IMPLEMENTING TARGET 10 OF THE GLOBAL STRATEGY FOR PLANT CONSERVATION AT THE NATIONAL BOTANIC GARDENS OF IRELAND: MANAGING TWO INVASIVE NON-NATIVE SPECIES FOR PLANT DIVERSITY IN IRELAND

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ABSTRACT

The importance of managing invasive non-native species (INNS), be it through eradication or limitation, is set out in the United Nations Convention on Biological Diversity (CBD) which states that parties to the Convention should 'prevent, control or eradicate alien species' (IUCN, 2000). Unfortunately there is some evidence that botanic gardens have been implicated in being responsible for the early introduction of many environmental weeds listed by IUCN as among the worst invasive species (Hulme, 2011). Stronger global networking between botanic gardens to tackle the problem of INNS has been suggested by Hulme. Botanic gardens have a remit to meet Target 10 of the Global Strategy for Plant Conservation (GSPC) and the European Strategy for Plant Conservation (ESPC) Targets 10.1 and 10.2. The National Botanic Gardens, Glasnevin, in conjunction with University College Dublin and Mayo and Fingal County Councils, with grant funding from the Heritage Council, has monitored populations then researched and implemented effective control methods of two escaped garden plants: Hottentot fig (*Carpobrotus edulis* (L.) N.E. Br.) and giant rhubarb (*Gunnera tinctoria* (Molina) Mirb.) in EU protected habitats and in Special Areas of Conservation (SACs) in Ireland. Chemical treatments were trialled and tested in the field for both species, and successful regeneration of native vegetation in formerly invaded areas has been observed since treatments began in 2009.

INTRODUCTION TO THE PROBLEM OF INVASIVE SPECIES AND BOTANIC GARDENS' REMIT

The effects of invasive non-native species (INNS) on biodiversity have been described as 'immense, insidious and usually irreversible' (IUCN, 2000). Many INNS are known to completely alter the nutrient cycling and hydrology in native ecosystems and diminish the abundance or survival of native species. Invasive non-native plant species are often more competitive than native plants, because of the lack of natural controls such as diseases and predators. Botanic gardens are in the unique position to supply both botanical and horticultural expertise to the problem of INNS and can be part of the

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solution rather than part of the problem, which they have been perceived to be in the past (Hulme, 2011).

Most INNS are familiar garden plants so in order to tackle the problem it takes a horticulturist to identify them and know about their lifecycle and growth habits outside their native ranges. In many instances these species invade botanically rich and diverse habitats, and likewise, it takes a botanist to know about these habitats and the native species growing there (Smyth & Jebb, 2012). Ireland has ratified a number of international conventions that oblige the Government of Ireland to address the problem of INNS including the Convention on Biological Diversity (CBD), the Bern Convention and the International Plant Protection Convention. In addition, there are obligations under the EU Habitats Directive to address any threats to the conservation status of the habitats and species listed for protection under the Directive. Botanic gardens themselves have a specific remit in Target 10 of the Global Strategy for Plant Conservation (GSPC) and the European Strategy for Plant Conservation (ESPC) Targets 10.1 & 10.2, to support effective management of important areas for plant diversity, and to control and monitor problematic invasive non-native species (Sharrock, 2012).

INVASIVE SPECIES CONTROL METHODS

There are three main methods of dealing with invasive non-native plant species: physical, chemical and biological control. They can be used separately or in conjunction, and each method has its own advantages and disadvantages (Myers & Bazly, 2003).

Physical control

Prior to the development of herbicides, weedy species were removed by mechanical or manual control, by pulling weeds, grubbing with hand tools or, in more extreme cases, bulldozing and dragging. The appeal of such methods is that they allow volunteers to get involved with the control of INNS and there is no danger of chemical damage to the natural environment or to other plants and animals.

