

Risk Assessment of *Hippophae rhamnoides*

Name of Organism:	<i>Hippophae rhamnoides</i> Linnaeus – Sea Buckthorn
Objective:	Assess the risks associated with this species in Ireland
Version:	Final 30/09/2014
Author(s)	Erin O'Rourke, Liam Lysaght
Expert reviewer	Matthew Jebb

Stage 1 - Organism Information

Stage 2 - Detailed Assessment

Section A - Entry
Section B - Establishment
Section C - Spread
Section D - Impact
Section E - Conclusion
Section F - Additional Questions

About the risk assessment

This risk assessment is based on the **Non-native species APplication based Risk Analysis (NAPRA)** tool (version 2.66). NAPRA is a computer based tool for undertaking risk assessment of any non-native species. It was developed by the European and Mediterranean Plant Protection Organisation (EPPO) and adapted for Ireland and Northern Ireland by Invasive Species Ireland. It is based on the Computer Aided Pest Risk Analysis (CAPRA) software package which is a similar tool used by EPPO for risk assessment.

Notes: Confidence is rated as low, medium, high or very high.
Likelihood is rated as very unlikely, unlikely, moderately likely, likely or very likely.
The percentage categories are 0% - 10%, 11% - 33%, 34% - 67%, 68% - 90% or 91% - 100%.
N/A = not applicable.

This is a joint project by Inland Fisheries Ireland and the National Biodiversity Data Centre to inform risk assessments of non-native species for the European Communities (Birds and Natural Habitats) Regulations 2011. It is supported by the National Parks and Wildlife Service.

DOCUMENT CONTROL SHEET

Name of Document:	Risk Assessment of <i>Hippophae rhamnoides</i>				
Author (s):	Dr Erin O'Rourke and Dr Liam Lysaght				
Authorised Officer:	Dr Liam Lysaght				
Description of Content:	Non-native species risk assessment				
Approved by:	Dr Liam Lysaght				
Date of Approval:	30/09/2014				
Assigned review period:	n/a				
Date of next review:	n/a				
Document Code	n/a				
This documents comprises	TOC	Text	List of tables	List of Figures	No. Appendices
	n/a	YES	n/a	1	0

Version Control Table

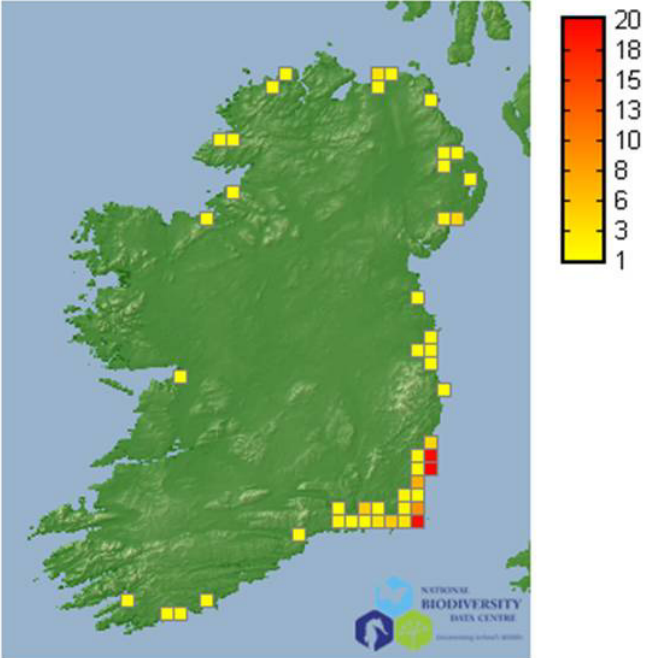
Version No.	Status	Authors(s)	Reviewed by	Approved by	Date of issue
Draft 1	Complete	Dr Erin O'Rourke	Dr Liam Lysaght		13/07/2014
Draft 2	Complete	Dr Erin O'Rourke	Dr Liam Lysaght		07/08/2014
Expert review	Complete	Dr Erin O'Rourke	Dr Matthew Jebb	Dr Michael Millane	05/09/2014
Public Consultation	Complete	Dr Erin O'Rourke		Dr Liam Lysaght	05/09/2014
Final	Complete	Dr Erin O'Rourke		Dr Liam Lysaght	30/09/2014

Stage 1 - Organism Information			
<i>The aim of this section is to gather basic information about the organism.</i>			
N	QUESTION	RESPONSE	COMMENT
1	What is the reason for performing the risk assessment?	-	A risk assessment is required as this species is listed as a "Non-native species subject to restrictions under Regulations 49 and 50" in the Third Schedule of the European Communities (Birds and Natural Habitats) Regulations 2011, SI 477/2011.
2	Identify the organism. Is it clearly a single taxonomic entity and can it be adequately distinguished from other entities of the same rank?	YES	<p><i>Hippophae rhamnoides</i> Linnaeus – Sea Buckthorn</p> <p>Taxonomy: Kingdom: Plantae Phylum: Magnoliophyta Class: Eudicotyledonae Order: Rosales Family: Elaeagnaceae Genus: Hippophae Species: rhamnoides</p> <p>Synonyms: n/a</p> <p>Common name (English): Sea Buckthorn</p> <p><i>Hippophae</i> is divided into three species based on morphological variations: a European species, <i>H. rhamnoides</i> L., a temperate Himalayan species, <i>H. salicifolia</i> D. Don, and a dwarf montane Himalayan species, <i>H. tibetana</i> Schlecht (Ranwell, 1972; Li and Schroeder, 1996). Liu and He (1978) also describe a fourth species, <i>H. neurocarpa</i>, found on the Qinghai-Xizang plateau of China. <i>Hippophae rhamnoides</i> is divided further into nine subspecies; <i>carpatica</i>, <i>caucasica</i>, <i>gyantsensis</i>, <i>mongolica</i>, <i>sinensis</i>, <i>turkestanica</i>, <i>yunnanensis</i>, <i>rhamnoides</i> and <i>fluviatilis</i> (Li and Schroeder, 1996).</p>
3	If not a single taxonomic entity, can it be redefined? (if necessary use the response box to re-define the organism and carry on)	N/A	
4	Describe the organism.	-	Ranwell (1972), describes <i>H. rhamnoides</i> as a "much branched, thorny, deciduous shrub, up to 9 m in height, which suckers freely. The narrow leaves are alternately placed, and the whole plant is densely covered in peltate silvery-brown scale-like hairs. The male and female flowers are borne on separate bushes. The sub-globose fruits are green at first, but by September, when ripe, they become orange, and may persist on the shrub all through the winter. The fruits are rich in vitamin C, and are normally single-seeded. Germination is epigeal and the seeds

