence is lacking on the number of deaths caused by livestock. This is a difficult issue to address, owing to the costs of testing to verify death.

Impact on human health

- More work is needed on transfer of PAs & their metabolites, specifically from ragwort, into meat, milk, eggs, honey, as well as a consensus on methodology to determine total PA exposure. In addition, a consensus is needed on safe limits (if any). The European Food Safety Authority EFSA have just commissioned a large survey of PAs in herbal teas and honey, and also in meat, eggs and milk (C. Crews, pers. comm.)

Control methods

- There is little published information on the effectiveness of pulling, although this is commonly undertaken.
- Currently, there is no biological control method readily available in the UK. As invertebrates are unlikely to be cost-effective in this country, research into the possibility of using fungal pathogens as biological control agents might be considered.

Environmental impacts of control

- There is insufficient evidence on the status of many species of invertebrate and fungi associated with ragwort, with respect to their status, distribution and degree of dependence on ragwort.
- There is a need for reconciliation of the various data sources for host-invertebrate interactions and easier access to up-to-date systematic information on designation and distribution of invertebrate species.

3.2. SUGGESTIONS FOR REVISION OF THE CODE OF PRACTICE

The points below are some suggestions for issues that could be considered if a revision of the Code of Practice were to be undertaken. This is not intended to be comprehensive as a full review of the code is beyond the scope of this report and detailed consideration may reveal other areas that would benefit from review.

Although the evidence review in this report has extended the information available on many aspects of ragwort and its control, and the reliability of evidence that is available, little has changed with respect to the control measures that are available for use since the previous version of the Code of Practice. Further research on the efficacy of some of these methods might be considered for the future.

- The code is quite long and consideration might be given to whether it could be shortened; in particular, whether all the information in appendices is required.
- Insufficient evidence exists to support the distance elements of the risk assessment on page 3 of the Code. It is suggested that this aspect of the Code of Practice is therefore left as it is for now, but consideration be given to the collection of further data (see above under data gaps).
- Rather than just referring to 'land used for grazing by horses and other animals', more detail on grazing intensity, timing and type of livestock could be used to refine the risk assessment.
- It is suggested that references to the use of biological control are removed as there is no practical method available for use in the UK. It is considered unlikely that the use of insects as biological control agents would be feasible in the UK owing to the presence of natural population regulatory mechanisms. Investigation of the use of fungal disease inoculum could be considered, but no research in this area was found.
- More information could be given on the relative effectiveness of different herbicides, and appropriate timing and situations in which they should be used.
- Page 18, paragraph 13 – it is hard to know what ecological impacts of taking no action would outweigh the negative effects of using a herbicide in the case of ragwort, as it is part of the natural ecosystem. The reasons for control are to prevent livestock poisoning, not negative effects on the ecology.
- Appendix 4, page 23 – remove paragraph on set-aside – no longer relevant.
- Information on agri-environment schemes will soon need updating as Environmental Stewardship is being phased out.
- The possibility might be considered of holding a stakeholder workshop, including practitioners, on how useful the guide is and how it could be improved.

- In addition to the full code, shorter leaflets could be produced giving advice on specific aspects. Keepers of horses could be circulated using the contact details held on the horse passport database[60]

[60] https://www.gov.uk/horse-passport/overview

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Appendix 1. Invertebrate species that are associated with but not dependent on ragwort

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[61] 1957 (80)	BRC ragwort hosts[62]	Buglife list (37)	Status in England[63]	No. 10 km² [64]	Other hosts for larva (reliable)	References	Ecology/Range
Lepidoptera (macro-moths)	Noctuidae Noctuinae	*Agrotis vestigialis*	Y			no NBN desig info; IUCN: not yet assessed	>100	polyphagous (Thirteen other named species 100)	59, 61, 100	
Hemiptera (Sternorrhyncha-aphids)	Aphididae	*Aphis fabae*				no NBN desig info; IUCN: not yet assessed	28	polyphagous (+/- anything)	100	
Hemiptera (Sternorrhyncha-aphids)	Aphididae	*Aphis fabae*						polyphagous (+/- anything)	larva 55, 100	
Coleoptera	Apionidae	*Apion laevigatum (*							71, 100	
Lepidoptera (macro-moths)	Noctuidae Cuculliinae	*Aporophyla*	Y			BAP (applied 2007)Species of principal importance in England (applied 2008)	>100	Seventeen other species including *Senecio vulgaris* 100	59, 100	
Lepidoptera (macro-moths)	Arctiidae	*Arctia caja*	Y			BAP (applied 2007)		number of herbaceous plants; No ragwort recorded 100		
Lepidoptera (macro-moths)	Arctiidae	*Arctia villica*	Y			no NBN desig info; IUCN: not yet assessed	>100	polyphagous (Thirteen other species including S.vulgaris 100)	59, 100	larvae eat leaves 80
Lepidoptera (macro-	Noctuidae Plusiinae	*Autographa pulchrina*				no NBN desig info; IUCN: not yet assessed	>100	polyphagous (Eleven other species including Senecio	1	