However, the timing of cutting and pulling is very important. For example, when *Cytisus scoparius* was pulled when flowering and seeding in British Columbia, the resulting soil disturbance, seed spread and trampling proved to be ideal conditions for the germination of even more *Cytisus scoparius* through the seed that was spread and from dormant seed from the seedbank (Myers & Bazly, 2003). Comparisons of control techniques for *Berberis thunbergii* showed that cutting and pulling methods were not as effective as cutting and applying herbicide to stumps. Manual control is only considered feasible when the cover of an invasive species is low and disposal of material by composting or burial at a depth of no less than 0.5m is required (Myers & Bazly, 2003).

As part of an EU-funded LIFE project (LIFE2000NAT/E/7355) (Fraga *et al.*, 2005), physical control of Hottentot fig (*Carpobrotus edulis*) was carried out on the island of Menorca in 2002–2005. In 2002, there were 28ha of Hottentot fig on Minorca; by 2005, 24ha had been eradicated by physical removal, consisting of 900 tonnes of vegetation removed to a hazardous waste facility. The transport of these plants, stems and seed capsules was essential as regeneration is possible from all plant parts, so traditional composting methods could not be used. Huge expense was incurred for the manpower and machinery such as helicopters and diggers required to move the material, along with the additional expense of disposing of plant material safely once removed from sites (Fraga *et al.*, 2005). The budget on this project ran into millions of euros.

Chemical control

Chemical control of invasive species is commonly recommended, often in conjunction with physical control (Ogden & Rejmánek, 2005; Tye *et al.*, 2002; Flint & Rehkemper, 2002; Environment Australia, 1997; Motooka *et al.*, 2002). The main advantage of using herbicides to control invasive species is that they are both cost-effective and quick-acting when compared to manual treatments, which are labour-intensive and can be slow. The choice of herbicide to use depends on the prioritisation of three factors: efficiency, economics and environmental protection (Motooka *et al*., 2002).

Commonly used broad-spectrum herbicides are glyphosphate and dibromide. Both are non-selective herbicides; they will kill and injure all plants to which they are applied. Glyphosphate (brand names Round-up, Round-up Biactive and Glyphosphate Gold™, all manufactured by Monsanto and containing 360gm/l (36%) glyphosphate) is a growth inhibitor in plants. It causes plant mortality by disrupting the synthesis of aromatic amino acids and proteins. Upon application glyphosphate is transported readily through the phloem and xylem. It is strongly absorbed in soils and readily decomposed by soil micro-organisms; its half-life in soil is 47 days. The oral LD_{50}, that is the lethal dose that kills 50 per cent of a test population of rats, is 4900mg/kg, which is considered to be almost non-toxic. The advantages of using glyphosphate are its effectiveness and low toxicity to both the environment and humans. The main disadvantage of glyphosphate is that rainfall within six hours of application washes it off and ideally there should be no rain for a period of twenty-four hours after application, so in wet conditions a second application is required (Bacon & Buck, 2003).

Diquat (dibromide) (brand names Reglone and Diquat) is a non-selective contact herbicide absorbed through the foliage with some translocation in the xylem. Diquat binds very tightly to soil and sediments, making it immobile; it will not move to groundwater once bound to soil particles. It is moderately toxic to mammals (oral LD_{50} in the rat of 408mg/kg) and to birds (oral LD_{50} for ducks 155mg/kg or parts per million) and non-toxic to bees (oral LD_{50} 22mg per bee) and is rapidly inactivated on contact with soil and plants. It can, however, cause skin and eye irritations to people. No drying time is required once it has been applied (Bacon & Buck, 2003).

The method of application can vary between foliar methods, where the herbicide is applied to actively growing leaves, and stem methods, where the herbicide is applied to cut stems which have the cambium, xylem or phloem exposed. With both foliar and stem methods 'high volume spraying' can be used. This requires the use of mechanical sprayers consisting of a tank, a hand/motorised pump and a lance with a nozzle. Sprayers convert the herbicide formulation containing the herbicide mixture and water into high-pressure droplets, which can be large rain-type drops or tiny mist-like droplets depending on the force applied to the spray mixture and nozzle adjustment.

Glyphosate and dibromide were used to develop the most effective control methods for both the Hottentot fig and giant rhubarb in Ireland.