Stage 1 - Organism Information			
<i>The aim of this section is to gather basic information about the organism.</i>			
N	QUESTION	RESPONSE	COMMENT
			exhibit a certain degree of dormancy which can be overcome by the cold treatment which is normally provided in nature during the winter. The plant bears root nodules, which are capable of fixing atmospheric nitrogen". The dioecious nature (separate sexes on individual plants) of the species is significant in predicting whether a population is capable of setting seed.
5	Does a relevant earlier risk assessment exist? (give details of any previous risk assessment for Ireland)	YES	In Ireland, a preliminary risk assessment was previously carried out. This was a prioritisation risk assessment as part of the Risk Analysis and Prioritisation for Invasive and Non-native Species in Ireland and Northern Ireland (ISI, 2012). It designated <i>Hippophae rhamnoides</i> as a "medium risk" invasive species.
6	If there is an earlier Risk Assessment is it still entirely valid, or only partly valid?	PARTIAL	Only a preliminary risk assessment was previously conducted in Ireland (refer to Question 5).
7	Where is the organism native?	-	<i>H. rhamnoides</i> is native to parts of Europe (Russia, Britain, France, Denmark, Netherlands, Germany, Poland, Finland, Sweden and Norway) and Asia (China, Mongolia, India, Nepal, Bhutan and in northern parts of Pakistan and Afghanistan; Wahlberg and Jeppsson, 1990; Lu, 1992; Yao and Tigerstedt, 1995). Note that in Britain the species is only native in the East, from East Sussex to Central Scotland (Stace, 1997; JNCC, 2007; Hackney, 2008).
8	What is the current global distribution of the organism (excluding Ireland)?	-	Including <i>H. rhamnoides</i> native range (refer to Question 7) the species has been introduced to Czech Republic, Estonia, Latvia and Lithuania (DAISIE, 2014; NOBANIS, 2014) and North America (Li and Schroeder, 1996).
9	What is the current distribution of the organism in Ireland?	-	<i>H. rhamnoides</i> is naturalised and locally abundant on sand dunes and sandy ground, mainly on the east and north coast of Ireland (National Biodiversity Data Centre, 2014; ISI, 2012; Reynolds, 2002). There are 170 records of the species covering 48 10km ² squares in Ireland verified by the National Biodiversity Data Centre; (Figure 1; National Biodiversity Data Centre, 2014). The plant has a history of introduction to sand dune systems as a sand-stabiliser (Ranwell, 1972; Reynolds, 2002). It has, for example, been planted on sand on Sherkin Island Co Cork, Kiltennel, Courtown, Co. Wexford, Raven Point, Wexford Harbour, Kilcoole and Newcastle stations in Co Wicklow, Rush, Co. Dublin the Dingle peninsula, Co Kerry (Reynolds, 2002), as well as on the Bull Island, Co Dublin. The earliest date of the use of the shrub in this way is not known for certain. Reynolds (2002) reports it to be planted from the late 1830s onward and thoroughly established some 30 years after. However, as early as 1756 it was recommended for planting in Ireland (Scully, 1916).

Stage 1 - Organism Information

The aim of this section is to gather basic information about the organism.

N	QUESTION	RESPONSE	COMMENT
			 <p>Figure 2. Map showing most of the verified records for <i>Hippophae rhamnoides</i> (sea buckthorn) per 10km² in Ireland. Colour scale bar shows density of records per 10km (National Biodiversity Data Centre, 2014).</p>
10	Is the organism known to be invasive anywhere in the world?	YES	<p>Across much of <i>H. rhamnoides</i> range it is considered a multipurpose, hardy, deciduous shrub, with considerable economic potential; planted for soil erosion control, land reclamation, wildlife habitat enhancement, and farmstead protection (Ranwell, 1972; Li and Schroeder, 1996). It has high nutritional and medicinal values for humans (Li and Schroeder, 1996). The vitamin C and E contents are as high as 600 and 160mg/100g of fruit, respectively and pulp and seeds contain essential oils important for its medicinal value (Bernath and Foldesi, 1992). <i>H. rhamnoides</i> develops an extensive root system rapidly and is therefore an ideal</p>

Stage 1 - Organism Information

The aim of this section is to gather basic information about the organism.

N	QUESTION	RESPONSE	COMMENT
			<p>plant for preventing soil erosion (Yao and Tigerstedt, 1994). It also has been used in land reclamation for its ability to fix nitrogen and conserve other essential nutrients (Dobritsa and Novik, 1992). The berries provide winter food and thickets provide birds with good cover, and it is often recommended for planting for this purpose in gardens. In China, <i>H. rhamnoides</i> has controlled soil erosion and water loss effectively and increased land reclamation. In addition, the harvest of fruit has provided value-added industries to support the economy of rural regions of Asian countries (Li and Schroeder, 1996). In Canada it has proved highly beneficial for enhancement of wildlife habitat, farmstead shelterbelts, erosion control and mineland reclamation (Li and Schroeder, 1996).</p> <p>However, the invasive spread of <i>H. rhamnoides</i>, via suckering and self seeding, can pose a threat to native vegetation of sand dunes (Reynolds, 2012; Richards, 2002). The deleterious effects of the species relate to its shading-out of native dune plants and production of floristically-poor dense thickets. Such thickets also inevitably completely alter the character of the local dune habitat, species composition, and the nutrient status of the soil where it grows. This has direct effects on the composition and balance of the invertebrate fauna (JNCC, 2007; Hackney, 2008; ISI, 2012). The species is considered invasive in Britain (introduced areas), Ireland, Latvia and Lithuania (Ranwell, 1972; Richards, 2002; National Biodiversity Data Centre, 2014; NOBANIS, 2014).</p>