[61] Harper & Wood 1957
[62] Biological Records Centre: Database of Insects and their Food Plants http://www.brc.ac.uk/dbif/hostsresults.aspx?hostid=5110 Accessed 25/09/2013
[63] NBN/IUCN designation
[64] Approx. no 10 km squares in England (from NBN)

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[61] 1957 (80)	BRC ragwort hosts[62]	Buglife list (37)	Status in England[63]	No. 10 km[2] [64]	Other hosts for larva (reliable)	References	Ecology/Range
moths)								vulgaris 100)		
Hemiptera (Heteroptera-bugs)	Berytidae (Berytinidae)	*Berytinus montivagus*				no NBN desig info; IUCN: not yet assessed	21	Five other species including Geranium, Medicago and Erica sp. 100	unspec, 100	
Hemiptera (Heteroptera-bugs)	Berytidae (Berytinidae)	*Berytinus signoreti*	Y			no NBN desig info; IUCN: not yet assessed	25	polyphagous (Five other named species 100)	unspec, 100	Found throughout much of Britain but rarer in the north, frequenting sandy and chalky habitats 104
Hemiptera (Sternorrhyncha-aphids)	Aphididae	*Brachycaudus cardui (L.) ssp. lateralis*	Y			no NBN desig info; IUCN: not yet assessed	2	*Prunus* spp. primary host, Aphids migrate to Asteraceae) especially *Carduus*, *Cirsium* spp. and *Borago* 106; *Senecio vulgaris*, plus 3 other species 100	unspec, 100	
Hemiptera (Sternorrhyncha-aphids)	Aphididae	*Brachycaudus helichrysi*	Y				1	*Prunus* sp primary host and a wide range of Asteraceae - asters, chrysanthemums, yarrow and groundsel 106; no ragwort 100	z	z
Hemiptera (Heteroptera-bugs)	Miridae	*Calocoris norvegicus (Closterotomus norwegicus)*	Y			no NBN desig info; IUCN: not yet assessed	>100	polyphagous (Nine other named species 100)	52, 100	BI
Diptera	Agromyidae	*Chromatomyia (Phytomya) syngenesiae*				no NBN desig info; IUCN: not yet assessed	11	Highly polyphagous species, exclusively genera of Asteraceae (recorded on 27) 13, 17; oligophagous 72	13, 16, 17, 72	z
Lepidoptera (micro-moths)	Tortricidae	*Cnephasia conspersana*		Y		no NBN desig info; IUCN: not yet assessed	22	polyphagous, Rosaceae and Asteraceae 100	z	coastal

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[61] 1957 (80)	BRC ragwort hosts[62]	Buglife list (37)	Status in England[63]	No. 10 km[2 64]	Other hosts for larva (reliable)	References	Ecology/Range
Lepidoptera (micro-moths)	Tortricidae	*Cochylis dubitana*		Y		no NBN desig info; IUCN: not yet assessed	30-100	Various Compositae, including ragwort (*Senecio*), Hawkbeards (*Crepis* spp.), Hawkweeds (*Hieracium* spp.), Perennial sow-thistle (*Sonchus arvensis*) and goldenrod (*Solidago virgaurea*) 74. Oligophagous 72	67, 72, 74, 100	distributed widely in the south of Britain, but becomes scarcer northwards. The drier substrates found on limestone and coastal sand, appear to favour it in North Wales and NW England.
Lepidoptera (micro-moths)	Coleophoridae	*Coleophora tricolor*				BAP (applied 2007)		*Acinos arvensis* & grasses 100	No ragwort 100	Breckland on poor scantily covered grassland on calcareous soils
Hymenoptera	Apidae	*Colletes daviesanus*		Y		IUCN: not assessed	>100	Oligolectic on pollen of Asteraceae. Flowers recorded visiting *Filipendula vulgaris*, *Heracleum sphondylium*, *Senecio* species, *Bellis perennis*, *Achillea* species, *Tanacetum parthenium*, *Chrysanthemum vulgare* and *Cirsium arvense*;		Virtually ubiquitous in lowland Britain; Univoltine; mid June to mid September
Hemiptera (Heteroptera-bugs)	Rhopalidae	*Corius hyoscyami*	Y			no NBN desig info; IUCN: not yet assessed	30-100	polyphagous; Asteraceae as a family (100)		
Diptera	Tephritidae	*Ensina sonchi*	Y				27	*Senecio vulgaris, Leontodon hispidus, Tragopogon pratensis, Crepis biennis, Picris hieracioides, Carduus nutans, Sonchus arvensis Hypochaeris radicata,*	41, 42, 100	