Biological control

Biological control is the 'holy grail' of invasive plant species control but it is fraught with ethical dilemmas and some sensational failures, for example *Opuntia* species and its biological control agent the *Cactoblastus cactorum* moth in Florida. This moth is spreading southwards from Florida and now threatens many rare native *Opuntias* in Mexico, the centre of cactus diversity. The same moth species, however, was used in Australia to control *Opuntia monocantha* and it did an excellent job (Myers & Bazly, 2003). There are also other reported biocontrol successes in Hawaii with a wide range of invasive plant species, such as *Lantana camara* (lantana), *Senna surattensis* (kolomona), *Passiflora tarminiana* (banana poka) and *Pennisetum clandestinum* (kikuyu grass) (Trujillo, 2005).

In 2012, the UK government was the first government in the EU to approve the release of a biocontrol agent. CABI released a tiny sap-sucking psyllid to control Japanese knotweed in the UK. This insect was released ten years after CABI scientists carried out stringent licensing testing (CABI, 2013). Biocontrol is the ideal solution to the invasive species problem. However, it takes time to research a suitable control agent and it is possible that even after many years of research the control agent may not work or might even cause ecological disaster. In the meantime, the invasive species is thriving and spreading. In this instance neither the large research funds required nor the time to carry out stringent tests were available so it was discounted as an option. Both species would, however, be ideal candidates for biological control research as relatives of both species are not found in the wild in northern Europe (Gunneraceae is found in the southern hemisphere, South America and New Zealand, and Aizoaceae is mainly centred in South Africa).

INVASIVE NON-NATIVE SPECIES MANAGEMENT CASE STUDY 1: HOTTENTOT FIG (*CARPOBROTUS EDULIS*)

Hottentot fig (*Carpobrotus edulis*) is a popular garden plant from South Africa (Table 1). It is also an aggressive invader of coastal habitats and forms vast mats to the exclusion of all other plants. On the Gower Peninsula of Wales and along the Cornish and Devon coasts of England it has formed extensive colonies, smothering many kilometres of coastal cliffs. On the drier eastern coasts of Ireland, especially on Howth Head Special Area of Conservation (SAC), it poses a serious ecological threat to EU-protected habitat, Vegetated Sea Cliffs (EU1230). Hottentot fig has a very dense fibrous root system concentrated in the upper 50cm of the soil, with new roots forming at each node as the plant spreads (D'Antonio and Mahall, 1991) and forming impenetrable mats over 50cm deep, which compete aggressively with native species (D'Antonio and Mahall, 1991 & D'Antonio, 1993). Once it becomes established, it shows a high vegetative reproduction rate, and its growth does not appear to be affected by herbivory or competition in California where it is also invasive (D'Antonio, 1993). In Ireland no herbivores other than rats gnawing on the seedpods have been observed by the author.

Taxon *Carpobrotus edulis* **(L) N.E. Br.**	**Family/Order Aizoaceae/Caryophyllales**
Common names (English only) Hottentot fig Freeway ice plant Cape fig **Synonyms** *Mesembryanthemum edule* L. *Mesembryanthemum acinaciformis* L. var. *flavum* **Short description** Succulent, trailing perennial, rooting at the nodes and forming large, dense mats. Leaves are opposite, 3-angled. Flowers are 8–10cm in diameter, large, solitary, yellow, pinkish or purple with numerous petals and stamens. In the Mediterranean *C. edulis* hybridises with *C. acinaciformis* forming a hybrid complex known as *C. affine acinaciformis*.	 Fig. 1 Hottentot fig flower. Photo: N. Smyth.  Fig. 2 Current known distribution of Hottentot fig (*Carpobrotus edulis*) in Ireland. Map courtesy of the National Biodiversity Data Centre, Waterford, Ireland.

Table 1 Hottentot fig background information.