Stage 2 - Detailed assessment: Section A - Entry

This section evaluates the probability of entry of an organism into Ireland. For organisms which are already present, only complete the entry section for currently active pathways of entry and potential future pathways. The entry section need not be completed for pathways which have allowed an organism to enter in the past but are no longer active.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.01	How many active/future pathways are relevant to the potential entry of this organism (n/a, very few, few, moderate number, many or very many)?	VERY FEW	HIGH	The main pathway of introduction of <i>H. rhamnoides</i> is the horticultural trade.
1.02	List significant pathways through which the organism could enter. Where possible give detail about the specific origins and end points of the pathways.	1. Horticultural trade	HIGH	Potential for the species to be sourced through the horticultural trade, via garden centres, mail order seed companies and the Internet. It is known to be used for the following purposes: dune stabilisation, land reclamation/soil improver, shelter, access management i.e. block up unauthorised entry, amenity planting i.e. as an ornament in gardens and parks, and habitat diversification (Ranwell, 1972; Richards, 2002; ISI, 2012; Parnell and Curtis, 2012). The plant may also be farmed for its fruits (Li and Schroeder, 1996). From wild or domestic habitats into which the plant is introduced it can escape (i.e. spread), becoming naturalised and/or invasive (Reynolds, 2002; Richards, 2002).

Pathway 1 – Horticultural trade

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.03	Is entry along this pathway intentional (e.g. the organism is imported for trade) or accidental (e.g. the organism is a contaminant of imported goods)?	INTENTIONAL	HIGH	Entry of the species along this pathway is deliberate. Berries persist on branches all winter, perhaps resulting in its use as an attractive ornamental plant in winter (Li and Schroeder, 1996).
1.04	How likely is it that large numbers of the organism will travel along this pathway from the point(s) of origin over the course of one year?	MODERATELY LIKELY	MEDIUM	There are no reliable data that exists to allow a reasonable assessment to be made of the number of plants that may, or may not, be brought into Ireland e.g. no figures available on the number of plants sold and subsequently planted. However, movement would be dependent on the level of supply and demand. Expectation would be for public land managers to be informed of the invasive traits of the plant and not use the plant, for any of the purposes listed in Question 1.02, particularly in environmentally sensitive areas (refer to Question 4.11).

Pathway 1 – Horticultural trade				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				<p>Other individuals or groups, including traders, gardeners and farmers, may have no, to little, appreciation of the invasive traits of the species. In Ireland there is, for example, an Irish Sea Buckthorn Growers Association, who promote the growth and development of the plant (see http://www.seabuckthorn.ie/index.html). Such an association highlights the interest to grow the plant commercially. Use of <i>H. rhamnoides</i> as a crop represents a likely future demand for the plant. Use of <i>H. rhamnoides</i> as an ornamental, mostly likely in coastal or well draining gardens, represents another likely future demand for the plant. Berries persist on branches all winter, perhaps resulting in its use as an attractive ornamental plant in winter (Li and Schroeder, 1996).</p> <p>Whether or not large numbers travel along this pathway, for a viable population in a new area to develop only a small number of opposite sex plants are needed (refer to Question 2.10).</p>
1.05	How likely is the organism to enter Ireland undetected or without the knowledge of relevant competent authorities?	LIKELY	MEDIUM	It is likely that the species could enter Ireland undetected and without the knowledge of the relevant authority, particularly as seed via the internet trade. It may be less likely for the species to go undetected as a plant, especially if it is labeled and checked at an entry point into the country. Introduction is most likely detected when the plant has established and flowering in winter or early spring, and is fruiting in autumn (Richards, 2002). It may be sometime before a plant grown from seed or cuttings is detected, with flowering and fruiting first observed on shoots in the second and third year (Ranwell, 1972).
1.06	How likely is the organism to survive during passage along the pathway?	LIKELY	HIGH	Likely for the species nutritional and housing requirements to be catered for by the importer. The species is known to have previously establishment via this pathway (refer to Question 9 and 1.02), substantiating that survival during passage is likely.
1.07	How likely is the organism to arrive during the months of the year appropriate for establishment?	LIKELY	MEDIUM	Horticultural traders and gardeners are likely to stock and buy <i>H. rhamnoides</i> at the time of year most appropriate to planting. It is normally transplanted or directly seeded in the spring (Li and Schroeder, 1996). Seeds need high temperatures to germinate; at 10 to 12°C Lu (1992) reports 13.2% germination after 47 days compared to 95% in 6 days for seeds at 24 to 26 °C.

Pathway 1 – Horticultural trade				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.08	How likely is the organism to be able to transfer from the pathway to a suitable habitat or host?	LIKELY	HIGH	In its natural environment <i>H. rhamnoides</i> is found on slopes, riverbanks and seashores (Li and Schroeder, 1996). In its introduced range it is a plant of sand dunes, sandy shores and sandy ground. In Ireland, <i>H. rhamnoides</i> occurs almost entirely in coastal habitats where it is most frequently found on sand dunes (Richards, 2002; Reynolds, 2012). The species is likely to be introduced into, and to a lesser extent encounter, such suitable habitat within the Irish landscape (Fossitt, 2000; CORINE, 2006).
1.09	Estimate the overall likelihood of entry into Ireland based on this pathway?	MODERATELY LIKELY	MEDIUM	See above.
1.10	Do other pathways need to be considered?	NO	HIGH	

Overall likelihood				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
1.11	Estimate the overall likelihood of entry into Ireland based on all pathways (comment on the key issues that lead to this conclusion).	MODERATELY LIKELY	MEDIUM	See Pathway 1.