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[61] 1957 (80)	BRC ragwort hosts[62]	Buglife list (37)	Status in England[63]	No. 10 km^2 [64]	Other hosts for larva (reliable)	References	Ecology/Range
								Sonchus asper 41		
Lepidoptera (macro-moths)	Noctuidae	*Eumichtis lichenea (Polymixis lichenea)*	Y			no NBN desig info; IUCN: not yet assessed	>100	Eighteen other species including *S. vulgaris* 100	61. 100	mostly coastal
Lepidoptera (macro-moths)	Geometridae	*Eupithecia absinthiata*	Y			no NBN desig info; IUCN: not yet assessed	>100	Twenty three other species including *S.erucifolius* and *S.vulgaris* 100	59, 61, 63, 100	
Lepidoptera (macro-moths)	Geometridae	*Eupithecia centaureata*	Y			no NBN desig info; IUCN: not yet assessed	>100	Twenty two other species including *S.erucifolius* and *S.vulgaris* 100	59, 61, 63, 100	
Lepidoptera (macro-moths)	Geometridae	*Eupithecia expallidata*	Y			no NBN desig info; IUCN: not yet assessed	30-100	*Solidago* is main food plant 108; Four other species 100	61, 64, 100	
Lepidoptera (macro-moths)	Geometridae	*Eupithecia goossesiata*	Y			synonym *Eupithecia absinthiata* f. *goossensiata*	>100	*Erica cinerea, E.tetralix, Calluna vulgaris & Achillea millefolium;*	no ragwort 100	
Lepidoptera (macro-moths)	Geometridae	*Eupithecia icterata (Villers) ssp. subfulvata*	Y			no NBN desig info; IUCN: not yet assessed	>100	Five other species	61, 100	Scotland?
Lepidoptera (macro-moths)	Geometridae	*Eupithecia pimpinellata*	Y				>100	*Pimpinella saxifraga & P. major* 100	no ragwort 100	
Lepidoptera (macro-moths)	Geometridae	*Eupithecia subfuscata*				no NBN desig info; IUCN: not yet assessed	>100	Eighteen other species 100	59, 64, 100	
Lepidoptera (macro-moths)	Geometridae	*Eupithecia subumbrata*				no NBN desig info; IUCN: not yet assessed	>100	Fourteen other species 100	64, 100	
Lepidoptera (macro-moths)	Geometridae	*Eupithecia succenturiata*				no NBN desig info; IUCN: not yet assessed	>100	Eight other species 100	59, 100	
Lepidoptera	Geometridae	*Eupithecia*				no NBN desig info;	>100	Eleven other species 100	64, 100	

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[61] 1957 (80)	BRC ragwort hosts[62]	Buglife list (37)	Status in England[63]	No. 10 km[2 64]	Other hosts for larva (reliable)	References	Ecology/Range
(macro-moths)	e	*tripunctaria*				IUCN: not yet assessed				
Lepidoptera (macro-moths)	Geometridae	*Eupithecia vulgata*	Y			no NBN desig info; IUCN: not yet assessed	>100	Thirteen other species 100	59, 61, 63, 65, 100	
Hemiptera (Auchenorrhyncha)	Cicadellidae	*Eupteryx aurata*				no NBN desig info; IUCN: not yet assessed	30-100	Polyphagous 72 (Eleven species 100)	49, 72, 100	S.Wales 49
Hemiptera (Auchenorrhyncha)	Cicadellidae	*Eupteryx notata*				no NBN desig info; IUCN: not yet assessed	16	oligophagous, probably associated with *Thymus* spp., *Prunella vulgaris* and other composites 103, subsidiary host 72 (Eighteen species 100)	50, 72, 1000	Found amongst low vegetation on chalky soils throughout the UK 103; Mersey 50
Lepidoptera (macro-moths)	Noctuidae	*Gortyna flavago*	Y			no NBN desig info; IUCN: not yet assessed	>100	Fifteen other species 100	61, 66, 100	
Lepidoptera (macro-moths)	Geometridae	*Gymnoscelis rufifasciata*				no NBN desig info; IUCN: not yet assessed	>100	Seventeen other species 100	64, 100	
Thysanoptera	Phlaeothripidae	*Haplothrips setiger*		Y		no NBN desig info; IUCN: not yet assessed	1	Nine other species including *S. squalidus and S.viscosus* 100	70, 100	
Lepidoptera (macro-moths)	Noctuidae	*Heliothis peltigera*		Y		no NBN desig info; IUCN: not yet assessed	>100	Immigrant; polyphagous; no ragwort but does include *S. viscosus* 100	No ragwort 100	
Lepidoptera (micro-moths)	Pterophoridae	*Hellinsia chrysocomae*				Endangered (proposed as a future Red Data Book species)no NBN desig info; IUCN: not yet assessed	3	Oligophagous 72; *Solidago vigaurea and Aster linosyris* 79	72, 79	woodland in south-eastern England 79
Hemiptera (Heteropter	Tingidae	*Kalama tricornis*				no NBN desig info; IUCN: not yet assessed	30	polyphagous (Eleven other named species 100); Food	53, 100	