BSBI vice-county code	Area in m² of Hottentot fig	Location
5	4,465m²	Near Roche's Point, Cork harbour 1978, 1985; still there 1999
6	1,750m² Not located Not located	Garrarus 2000, coastal cliffs Dungarvan 1974, X2793 Ballynamona X1677
12	Not located	T01Y, T10L
20	45m² 1,205m² Not located	The Murrough 1972, sparingly in a few places; the Breaches south of Kilcoole Station 1994, by railway north of Arklow 1972 Greystones harbour. Planted at back of harbour
21	55,255m² Not located Cleared by Birdwatch Ireland	Howth; south coast of Howth from west of Drumleck Point to Baily Lighthouse; extensively naturalised there 2001 Bull Island, 600m south of Visitor Centre Rockabill 1990
31	Not located	Coast south of Clogher Head mid-1990s
38	3,920m²	Cranfield by Carlingford Lough 1980, J269104, on sand Orlock Point, 1984, J555835, abundant on rocks by shore Near Annalong, J31U

Table 2 Detailed location information for Hottentot fig sites in Ireland from Reynolds, 2002 and Preston *et al.*, 2002.

The first record for Hottentot fig in the wild in Ireland is from Howth Head with an atlas record for 1962 (Perring & Walters, 1962) (Tables 1 & 2). A further 14 records occur in Ireland in counties Cork, Waterford, Wexford, Wicklow and Down (Table 2). The largest colonies (>150 × 50m) known in the Republic of Ireland are those on Howth Head.

Control of Hottentot fig pilot experiment

The largest area affected by Hottentot fig is on Howth Head in Ireland and lies within the Howth Head SAC (SAC 000202) so no experimental chemical treatments could be carried out during the nesting season, from March to September. Therefore pilot chemical treatment and native species recruitment experiments were carried out at an alternative coastal site in Wicklow at the Breaches (approximately 6km south of Greystones, Co. Wicklow) in 2009 (Smyth *et al.*, 2011). Tetrads of 1.5m × 1.5m (2.25m²) were each treated with one of the three herbicide products trialled (Table 3), two replicate tetrads for each of the three herbicide products trialled were set out.

Treatment code	Name of product	Active ingredient	Tetrads treated
W (white bottle)	B&Q Lawn Weedkiller	0.358g/l mecoprop-P and 0.191g/l dichlorprop-P soluble	W1 & W2
B (blue bottle)	Resolva Weedkiller 24H Action	3g/l glyphosate and 0.3g/l diquat	B1 & B2
G (green bottle)	Monsanto, Fast Action Roundup Weedkiller	7.2g/l glyphosate acid, present as 9.7g/l isopropylamine salt of glyphosate	G1 & G2

Table 3 Herbicides trialled for control of Hottentot fig.

The tetrads were marked using white pebbles, with a minimum distance of 1m between each tetrad. The spray was applied at high volume until all leaf surfaces were fully wetted. About 0.25l was used for the two tetrads of each treatment. Each herbicide had a different coloured bottle and was given a code letter according to that colour. The sequence of the three treatments was randomised between the two patches. The herbicides chosen were those that are readily available over the counter from the hardware store B&Q. The herbicide treatments were conducted in the evening of a still, dry day. No rain fell in the following 24 hours, and the herbicide was applied according to the manufacturer's instructions to prevent contamination of the surrounding habitat. A series of photographs of the tetrads were taken nine and thirty-seven days after each treatment was applied.

Results of pilot experimental chemical control on Hottentot Fig

Hottentot fig mortality[5] after 50 days ranged from 25 per cent with B&Q Lawn Weedkiller to 95 per cent with Resolva 24H Action (Table 4). Prior to the experiment it had been hoped that the B&Q Lawn Weedkiller, which kills only broadleaved plants, would be the most useful, because this would ensure the survival of native grasses found in the area such as *Festuca rubra* and *Dactylis glomerata*. Broadleaved lawn weedkillers are often recommended for the control of Hottentot fig (Kelly & Maguire, 2009). The results of this trial demonstrated that this might not be the case because it was the least effective in this experiment. Full results of the different herbicides used are listed in Table 4.