Stage 2 - Detailed assessment: Section B – Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.01	Is the organism well established in Ireland (if there is any uncertainty answer 'unsure')	NO	HIGH	<i>H. rhamnoides</i> is naturalised and locally abundant on sand dunes and sandy ground, mainly on the east and north coast of Ireland (Reynolds, 2002; ISI, 2012; National Biodiversity Data Centre, 2014). There are 170 records for the species covering 48 10km ² squares in Ireland verified by the National Biodiversity Data Centre; (Figure 1; National Biodiversity Data Centre, 2014). It could not be described as well established i.e. widespread.
2.02	How likely is it that the organism will be able to establish in Ireland based on the similarity between local climatic conditions and the organism's current global distribution?	VERY LIKELY	HIGH	Most of <i>H. rhamnoides</i> native and introduced range (refer to Question 7 and 8) covers the north temperate climate zone. It can withstand temperatures from -43 to 40 °C (Lu, 1992). It is considered to be drought resistant but most populations grow in areas receiving 400 to 600 mm of annual precipitation (Kondrahov and Sokolova, 1990). Growth and development is most successful between 60-70% soil moisture (Li, 1990). It has established in Ireland; a country with a temperate oceanic climate which is mild, moist and changeable, with abundant rainfall and lack of temperature extremes (Keane and Collins, 2004). The plant is also both native and alien in Britain, Ireland closest and most climatically similar neighbour.
2.03	How likely is it that the organism will be able to establish in Ireland based on the similarity between other local abiotic conditions and the organism's current global distribution?	VERY LIKELY	HIGH	<i>H. rhamnoides</i> is predominantly a calcicolous shrub of well-drained, open dune soils; tolerating low temperatures, high and low soil pH and salt spray (Bond, 1983). Best growth occurs in deep, well drained, sandy loam soil with ample organic matter (Wolf and Wegert, 1993). Soil acidity and alkalinity, except at extreme levels, are not limiting factors (Li and Schroeder, 1996). It can be planted in marginal soils due to its symbiotic association with nitrogen-fixing actinomycetes (Dobritsa and Novik, 1992). It is salt tolerant and soaking seeds for 24 h in 0.15% NaCl was shown to increase the number of vigorous seedlings (Li and Schroeder, 1996). It grows most vigorously on semi-fixed dunes and where dunes become fully fixed, it loses some vigour. It does not tolerate shade.
2.04	How likely is the organism to encounter habitats necessary for the survival, development and multiplication of the organism in Ireland?	LIKELY	HIGH	In its natural environment <i>H. rhamnoides</i> is found on slopes, riverbanks and seashores (Li and Schroeder, 1996). In its introduced range it is a plant of sand dunes, sandy shores and sandy ground. It is also planted along roadsides. In Ireland, <i>H. rhamnoides</i> occurs almost entirely in coastal habitats where it is most frequently found on sand dunes (Richards, 2002; Reynolds, 2012). The species is likely to be introduced

Stage 2 - Detailed assessment: Section B – Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				<p>to, and to a lesser extent encounter, such suitable habitat within the Irish landscape (Fossitt, 2000; CORINE, 2006).</p> <p>There is still some doubt as to how important seed recruitment may be in local spread, compared to suckering and fragmentation. It is likely that all initial populations in Ireland have been a consequence of deliberate introduction rather than by natural long-distant spread.</p>
2.05	How likely is it that establishment will occur despite competition from existing species in Ireland?	LIKELY	MEDIUM	<p>Competition is not likely to be an impinging factor in the establishment of the species, particularly when growing under preferable habitat and abiotic conditions and in early to medium term successional growth (refer to Question 2.03 and 2.04). Vigorous growth and vegetative spread enables it to dominate most other vegetation.</p> <p>Where is it not the dominate flora mature plants are unable to tolerate heavy shade from taller trees and tall scrub, but persist in clearings (Pearson and Roders, 1962). At sites along the Lincolnshire coast, England, some areas of <i>H. rhamnoides</i> scrub are developing, through succession, into other forms of scrub and even into woodland and where this occurs, <i>H. rhamnoides</i> dies out (JNCC, 2007).</p>
2.06	How likely is it that establishment will occur despite predators, parasites or pathogens already present in Ireland?			<p>There is a paucity of information.</p> <p>There may be limitations on growth due to grazing activity by rabbits or stock or the destructive effects of human trampling, but only affecting the edge growth of thickets (Ranwell, 1972).</p> <p>Historically the spread of the plant was likely aided after the human induced reduction in rabbit populations from <i>myxomatosis</i> virus (Ranwell, 1972).</p> <p>Neither the male nor the female flowers have nectaries and do not attract insects (Li and Schroeder, 1996).</p> <p>It has been noted that its growth and resistance to insect attack are markedly affected by the amount of lime in the soil in countries outside Ireland. For example, growth is poor on lime-deficient dunes in the North Netherlands and plants are killed locally by defoliating insects; on lime-</p>

Stage 2 - Detailed assessment: Section B – Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				rich dunes, growth is much stronger and plants are more resistant to insect attack.
2.07	How likely is it that establishment will occur despite existing management practices?	LIKELY	HIGH	<p>With well-established infestations only physical removal, cutting or digging up the plants, either by hand or mechanically, is feasible and herbicide should be applied to remaining stumps (Hackney, 2008).</p> <p>Dublin City Council are making continual efforts to control <i>H. rhamnoides</i> at North Bull Island, Dublin. This is a Special Protection Area (SPA) where the objective is to maintain or restore the favourable conservation condition of the bird species listed as Special Conservation Interests for this SPA. Sustained control of the plant at this site is compounded by the fact that access is restricted to times outside of the nesting period for birds (McCorry and Ryle 2009).</p> <p>In Ireland, <i>H. rhamnoides</i> occurs almost entirely in coastal habitats where it is most frequently found on sand dunes (Richards, 2002; Reynolds, 2012). Under Article 17 of the EU Habitats Directive, Ireland is obligated to protect the conservation status of Annex I sand dune habitats. Conflicting issues at such sites makes the establishment of <i>H. rhamnoides</i> likely despite existing management practices. This is an issue which requires examination but which is beyond the scope of a Risk Assessment.</p>
2.08	How likely is it that management practices in Ireland will facilitate the establishment of the organism?	LIKELY	MEDIUM	<p>The intentional use of <i>H. rhamnoides</i> to stabilise sandy habitats, particularly dunes, the landscaping of sandy ground, most likely roadsides or for ornament in gardens and parks would clearly facilitate establishment. In Ireland there is a developing appreciation for the invasiveness of <i>H. rhamnoides</i>, particularly among land managers of public sites. It is to be hoped that the use of the plant for such purposes will decline (refer to Question 1.02 and 1.04).</p> <p>In Ireland there is an Irish Sea Buckthorn Growers Association, who promote the growth and development of the plant as a crop (see http://www.seabuckthorn.ie/index.html). Such promotion of the plant to be grown on sandy habitat, where it has known invasive traits, would be particularly unwelcome.</p>