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[61] 1957 (80)	BRC ragwort hosts[62]	Buglife list (37)	Status in England[63]	No. 10 km[2 64]	Other hosts for larva (reliable)	References	Ecology/Range
a-bugs)								plants unknown 105		
Diptera	Agromyidae	*Liriomya strigata*					13	*Capsella bursa-pastoris 13,14; Sonchus oleraceous 13,14; Lactuca bourgaei 13; Centaurea nigra & C. cyaneus 13; Valeriana officinalis 13; Lapsana communis 13; Centranthus ruber 13; Cirsium palustre 13; Taraxacum officinale 13, 14*	13, 100	polyphagus
Coleoptera	Chrysomelidae	*Longitarsus flavicornis*					100+	*Senecio aquaticus 5; Senecio erucifolius 5*	5, 6, 29, 100	
Coleoptera	Chrysomelidae	*Longitarsus membranaceus*					30-100	*Teucrium scorodonia 5,9,11,33; Lamiaceae 33*	11, 100	
Coleoptera	Chrysomelidae	*Longitarsus suturellus*	Y	Y			100+	*Senecio vulgaris* (Only larval record); presumed various Asteraceae 27	27	
Lepidoptera (butterflies)	Lycaenidae	*Lycaena phlaeas*				no NBN desig info; IUCN: not yet assessed	>100	polyphagous (Seven other species 100)	58	
Hemiptera (Heteroptera-bugs)	Miridae	*Lygus punctatus*				Nationally notable B (applied 1992) 95	5	polyphagous (six other named species 100)	100	
Diptera	Agromyidae	*Melanagromya dettmeri*		Y			5		13, 15, 100	Not British, Spencer (1966a: 21) and Spencer (1972b: 16, 19, 111, 112) MISIDENTIFIED British specimens of oligophaga as dettmeri 84
Diptera	Agromyidae	*Melanagromya oligophaga*					5	*Centaurea scabiosa 13; Achillea millefolium 13;*	13, 15, 72	

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[61] 1957 (80)	BRC ragwort hosts[62]	Buglife list (37)	Status in England[63]	No. 10 km[2 64]	Other hosts for larva (reliable)	References	Ecology/Range
								Centaurea nigra 13; Artemisia vulgaris 13; Senecio erucifolius 37, oligophagous 72		
Lepidoptera (macro-moths)	Noctuidae	*Mythimna conigera*				no NBN desig info; IUCN: not yet assessed	>100	Ten other species 100	66, 100	
Lepidoptera (macro-moths)	Noctuidae	*Mythimna impura*				no NBN desig info; IUCN: not yet assessed	>100	Nine other species 100	66, 100	BI
Diptera	Agromyidae	*Napomya lateralis*		Y			23	Polyphagous on Asteraceae, *Senecio vulgaris, Anthemis, Matricaria, Bidens, tripleurospermum, Calendula, Dimorphotheca 13, 37*	13, 37	
Coleoptera	Oedemeridae	*Oedemera virescens*				IUCN (pre-1994) Vulnerable (90, applied 1992)	5 post 1960 + 3 old England	*Typha spp. 12; Helianthus tuberosus*	12, 100	
Coleoptera	Phalacridae	*Olibrus corticalis*		Y			30-100	*Conya canadensis 40;* Adults in Flowers of *Taraxacum*, *Senecio vulgare, Hypocharis radicata 38; adult on ragwort 39*	40?	
Lepidoptera (macro-moths)	Geometridae	*Orthonama obstipata*				no NBN desig info; IUCN: not yet assessed	>100	Nine other species including Senecio vulgaris 100	1, 61	
Lepidoptera (macro-moths)	Noctuidae	*Orthosia opima*				no NBN desig info; IUCN: not yet assessed	30-100	seventeen other species including *Senecio vulgaris* 100	59, 66, 100	
Hemiptera	Pentatomid	*Pentatoma*	Y			no NBN desig info;	>100	Seven tree species but not		