Actions following the pilot experiment

All known sites where Hottentot fig is invasive in the Republic of Ireland were surveyed, measured and chemically treated during the period 2010–2012. Special permission was granted from National Parks and Wildlife Services to use chemicals in SACs once the pilot experiment had shown the treatment to be effective with little or no damage to

5. Plants with no growing shoots were considered to be dead.

Treatment code	Name of product	Active ingredient	Hottentot fig % mortality
W (white bottle)	B&Q Lawn Weedkiller	0.358g/l mecoprop-P and 0.191g/l dichlorprop-P soluble	25%
B (blue bottle)	Resolva Weedkiller 24H Action	3 g/l glyphosate and 0.3g/l diquat	95%
G (green bottle)	Monsanto, Fast Action Roundup Weedkiller	7.2g/l glyphosate acid, present as 9.7g/l isopropylamine salt of glyphosate	75%

Table 4 Hottentot fig mortality 50 days after herbicide treatment.

wildlife or surrounding native vegetation. The chemical was applied carefully to avoid birds, insects and native plants during the nesting season. For each site a management plan was drawn up using the template found in Kelly & Maguire (2009). One of the authors (Andy Booth) was contracted and between two and ten volunteers per site were recruited to refill sprayers, inform the public, measure stands and make morphological measurements of leaves, flowers and fruits prior to chemical treatment. The chemical was applied during early March and early September. A power sprayer on wheels (with a 120-l tank and a petrol motor) was used, which was easily wheeled to access points along sea cliff paths, and the 30m hose extension to the tank meant that operators could access the areas where the plant was growing without having to wear a cumbersome knapsack sprayer. At sites where it was safe for operators to do so, 10-l knapsack sprayers were used. A chemical mix of Resolva (3g/l glyphosate and 0.3g/l diquat) was mixed on site.

The total area treated amounted to 66,640m^2 (or 6.664ha). The total Heritage Council grant awarded to the project was €25,000 (£21,000), which worked out at a cost of 37 cents (31 pence) per m^2 treated. Commercial invasive species control projects can cost in the region of £50–£200 per m^2 (Williams *et al.*, 2010). These costs depend on whether the invasive species has to be dealt with as hazardous waste following chemical or physical treatment or whether it can be just sent to landfill. The main advantage of carrying out the pilot research and using botanic garden staff to implement the work is that the researcher costs are zero and the volunteer network associated with the botanic garden can be accessed, which means that sites can be treated without incurring labour charges. The advantage of using chemical control is that no physical removal of material was required once Hottentot fig stems were dead. The main costs of the project were in the transport of staff, contractor fees, spraying equipment and the purchase of chemical and safety equipment.

Along the treated sites at Howth Head the leaf litter which remained after treatment was found to vary from 1cm to 20cm in depth with an average pH of 6.4 and average organic matter content of 16.4 per cent. This differed, though not significantly, from the surrounding soil pH of 7.5 and organic matter content of 12.2 per cent. The depth

Fig. 3 *Crithmum maritimum* (rock samphire) re-establishing among the dead Hottentot fig stems. Photo: N. Smyth.

and pH of the leaf litter remaining was not, however, found to adversely affect native species regeneration (Murray, 2013). In less than a year, native plants were re-establishing themselves from among the dead Hottentot fig stems, which is a rapid vegetation response. On Howth Head extensive populations of rare species such as *Inula crithmoides* (golden samphire) and *Crithmum maritimum* (rock samphire) have been observed (Figs 3 & 4). Currently some 50 per cent of the all treated sites have been revegetated in this way.

Fig. 4 *Inula crithmoides* (golden samphire) re-establishing amongst the dead Hottentot fig stem. Photo: N. Smyth.