Stage 2 - Detailed assessment: Section B – Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
				Ranwell (1972) notes that the increasing supply of nutrients in rainfall from polluted air may well favour the future spread of <i>H. rhamnoides</i> to dune systems too nutrient deficient for its healthy growth.
2.09	How likely is it that the biological characteristics of the organism would allow it to survive eradication campaigns in Ireland?	VERY LIKELY	HIGH	The fast growth, strong coppicing ability, reproduction from vegetative cuttings, suckering habits, abundant seed production coupled with efficient nitrogen fixation (Ranwell, 1972; Li and Schroeder, 1996) are biological characteristics of <i>H. rhamnoides</i> which are very likely to allow it to survive eradication. In stable soils most of the roots lie 10 to 20 cm below the surface, but they may be buried more deeply in mobile sand (Ranwell, 1972). Rhizome-like roots penetrate to at least 1.2 m and probably deeper on dunes (Pearson and Rogers 1962), which is an additional difficulty in the removal of the plant. It is extremely unlikely that <i>H. rhamnoides</i> will be eradicated from all the sites that it has been introduced to; it may be more likely to become an accepted part of the dune vegetation, rather than an unwelcome lodger. (JNCC, 2007).
2.10	How likely is it that the biological characteristics of the organism will facilitate its establishment?	VERY LIKELY	HIGH	<p><i>H. rhamnoides</i> can be reproduced by seed; softwood and hardwood cutting, and layering and suckers (Ranwell, 1972; Li and Schroeder, 1996).</p> <p>The species is dioecious, that is the sexes are on separate plants. One male plant can fertilise up to 5 or 6 female plants and pollination is by wind (Ranwell, 1972; Richards, 2002; Hackney, 2008). Female plant's produce abundant fruit in September by their second or third year of growth (Ranwell, 1972; Hackney, 2008). Fruits are single-seeded and may reach a density of 100 per decimetre of stem length (Ranwell, 1972). Holt (1958) notes that a bush 1.2 m high on calcareous dunes at Berrow, Somerset, England, produced some 15,000 berries. Seeds remain viable after passage through the alimentary tract of birds (Pearson and Rogers 1962). Potentially viable seeds have a 95 to 100 per cent germination rate. Where both sexes occur together 98 to 100 per cent of the fruits contain potentially viable seeds (Ranwell, 1972).</p> <p><i>H. rhamnoides</i> can live for at least 40 years and grow to a maximum height of 12 m (Ranwell, 1972). The maximum rate of horizontal vegetative spread recorded is 4 m in 2 years (Rogers, 1961) and of vertical shoot elongation of 0.7 m per year (Pearson and Rogers 1962).</p>

Stage 2 - Detailed assessment: Section B – Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.11	How likely is it that the organism's capacity to spread will facilitate its establishment?	LIKELY	MEDIUM	Refer to Question 3.02.
2.12	How likely is it that the organism's adaptability will facilitate its establishment?	LIKELY	MEDIUM	<p>Schroeder (1988) describes <i>H. rhamnoides</i> as one of the hardiest and most adaptable woody plants. Ranwell (1972) describes the plant as having a wide ecological tolerance and wide distribution and becoming increasingly abundant in Great Britain. As detailed in Questions 2.02, 2.03 and 2.10, <i>H. rhamnoides</i> is not, to any great extent, limited by climatic and abiotic conditions or biological traits.</p> <p>Its occurrence is restricted to coastal habitats where it is most frequently found on sand dunes (Richards, 2002; Reynolds, 2012). This factor may just be circumstantial i.e. intentional planting in sand dunes, and it is not to stay that the plant would not be successful and manifest invasive traits on other sites with features similar to those detailed in Question 2.03.</p>
2.13	How likely is it that the organism could establish despite low genetic diversity in the founder population?	MODERATELY LIKELY	MEDIUM	<p>Low genetic diversity in the founder population may play a role in limiting, to some extent, the establishment of the plant. In pure female stands at Sandy Hirst, East Lothian, Scotland, no fruits with viable seed were found (Pearson and Rogers 1962). Although vegetative (rhizomous growth) more than sexual reproduction underpins the establishment and spread of the plant (refer to Question 2.10), colonies nearly entirely single-sex are found at Portstewart, Co. Derry (Hackney, 2008). Ranwell (1972) notes that the of limiting sexual reproduction by regulating the sex ratio in <i>H. rhamnoides</i> existing stands would be worth exploring as a possible means of control.</p>
2.14	Based on the history of invasion by this organism elsewhere in the world, how likely is it to establish in Ireland? If possible, specify the instances of invasion elsewhere in the justification box	VERY LIKELY	HIGH	<p><i>H. rhamnoides</i> is already established in Ireland. Refer to Question 9 for an account of historic introduction. It is naturalised and locally abundant on sand dunes and sandy ground, mainly on the east and north coast of Ireland (National Biodiversity Data Centre, 2014; ISI, 2012; Reynolds, 2002).</p>

Stage 2 - Detailed assessment: Section B – Establishment

This section evaluates the probability of establishment of an organism within Ireland. For organisms which are already well established in Ireland there is no need to complete this section - move straight to the Spread section.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
2.15	If the organism does not establish, then how likely is it that transient populations will continue to occur?	VERY UNLIKELY	MEDIUM	The species is established and there are no known reports of short-lived individuals or populations. Transient populations are only likely to occur in very unfavourable climatic and abiotic conditions (refer to Question 2.02 and 2.03).
2.16	Estimate the overall likelihood of establishment. Mention any key issues in the comments box	VERY LIKELY	HIGH	See above.