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[61] 1957 (80)	BRC ragwort hosts[62]	Buglife list (37)	Status in England[63]	No. 10 km^2 [64]	Other hosts for larva (reliable)	References	Ecology/Range
(Heteroptera-bugs)	ae	*rufipes*				IUCN: not yet assessed		ragwort 100		
Lepidoptera (micro-moths)	Pyralidae	*Perinephela lancealis*		Y		no NBN desig info; IUCN: not yet assessed	30-100	polyphagous, *Eupatorium* mostly, *Senecio* sp and three other species 100		
Lepidoptera (macro-moths)	Noctuidae	*Phlogophora meticulosa*	Y			no NBN desig info; IUCN: not yet assessed	>100	herbaceous plants 100	No ragwort 100	
Lepidoptera (macro-moths)	Arctiidae	*Phragmatobia fuliginosa*	Y	Y		no NBN desig info; IUCN: not yet assessed	>100	polyphagous (Twenty four other species 100)	59, 60, 100	abundant Scolt Head, Norfolk 1937
Coleoptera	Chrysomelidae	*Phyllotreta nodicornis*		Y			30-100	*Reseda* spp mainly 36	37	
Hemiptera (Heteroptera-bugs)	Miridae	*Phytocoris ulmi*	Y			no NBN desig info; IUCN: not yet assessed	30-100	hawthorn and unspecified shrubs/trees, no ragwort 100		
Diptera	Agromyidae	*Phytomya albiceps*	Y				0	*Cirsium heterophyllum only host 89, 100*	No larval evidence 89	Yorkshire, Northumberland
Diptera	Agromyidae	*Phytomya atricornis*	Y			Synonym of *Chromatomyia (Phytomya) syngenesiae*	0		100	
Acari	Eriophyidae	*Phytoptus leioproctus (Ktenocoris)*					30-100	*S. vulgaris* (3)	100	
Hemiptera (Heteroptera-bugs)	Miridae	*Plagiognathus chrysanthemi*				no NBN desig info; IUCN: not yet assessed	>100	polyphagous (Five other named species 100)	52, 100	BI
Lepidoptera (micro-moths)	Pterophoridae	*Platyptilia isodactylus*		Y		no NBN desig info; IUCN: not yet assessed	3	*Senecio aquaticus* only 100	no ragwort 100	Local
Lepidoptera (macro-	Noctuidae	*Rhyacia simulans*	Y			no NBN desig info; IUCN: not yet assessed	>100	polyphagous (nine other species including *Senecio*	59, 100	

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[61] 1957 (80)	BRC ragwort hosts[62]	Buglife list (37)	Status in England[63]	No. 10 km^{2} [64]	Other hosts for larva (reliable)	References	Ecology/Range
moths)								*vulgaris* 100)		
Hemiptera (Sternorrhyncha-aphids)	Pemphigidae	*Schioneura patchae*				check nomenclature	1 *for Schioneura*	Monophagous 72?, different or same species recorded on *Ulmus*	unspec; roots 72, 100	
Lepidoptera (micro-moths)	Pyralidae	*Scoparia pyralella*		Y		no NBN desig info; IUCN: not yet assessed	>100	Dead leaves of ribwort plantain 111; no other species? 100	Very rarely found 111, 67, 68, 100	
Lepidoptera (macro-moths)	Arctiidae	*Spilosoma urticae*	Y			no NBN desig info; IUCN: not yet assessed	30-100	polyphagous (Six other species 100)	61, 100	mostly south and east coast of England
Lepidoptera (macro-moths)	Geometridae	*Thalera fimbrialis (Scopoli)*		Y		RDB1, BAP IUCN pre1994: Endangered, BAP, Species of principal importance England, protected species under W&C Act 1981	5 + 2 old	Feeds mostly on Wild Carrot 1; *Achillea millefolium 112 but may be erroneous 1*. Ten other species including *Senecio erucifolius* recorded 100	1, 100, 112	On shingle beaches , small area of south-east England,
Lepidoptera (macro-moths)	Noctuidae	*Thalpophila matura*				no NBN desig info; IUCN: not yet assessed	>100	Four other species 100	1, 100	
Thysanoptera	Thripidae	*Thrips major*	Y			no NBN desig info; IUCN: not yet assessed	2	Polyphagous (Thirteen other species 100)	69, 100	
Thysanoptera	Thripidae	*Thrips tabaci*	Y			no NBN desig info; IUCN: not yet assessed	4	Fifteen other species 100	69, 100	
Thysanoptera	Thripidae	*Thrips vulgatissimus*	Y			no NBN desig info; IUCN: not yet assessed	3	polyphagous (Twenty one other species 100)	69, 100	
Lepidoptera (macro-moths)	Geometridae	*Timandra griseata*				no NBN desig info; IUCN: not yet assessed	>100	Nine other species 100	59, 100	
Hemiptera (Heteroptera-bugs)	Tingidae	*Tingis reticulata*	Y			Nationally notable B (applied 1992) 95	7	*Senecio* sp 53, 100	unspec	
Diptera	Tephritidae	*Trupanea*		Y		Nationally scarce? no	27 + 8	*Senecio spp. 37, Artemisia*	18?, 20?, 37,	