INVASIVE NON-NATIVE SPECIES MANAGEMENT CASE STUDY 2: GIANT RHUBARB (*GUNNERA TINCTORIA*)

Giant rhubarb (*Gunnera tinctoria*) is an INNS on the west coast of Ireland. It is having a significant impact on the native vegetation of Achill Island, County Mayo, where it has spread throughout the peninsula and through Connemara and much of the west of Ireland (Sheehy-Skeffington & Hall, 2011) (Table 5). It was originally planted as an ornamental garden plant and the first records of it in the wild in Ireland date back to 1939 (Praeger in Reynolds, 2002) though it was recorded originally as *Gunnera manicata* in error. Its native range is in southern Chile, where climatic conditions are similar to those found on the west coast of Ireland. Both experience high annual rainfall with temperatures rarely falling below 0°C. In Ireland it is found in a range of habitats on coastal cliffs, waterways, roadsides, wet meadows and derelict gardens and fields. The negative effect of giant rhubarb on semi-natural grassland habitats has been studied by Hickey & Osborne (1999). It propagates both by seed and by vegetative means. In early spring its leaves begin to grow and in a couple of weeks it can reach over 2m in height. Its large leaves (up to 2m wide) shade all plants growing below. In the winter the leaves die back leaving the exposed rhizomes (Table 5).

BSBI vice-county code	Location
1	Valencia Island 1994, by coast road south of Knightstown
3	Durrus 1979; Bantry, Castletownberehaven and Glengarriff area 1989; near Rosscarberry 1993; Bere (Bear) Island, roadsides; Whiddy Island, extensively naturalised on low sea cliffs 1997
6	Cappoquin 2001, two plants by river, discarded or possibly planted
10	Shore of Lough Derg near Waterloo Lodge 1972
16	Near Leenane mid-1930s; seedlings above Leenane Hotel 1957. Abundantly naturalised in much of north and west Connemara
21	Howth 1991, in wet birch grove
27	Near Leenane mid-1930s and Curraun Achill Island Bangor Erris 1957; Clare Island 1968, also 1984; north-west of Leenane 1973. Serious weed of damp pastures in south-east part of Achill Island. Achill Beg. Clare Island.
28	Lissadell estate; Ballyconnell, roadside.
34	Carrick 1989, near Glen River.
38–40	Frequently planted by streams in estates and large gardens, and often almost naturalised.

Table 6 Detailed location information for giant rhubarb in Ireland (Reynolds, 2002 and Preston *et al.*, 2002).

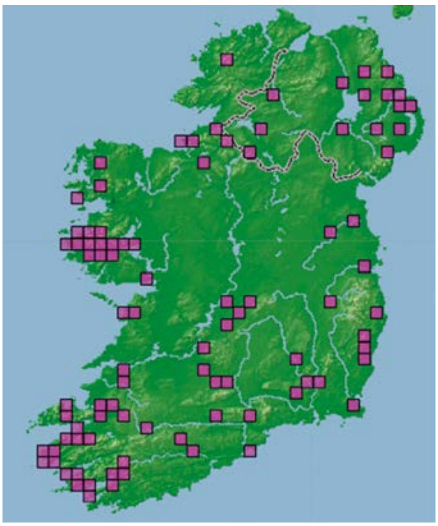
Taxon	Family/Order
Gunnera tinctoria (Molina) Mirb.	Gunneraceae/Gunnerales
Common names (English only) Giant rhubarb **Synonyms** *Gunnera chilensis* *Panke tinctoria* **Short description** *G. tinctoria* is a large herbaceous perennial which can grow up to 2m tall, with leaves of up to 2m in diameter. It is a rhizomatous plant and the rhizomes of mature plants can be up to 2m long growing above ground. It is deciduous, with leaves dying off in autumn (October) leaving the large brown rhizomes exposed. Growth starts in early spring (March). It can reproduce by both sexual (seed) and asexual (vegetative) means. Inflorescence development occurs early in the spring, with the fruits maturing in late summer/ early autumn. Large numbers (up to 250,000) of drupe-like red or orange seeds are produced. Small fragments of the rhizome have the potential to establish new plants. **Distribution in Ireland**  Fig. 7 Current known distribution of *Gunnera tinctoria* in Ireland. Map courtesy of the National Biodiversity Data Centre, Waterford, Ireland.	 Fig. 5 Close-up of the seeding spike of giant rhubarb (*G. tinctoria*). Photo: C. Armstrong.  Fig. 6 A field full of giant rhubarb (*G. tinctoria*) on Achill Island, Co. Mayo. Photo: C. Armstrong.