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
3.01	What area (given in % or 10km squares) in Ireland could the organism establish (0% - 10%, 11% - 33%, 34% - 67%, 68% - 90% or 91% - 100%)?	0%10%	HIGH	<p><i>H. rhamnoides</i> is a plant of sand dunes, sandy shores and sandy ground. Its rapid establishment and spread at sites where it has been planted shows that it has the potential to grow on all sandy ground and dunes around the Irish coast (ISI, 2012). With reference to the CORINE land cover data such habitat accounts for <1% of the Irish land surface (beaches, dunes and sand – 0.15%).</p> <p><i>H. rhamnoides</i> has the potential to establish and spread in any habitat where suitable abiotic conditions exist i.e. well drained soil on open ground. It has particular potential to be grown on soil rich in lime and also marginal soils due to its symbiotic association with nitrogen-fixing actinomycetes (Dobritsa and Novik, 1992; Li and Schroeder, 1996).</p> <p>It is of note that CORINE land cover data does not define the size of coastal gardens, scrub or grassland, which represent important potential habitat for the species. However, it is suspected that even if these habitat features of coastal regions were accounted for, the area in Ireland that the species has the potential to establish in would still lie between 0%-10%.</p> <p>Outside of Ireland it is known to have been planted on roadsides, making the Irish roadsides, with also account for <1% of land cover (road and rail networks – 0.06%), potential habitat.</p>
3.02	How important is the expected spread of this organism in Ireland by natural means (minimal, minor, moderate, major or massive)?	MINIMAL	HIGH	<p>The plant rapidly spreads by rhizomatous root growth and layering, forming an extensive root system and quickly colonising adjacent areas (Yao and Tigerstedt, 1994; Li and Schroeder, 1996). This represents fast, localised growth. Distribution of seeds by birds feeding on the berries has been observed to cause rapid spread of <i>H. rhamnoides</i> in calcareous dune systems in Great Britain when plants of both sexes are present (Ranwell, 1972). Whilst at other sites bird-sown plants are occasionally encountered, with the primary source of spread vegetative (ISI, 2012). The likelihood of long distance dispersal by natural means seems remote, with all populations being more likely to have established from local cultivated plants or deliberate introduction (Reynolds, 2002).</p>

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
3.03	How important is the expected spread of this organism in Ireland by human assistance (minimal, minor, moderate, major or massive)?	MAJOR	HIGH	<i>H. rhamnoides</i> was intentionally introduced to Ireland (refer to Question 9), at which time human assistance played a central role in the spread of the species. There is a high likelihood that the plant continues to be spread to new sites <i>via</i> intentional planting from the horticultural trade or by attempts to establish wild stands for cropping such as at Bull Island (Dempsey, 2010) (refer Stage 2 -Entry). At existing sites of establishment the plant may be spread by inappropriate discarding of vegetative parts during control practices. Historically the spread of the plant was likely aided after the human induced reduction in rabbit populations from <i>myxomatosis</i> virus (Ranwell, 1972).
3.04	Within Ireland, how difficult would it be to contain the organism (minimal, minor, moderate, major or massive)?	MINOR	MEDIUM	Difficulties encountered in relation to containment of the plant, relative to other invasive plant species, would be minor. <i>H. rhamnoides</i> is naturalised and locally abundant on sand dunes and sandy ground, mainly on the east and north coast of Ireland (Reynolds, 2002; ISI, 2012; National Biodiversity Data Centre, 2014). It is currently geographically confined to coastline habitat with a preference for sand dunes, sandy shores and sandy ground.
3.05	What proportion (%) of the area in Ireland suitable for establishment, if any, has already been colonised by the organism?	0%-10%	HIGH	The preferred habitat to which the plant has the potential to invade accounts for <1% of total land cover in Ireland. There are 170 records of the species covering 48 10km ² squares in Ireland verified by the National Biodiversity Data Centre; (Figure 1; National Biodiversity Data Centre, 2014). The proportion of the area in Ireland suitable for establishment, that has already been colonised by <i>H. rhamnoides</i> is likely less than 0.15% (refer to Question 3.01)
3.06	What proportion of the area in Ireland suitable for establishment, if any, do you expect to have been invaded by the organism five years from now (including any current presence)?	0%-10%	MEDIUM	In five years <i>H. rhamnoides</i> may become more abundant at existing sites as a result of natural dispersal (refer to Question 3.02). Introduction of the plant to new sites is largely dependent on intentional planting.

Stage 2 - Detailed assessment: Section C - Spread

This section evaluates the probability of spread of an organism within Ireland. Spread is defined as the expansion of the geographical distribution of an organism within the risk assessment area.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
3.07	What other timeframe would be appropriate to estimate any significant further spread of the organism (10, 20, 40, 80 or 160 years)? Please comment on why this timeframe is chosen.	10	MEDIUM	Significant future spread of <i>H. rhamnoides</i> to new sites is dependent on intentional planting by humans, whilst localised spread at existing sites is dependent on vegetative growth, known to be rapid and which may be aided by lax control practices. In Great Britain rates of spread of up to 2 m per year (Rogers, 1961) suggest that a short time frame may be significant in avoiding significant damage to small sand dune systems.
3.08	In this timeframe, what proportion of the area (including any currently occupied areas) is likely to have been invaded by this organism?	0-10%	MEDIUM	Given the availability of suitable habitat for <i>H. rhamnoides</i> (refer to Question 3.01), the proportion of area invaded by the species will always be well below 10%.
3.09	Based on the answers to questions on the potential for establishment and spread in Ireland, define the area endangered by the organism. Be as specific as possible. If available, provide a map showing the area most likely to be endangered.	-	MEDIUM	Coastal dunes, sands, scrub, grassland, gardens and roadsides are most at risk to invasion by the species (ISI, 2012).
3.10	Estimate the overall potential for future spread for this organism in (very slowly, slowly, moderately, rapidly or very rapidly). Use the justification box to indicate any key issues.	MODERATELY	MEDIUM	Significant future spread of <i>H. rhamnoides</i> to new sites is dependent on intentional planting by humans.

Stage 2 - Detailed assessment: Section D – Impact*This section evaluates the probability of impact of an organism within Ireland.*

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.01	How great is the economic loss caused by the organism within its global distribution (excluding Ireland), including the cost of any current management?	MODERATE	MEDIUM	<p>Positive economic and social effects of the plant are reported from its native and, to a lesser extent, introduced range (refer to Question 10).</p> <p>Unlike other invasive plant species, there are no reports of <i>H. rhamnoides</i> directly causing losses to human enterprises e.g. agriculture and forestry. The losses caused by invasion of <i>H. rhamnoides</i> are due to control costs of the species, losses to biodiversity and losses to ecosystem function (refer to Question 4.06). No figure is available for the cost of control of <i>H. rhamnoides</i> throughout its global distribution but, drawing on Question 4.04, are here considered moderate.</p>
4.02	How great has the economic cost of the organism been in Ireland from the time of introduction to the present? Exclude any costs associated with managing the organism from your answer.	N/A	HIGH	There is no knowledge of any economic costs, excluding the costs associated with management of <i>H. rhamnoides</i> , incurred to-date in Ireland.
4.03	How great is the economic cost of the organism likely to be in the future in Ireland? Exclude any costs associated with managing the organism from your answer.	N/A	HIGH	Future economic costs are likely to only be associated with management of the species.
4.04	How great have the economic costs of managing this organism been in Ireland from the time of introduction to the present?	MODERATE	MEDIUM	Due to its highly competitive behaviour, especially on semi-fixed dunes, control measures have been instigated in Ireland. Substantial effort has been expended in containing and reducing the area of <i>H. rhamnoides</i> on dunes in North Bull Island by Dublin City Council. Invasive Species Ireland describes the economic impact due to management as moderate (ISI, 2012).