Invertebrate order	Invertebrate family: subfamily	Invertebrate	H&W[61] 1957 (80)	BRC ragwort hosts[62]	Buglife list (37)	Status in England[63]	No. 10 km[2 64]	Other hosts for larva (reliable)	References	Ecology/Range
		stellata				NBN desig info; IUCN: not yet assessed	old	*46, Tripleurospermum 41, Anthemis 41, Serratula* 41, 46	41, 43, 100	
Diptera	Tephritidae	*Trypeta artemisiae*		Y			30	*Senecio* spp, *Achillea ptarmica, Artemisia, Tanacetum* 37	37	
Lepidoptera (micro-moths)	Pyralidae	*Udea uliginosalis*				Nationally Notable B (applied 1993) 92	0	No other host species	67, 68, 92, 100	Restricted to the uplands or mountains of Scotland, and in some Scottish islands such as Orkney and Rhum
Lepidoptera (macro-moths)	Noctuidae	*Xylena exsoleta*				BAP (applied 2007)	30-100	Nineteen other species including *Senecio vulgaris* 100	59, 100	Commoner in the north of England

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APPENDIX 2 FUNGI ASSOCIATED WITH RAGWORT

Table A2. Native species

Species	Synonym	Phylum: Order	Number of Hosts	Reference	Distribution
Albugo tragopogonis	*Pustula tragopogonis*	Oomycota: Albuginales	Oligophagous Tragopogon pratensis, Cirsium, Senecio	1	NBN >100 10k squares, Widespread over England; FRDBI 434 records
Alternaria alternata		Ascomycota: Pleosporales	Polyphagous	1	NBN 68 10km squares throughout England, commonest Yorkshire; FRDBI 600 records
Bremia lactucae		Oomycota: Peronosporales	Polypahgous Asteraceae	1, 5, 23,24	NBN >100 10k squares; Widespread over England; FRDBI 681 records
Calyptella capula		Basidiomycota: Agaricales	Polyphagous	1	NBN >100 10k squares, Widespread over England; FRDBI 795 records
Coleosporium tussilaginis	*Coleosporium senecionis*	Basidiomycota: Pucciniales	Polyphagous Pinus	1, 2, 6, 23, 24	NBN >100 10k squares, Widespread over England; FRDBI 2779 records
Collybia cookei		Basidiomycota: Agaricales	Polyphagous	1	NBN >100 10k squares; Widespread over England; FRDBI 597 records
Conocybe velata		Basidiomycota: Agaricales	Polyphagous	1	NBN 54 10k squares, Widespread over England; FRDBI 147 records
Crocicreas cyathoideum var. cyathoideum		Ascomycota: Helotiales	Polyphagous	1	NBN >100 10k squares, Widespread over England; FRDBI 2066 records
Dendryphion nanum		Ascomycota: Pleosporales	Polyphagous	1	NBN 33 10k squares, Widespread over England; FRDBI 136 records
Diaporthe arctii		Ascomycota: Diaporthales	Polyphagous	1	NBN >50 10k squares; Widespread over England; FRDBI 160 records
Didymella		Ascomycota: Pleosporales	Polyphagous	1	NBN >50 10k squares; Widespread over England; FRDBI 47 records
Diplodia herbarum		Ascomycota: Botryosphaeriales	Polyphagous	1	NBN 7 10km records; FRDBI 11 records, SW Yorkshire (four 1904), N Lincs (one 1907), Notts (one 1950's, last record), one S. jacobaea record (1907)

Species	Synonym	Phylum: Order	Number of Hosts	Reference	Distribution
Episphaeria fraxinicola		Basidiomycota: Agaricales	Oligophagous *Fraxinus excelsior, Fagus sylvatica, Populus tremula, Quercus, Acer campestre*	1	NBN 5 10 km; FRDBI 23 records, all tree species (Mainly Fraxinus excelsior) except one record S. jacobaea
Gibberella zeae		Ascomycota: Hypocreales	Polyphagous mainly Poaceae	1	NBN 24 10km squares; FRDBI 188 records, no records for Senecio jacobaea
Golovinomyces cichoracearum var. fischeri	*Erysiphe cichoracearum var. fischeri, Erysiphe fischeri*	Ascomycota: Erysiphales	Oligophagous Senecio vulgaris (Main), Senecio viscosus, Senecio squalidus	1, 10, 11, 23	NBN >50 10k squares, Widespread over England; FRDBI Only 2/153 records from S. jacobaea
Hyalopeziza millepunctata		Ascomycota: Helotiales	Polyphagous	1	NBN >100 10k squares, Widespread over England; FRDBI 405 records
Hypoderma commune		Ascomycota: Rhytismatales	Polyphagous	1	NBN 21 10km records widespread; FRDBI 61 records, only one S. jacobaea
Kalmusia clivensis	*Diapleela clivensis*	Ascomycota: Pleosporales	Polyphagous Cirsium arvense, Centaurea sp, Senecio spp 3	1, 3, Hebrides 8, 23	NBN 16 10km records widespread; FRDBI 42 records only two S. jacobaea
Lachnella villosa		Basidiomycota: Agaricales	Polyphagous	1	NBN >100 10k squares, Widespread over England; FRDBI 383 records
Leptosphaeria agnita		Ascomycota: Pleosporales	Oligophagous; main host *Eupatorium cannabinum*	1	NBN 20 10km records widespread; FRDBI 70 records, only one S. jacobaea
Leptosphaeria doliolum var. doliolum		Ascomycota: Pleosporales.	Polyphagous mainly Urtica dioica	1, 3	NBN >100 10k squares, Widespread over England; FRDBI 376 records,
Leptosphaeria macrospora	*Scolecosporiella bernardiana*	Ascomycota: Pleosporales	Polyphagous	1, 19, 23	NBN 20 10km records widespread; FRDBI 60 records, only one S. jacobaea
Leptosphaeria ogilviensis		Ascomycota: Pleosporales	Polyphagous	1, 3, 13, 14, 23	NBN 8 10km records widespread; FRDBI 22 records, only one S. jacobaea
Leptosphaeria purpurea		Ascomycota: Pleosporales	Polyphagous	1	NBN 24 10km records widespread; FRDBI 57 records, only two S. jacobaea

Species	Synonym	Phylum: Order	Number of Hosts	Reference	Distribution
Leptospora rubella	*Ophiobolus rubellus*	Ascomycota: Pleosporales	Polyphagous	1	NBN >100 10k squares, Widespread over England; FRDBI 515 records
Lophiostoma caulium		Ascomycota: Pleosporales	Polyphagous	1	NBN 29 10km records widespread; FRDBI 197 records, only one S. jacobaea
Marasmius epiphyllus		Basidiomycota: Agaricales	Polyphagous	1	NBN >100 10k squares, Very Widespread over England; FRDBI 1075 records
Melanoleuca langei		Basidiomycota: Agaricales	Polyphagous	1	NBN 1 10km records ; FRDBI 15 records, one S. jacobaea
Metasphaeria complanata		Ascomycota: Pleosporales	Oligophagous Apiaceae	1	NBN 43 10km records widespread; FRDBI 135 records, none S. jacobaea
Mollisia clavata		Ascomycota: Helotiales	Polyphagous	1	NBN >50 10km records widespread; FRDBI 308 records, none S. jacobaea
Mycena galericulata		Basidiomycota: Agaricales	Polyphagous	1	NBN >100 10k squares, Very Widespread over England; FRDBI 9519 records
Mycosphaerella tassiana		Ascomycota: Capnodiales	Polyphagous	1	NBN 9 10km records ; FRDBI 856 records
Nodulosphaeria dolioloides		Ascomycota: Pleosporales	Polyphagous	1, 3	NBN 27 10km records ; FRDBI 47 records, two for S. jacobaea
Ophiobolus acuminatus		Ascomycota: Pleosporales	Oligophagous mainly *Cirsium* spp.	1	NBN >50 10km records widespread; FRDBI 275 records, one S. jacobaea
Ophiobolus erythrosporus		Ascomycota: Pleosporales	Polyphagous	1	NBN 21 10km records widespread; FRDBI 55 records, one S. jacobaea
Orbilia leucostigma		Ascomycota: Orbiliales	Polyphagous	1	NBN >100 10k squares, Widespread over England; FRDBI 321 records,
Phoma exigua	*Phoma solanicola*	Ascomycota: Pleosporales	Polyphagous	24, 25	NBN 35 10km records mainly Herefordshire; FRDBI 495 records
Phoma nebulosa		Ascomycota: Pleosporales	Polyphagous	1	NBN 15 10km records; FRDBI 58 records; S. jacobaea record Scottish
Pleospora herbarum		Ascomycota: Pleosporales	Polyphagous	1, 24	NBN >50 10km records widespread; FRDBI 568 records
Pleospora penicillus		Ascomycota:	Polyphagous	1	NBN 14 10km records mainly Yorkshire; FRDBI 28