Stage 2 - Detailed assessment: Section D – Impact

This section evaluates the probability of impact of an organism within Ireland.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.05	How great is the economic cost of managing this organism likely to be in the future in Ireland?	MODERATE	MEDIUM	May be difficult and moderately costly to control, presenting an economic burden to landowners and state organisations charged with its management. The Joint Nature Conservation Committee (2007) consider it extremely unlikely that <i>H. rhamnoides</i> will be eradicated from all the sites that it has been introduced to; it may be more likely to become an accepted part of the dune vegetation, rather than an unwelcome lodger (JNCC, 2007).
4.06	How important is environmental harm caused by the organism within its global distribution?	MAJOR	MEDIUM	The invasive spread of <i>H. rhamnoides</i> , via suckering and seeding, can pose a threat to native vegetation of sand dunes (Richards, 2002; Reynolds, 2012). The deleterious effects of the species relate to its shading-out of native dune plants and production of floristically-poor dense thickets. Such thickets inevitably alter the character of the local dune habitat, species composition and the nutrient status of the soil where it grows, which has direct effects on the composition and balance of the invertebrate fauna (JNCC, 2007; Hackney, 2008; ISI, 2012).
4.07	How important has the impact of the organism on biodiversity* been in Ireland from the time of introduction to the present? *e.g. decline in native species, changes in community structure, hybridisation	MAJOR	MEDIUM	Through suckering and seeding <i>H. rhamnoides</i> has rapidly taken advantage of suitable dune conditions, in localised areas (e.g. North Bull Island), over time shading out dune grassland and significantly increasing the soil nutrient status by nitrogen fixation (ISI, 2012). This impact to biodiversity is of greater detriment because of its occurrence in areas of conservation interest (refer to Question 4.11).
4.08	How important is the impact of the organism on biodiversity likely to be in the future in Ireland?	MAJOR	MEDIUM	<i>H. rhamnoides</i> is already impacting upon biodiversity and it is not expected that this negative impacts will change in the future if current management campaigns are not increased and/or are effective (refer to Question 2.07). If the species spreads further the threat to biodiversity is likely to increase.

Stage 2 - Detailed assessment: Section D – Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.09	How important has alteration of ecosystem function* caused by the organism been in Ireland from the time of introduction to the present? *e.g. habitat change, nutrient cycling, trophic interactions	MAJOR	MEDIUM	If <i>H. rhamnoides</i> becomes a dominant species, major successional changes arise. There is increasing shade, altered microclimate, nitrification of soil and animal and plant species formerly associated with an open habitat of a sand dune are lost (Ranwell, 1972).
4.10	How important is alteration of ecosystem function caused by the organism likely to be in Ireland in the future?	MAJOR	MEDIUM	<i>H. rhamnoides</i> is already altering ecosystem functioning and it is not expected that this negative impact will change in the future if current management campaigns are not increased.
4.11	How important has decline in conservation status* caused by the organism been in Ireland from the time of introduction to the present? *e.g. sites of nature conservation value, WFD classification, etc.	MAJOR	MEDIUM	<i>H. rhamnoides</i> is regarded as a conservation problem as its invasive traits manifest in dune habitats and change the nutrient status of the soil where it grows (JNCC, 2007). Under Article 17 of the EU Habitats Directive, Ireland is obligated to protect the conservation status of Annex I sand dune habitats, but the establishment and spread of <i>H. rhamnoides</i> at such sites is impacting upon conservation objectives (ISI, 2012).
4.12	How important is decline in conservation status caused by the organism likely to be in the future in Ireland?	MAJOR	MEDIUM	<i>H. rhamnoides</i> is already impacting upon the conservation status of protected and/or important sites and it is not expected that these negative impacts will change in the future if current management campaigns are not increased.
4.13	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within its global distribution?	N/A	HIGH	There is no knowledge of any social or human health harm caused by <i>H. rhamnoides</i> within its global distribution to-date. Conversely, positive economic and social effects of the plant are reported from its native and, to a lesser extent, introduced range (refer to Question 10).
4.14	How important is social or human health harm (not directly included in economic and environmental categories) caused by the organism within Ireland?	MINIMAL	MEDIUM	Anecdotal information suggests reduced recreational enjoyment of sites at which <i>H. rhamnoides</i> is the dominant vegetative cover.

Stage 2 - Detailed assessment: Section D – Impact				
<i>This section evaluates the probability of impact of an organism within Ireland.</i>				
N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
4.15	How important is it that genetic traits of the organism could be carried to other organisms / species, modifying their genetic nature and making their economic, environmental or social effects more serious?	N/A	MEDIUM	It is the only <i>Hippophae</i> species known in Ireland, there are no hybrids (Parnell and Curtis, 2012).
4.16	How important is the impact of the organism as food, a host, a symbiont or a vector for other damaging organisms (e.g. diseases)?	N/A	MEDIUM	The species is not known as a host or habitat for pests or diseases (ISI, 2012).
4.17	How important might other impacts not already covered by previous questions be resulting from introduction of the organism? Specify in the justification box.	N/A	MEDIUM	We are not aware of any other impacts the introduction of this species would have.
4.18	How important are the expected impacts of the organism despite any natural control by other organisms, such as predators, parasites or pathogens that may already be present in Ireland?	LOW	MEDIUM	The only likely natural control may come from rabbit grazing, but this is usually only significant where very large populations may graze and slow down the vegetative spread of thickets. The overall impact of this is likely to be slight.
4.19	Indicate any parts of where economic, environmental and social impacts are particularly likely to occur. Provide as much detail as possible, where possible include a map showing vulnerable areas.	-	MEDIUM	It is an economic problem of conservation sites (ISI, 2012).
4.20	Estimate the overall potential impact of this organism in Ireland. Use the justification box to indicate any key issues.	MODERATE	HIGH	The rapid spread of the plant once established in sand dune systems, coupled with its deleterious impact on this Annex I habitat presents a serious problem for Ireland in fulfilling its obligations under the Habitat Directive