Species	Synonym	Phylum: Order	Number of Hosts	Reference	Distribution
		Pleosporales			records, 2 S. jacobaea
Podosphaera fusca	*Sphaerotheca fusca*	Ascomycota: Erysiphales	Polyphagous	1, European publication 11, 23	NBN >100 10k squares, Widespread over England; FRDBI 664 records Asteraceae
Pseudolachnea hispidula	*Dinemasporium herbarum*	Ascomycota: Incertae sedis	Polyphagous	1, 24	NBN 36 10k squares Widespread; FRDBI 86 records, one record S. jacobaea
Puccinia lagenophorae		Basidiomycota: Pucciniales	Oligophagous Senecio, mainly S. vulgaris, S squalidus	1	NBN >100 10k squares, Widespread over England; FRDBI 828 records; 1 record S jacobaea
Pyrenopeziza adenostylidis		Ascomycota: Helotiales	Polyphagous	1, 3	NBN 36 10km records widespread; FRDBI 99 records; 1 S. jacobaea record
Pyrenopeziza revincta		Ascomycota: Helotiales	Polyphagous	1	NBN >100 10k squares, Widespread over England; FRDBI 505 records
Ramularia senecionis		Ascomycota: Capnodiales	Oligophagous S. vulgaris	1, Hebrides 8, 23	NBN 5 10km records; FRDBI 2 records; No S. jacobaea records (7 Scotland)
Rhabdospora pleosporoides		Ascomycota: Capnodiales	Polyphagous	1	NBN 4 10km records; FRDBI 5 records; Durham, Lancs, Yorks, One S. jacobaea record
Sarcopodium circinatum			Polyphagous	3	NBN 25 10km records widespread; FRDBI 59 records; No records S. jacobaea
Sphaerotheca fuliginea	*Podosphaera fuliginea, Sphaerotheca humuli. var. fuliginea*	Ascomycota	Polyphagous commonest Veronica chamaedrys	24	NBN 25 10km records widespread; FRDBI 65 records; No records S. jacobaea
Stachybotrys dichroa		Ascomycota: Hypocreales	Polyphagous	1	NBN 24 10km records widespread; FRDBI 81 records; one record S. Jacobaea (British Isles)
Stictis stellata		Ascomycota: Ostropales	Polyphagous	1	NBN 44 10km records widespread; FRDBI 113 records; one record S. Jacobaea (Cornwall)
Torula herbarum		Ascomycota: Incertae sedis	Polyphagous	1	NBN Widespread over England with >100 10k squares; FRDBI 843 records
Trechispora		Basidiomycota:	Polyphagous	1	NBN Widespread over England with >100 10k

Species	Synonym	Phylum: Order	Number of Hosts	Reference	Distribution
		Trechisporales			squares; FRDBI 61 records; one record S. jacobaea (Yorkshire)
Unguicularia		Ascomycota: Helotiales	Polyphagous	1	NBN 43 10km records widespread; FRDBI 11 records; one record S. jacobaea (Scotland)

Table A3 Non-natives/unknown status of fungi species

Species	Synonym	Phylum: Order	Number of Hosts	Reference	Distribution
Alternaria cinerariae		Ascomycota: Pleosporales	Non native Main host *Pericallis hybrida*	1	NBN no records; FRDBI 9 records but found on Non-native *Pericallis hybrida*
Alternaria dennisii		Ascomycota: Pleosporales	Monophagous	1, 2, 4 (Non-native), 22, 23	NBN no records; FRDBI no records; Non-native
Ascochyta senecionis	*Pirottaea senecionis 24*	Ascomycota: Pleosporales	?	1, 24	NBN one record Norfolk; FRDBI 2 records, one on ragwort in Norfolk 1940; one in Dorset on non-native Senecio 1985
Boeremia exigua var. exigua		Ascomycota: Pleosporales	Non-native	1	NBN No records; FRDBI no records; Non-native
Coleroa		Ascomycota: Pleosporales	?	1	NBN no record; FRDBI 1 record 1957 *S. jacobaea* S. Lincs
Embellisia dennisii		Ascomycota: Pleosporales	Monophagous?	1, 9, 23	NBN No records; FRDBI Two records from 1970's: Suffolk and Isle of Man;
Leptosphaeria olivensis		Ascomycota	Non-native	24	NBN no records; FRDBI no records; Non-native
Phlyctema johnstonii		Ascomycota: Helotiales	Monophagous	1	NBN 1 10km records east Sussex; FRDBI one record *S. jacobaea* East Sussex 1850's
Phoma sydowii	*Phoma senecionis 19, 23*	Ascomycota: Pleosporales	Unknown	1, Hebrides 8, 23	NBN No record; FRDBI one record Hebrides S. jacobaea
Podosphaera senecionis			Unknown	European publication 12, 23	NBN no record; FRDBI no record
Septoria senecionis-silvaticae		Ascomycota: Capnodiales	Oligophagous *S. aquaticus*	1, 2, Hebrides 8, 23, 24	NBN No records; FRDBI 1 english record?(British Isles) *S. jacobaea* (3 records Scotland)
Trichobasis senecionis		Basidiomycota: Pucciniales	Unknown	1	NBN No records; FRDBI 1 english record?(1860) nomen dubium

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