Stage 2 - Detailed assessment: Section E – Conclusion

This section requires the assessor to provide a score for the overall risk posed by an organism, taking into account previous answers to entry, establishment, spread and impact questions.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
5.01	Estimate the overall risk of this organism in Ireland. Noting answers given in 1.11, 2.16, 3.10 & 4.20	MODERATE	MEDIUM	The rapid spread of the plant once established in sand dune systems, coupled with its deleterious impact on this Annex I habitat presents a serious problem for Ireland in fulfilling its obligations under the Habitat Directive.

Stage 2 - Detailed assessment: Section F – Additional questions

This section is used to gather information about the potential effects of climate change on the risk posed by an organism. It is also an opportunity for the risk assessor to highlight high priority research that could help improve the risk assessment.

N	QUESTION	RESPONSE	CONFIDENCE	JUSTIFICATION
6.01	What aspects of climate change, if any, are most likely to affect the risk assessment for this organism?	-	MEDIUM	Future scenarios on climate alteration in Ireland suggest increases in mean temperature, higher winter rainfall and more intense storm events (Sweeney <i>et al.</i> , 2003). With reference to Question 7, 8 and 2.02, the distribution and establishment of <i>H. rhamnoides</i> is not restricted by climate (Ranwell, 1972) and such changes in climate are not likely to have any significant barely on the risk assessment.
6.02	What is the likely timeframe for such changes (5, 10, 15, 20, 50 or 100 years)?	N/A	N/A	Refer to Question 6.01
6.03	What aspects of the risk assessment are most likely to change as a result of climate change	-	N/A	Refer to Question 6.01
6.04	If there is any research that would significantly strengthen confidence in the risk assessment, please note this here. If more than one research area is provided, please list in order of priority.	NO	HIGH	

References

- CORINE 2006. Environmental Protection Agency, (2008); CORINE Landcover 2006 update (Ireland). Final Report.
- DAISIE. 2014. *Species Factsheet: Hippophaë rhamnoides* [Online]. Delivering Alien Invasive Species Inventories for Europe. Available: <http://www.europe-aliens.org/speciesFactsheet.do?speciesId=14650> [Accessed 21st May 2014].
- DEMPSEY, D. 2010. Project to determine if the total eradication of the invasive species *Hippophaë rhamnoides* from the North Bull Island is technically feasible and environmentally benign. BSc Horticulture Thesis, Teagasc College of Amenity Horticulture, Glasnevin.
- FOSSITT, J. A. 2000. *A guide to habitats in Ireland*, Heritage Council/An Chomhairle Oidhreachta.
- HACKNEY, P. 2008. *Hippophaë rhamnoides*, *Sea-buckthorn* [Online]. Invasive Alien Species in Northern Ireland. Available: <http://www.habitas.org.uk/invasive/species.asp?item=3533> [Accessed 21st May 2014].
- ISI 2012. *Hippophaë rhamnoides*. Risk analysis and prioritisation access database: Invasive Species Ireland.
- JNCC 2007. Conservation status assessment for: H2160: Dunes with *Hippophaë rhamnoides*. Second Report by the UK under Article 17 on the implementation of the Habitats Directive from January 2001 to December 2006. Peterborough: JNCC. Available from: www.jncc.gov.uk/article17.
- LI, T. S. & SCHROEDER, W. 1996. Sea buckthorn (*Hippophaë rhamnoides* L.): a multipurpose plant. *HortTechnology*, 6, 370-380.
- August 2009
- MCCORRY, M. & RYLE, T. 2009. A Management Plan for North Bull Island. Dublin City Council pp. 131.
- NATIONAL BIODIVERSITY DATA CENTRE. 2014. *Hippophaë rhamnoides interactive distribution map* [Online]. National Biodiversity Data Centre. Available: <http://maps.biodiversityireland.ie/#/Species/29006> [Accessed 10th April 2014].
- NOBANIS. 2014. *Hippophaë rhamnoides (Elaeagnaceae, Angiosperms)* [Online]. NOBANIS European Network on Invasive Alien Species. Available: <http://www.nobanis.org/speciesInfo.asp?taxalD=1250> [Accessed 10th April 2014].
- PARNELL, J. & CURTIS, T. 2012. *Webb's An Irish Flora*, Cork University Press.
- RANWELL, D. 1972. The management of sea buckthorn (*Hippophaë rhamnoides* L.) on selected sites in Great Britain. Report of the Hippophaë Study Group. The Nature Conservancy.
- REYNOLDS, S. C. 2002. *A catalogue of alien plants in Ireland*, National Botanic Gardens, Glasnevin, Dublin, Ireland.
- RICHARDS, A. J. 2002. *Hippophaë rhamnoides* Sea-buckthorn. In: PRESTON, C. D., PEARMAN, D. A. & DINES, T. D. (eds.) *New atlas of the British and Irish flora*. Oxford University Press.
- ROGERS, J.A. 1961 The autecology of *Hippophaë rhamnoides* L. Ph.D. Thesis University of Nottingham.
- SCULLY, R. W. 1916. *Flora of County Kerry*, Dublin, Hodges, Figgis & Company.
- STACE, C. 1997. *New flora of the British Isles*, Cambridge University Press.
- SWEENEY, J., BRERETON, T., BYRNE, C., CHARLTON, R., EMBLOW, C., FEALY, R., HOLDEN, N., JONES, M., DONNELLY, A., MOORE, S., PURSER, P., BYRNE, K., FARRELL, E., MAYES, E., MINCHIN, D., WILSON, J. & WILSON, J. 2003. Climate Change: Scenarios & Impacts for Ireland (2000-LS-5.2. 1-M1) ISBN: 1-84095-115-X Technical Report. Environmental Protection Agency, Wexford, Ireland.