Table 5 Giant rhubarb background information.

Control of giant rhubarb pilot experiment

Experiments were carried out in the greenhouse (Fig. 8) and field (Table 7) to determine the most suitable product, method and timing of chemical application for control of giant rhubarb by Armstrong (2009). Greenhouse trials of two herbicides, triclopyr (Garlon) and glyphosate (Roundup), showed both to be equally effective in killing it. Triclopyr (Garlon) is rapidly absorbed by the foliage and roots and translocated throughout the plant. However, it is water-soluble and persistent in soil, and constitutes a larger risk to groundwater. Given its mobility in soil and the high rainfall in the west of Ireland it was decided not to use triclopyr (Garlon) in the field trials given the high risk of groundwater contamination**.** Glyphosate (Roundup) was deemed less toxic to the environment and also more cost-effective. The initial field trials on Achill Island suggested that application of herbicide was most effective late in the growing season (late August to early September) by direct application to cuts made on the stems or on leaf stalks after cutting back the leaves (Armstrong, 2009). Glyphosate has also been used extensively in New Zealand for giant rhubarb control and has been found to be effective using high-volume foliar spray (Law, 2003). After treatment, some rhizomes can take up to 18 months to decay. Sub-lethal doses of herbicide have resulted in multi-headed regrowths capable of producing even more seeding spikes. Follow-up applications are required to control regrowth and subsequent seedling germination (Armstrong, 2009).

Fig. 8 Giant rhubarb 15 days after application of glyphosate (Roundup) as a high-volume spray.

The results of the field trial on Achill Island after application of Roundup showed a mortality rate of >90 per cent. However, two years later some resprouting had occurred and in 2008 there was evidence of regrowth, with the mortality rates decreasing to ~60 per cent. The reason for not having 100 per cent mortality in the field trials was probably due to the increased size of the plants compared to those used in the greenhouses. Another disadvantage of using glyphosate alone in the west of Ireland is the high level of rainfall. Very often it begins to rain during the necessary six hours' drying time, which means that a lot of the chemical is washed off.

In 2008, two of the authors (C. Armstrong & N. Smyth) from the National Botanic Gardens, Glasnevin visited Clare Island, a small island off the west coast of Mayo, for the first time and found giant rhubarb to be widespread near the harbour and in damp fields. Clare Island is listed as an SAC and is also unique among Irish islands in that a full survey of the island was carried out in 1909 and 1911 (Royal Irish Academy, 1911–1915). Many important EU annexed habitats also occur on the island. A large group of volunteers visited the island to record and to physically and chemically treat giant rhubarb in 2009 (Armstrong, 2009).

A follow-up monitoring visit in 2011 by Smyth and Booth found additional large stands of giant rhubarb on sea cliffs and high sea cliffs around the island (Figs 9 & 10 and Table 8). On the upper section of sea cliffs, there is species-rich alpine vegetation that includes a number of rare and Red Data Book species such as moss campion (*Silene acaulis*), alpine saw-wort (*Saussurea alpina*), saxifrage (*Saxifraga oppositifolia*), fern (*Polystichum lonchitis*), heath cudweed (*Omalotheca sylvatica*) and sea pea (*Lathyrus japonicus*). The cliffs on Clare Island also support important colonies of breeding seabirds, especially one of the largest colonies of fulmar (2,555 pairs) and an embryonic gannet colony (1 or 2 pairs), which is the most northerly in Ireland (NPWS, 2006). In July 2012, the team returned to the cliffs on Clare Island and carried out a full survey of the entire coastline of the island by boat. Giant rhubarb was found on eight coastal cliff locations around the island. Locations 1–6 (Fig. 9 & Table 8) were treated with the high-volume spray of Resolva and locations 7 and 8, which are severely infested, still need further treatments.

Given the inclement weather during visits, Resolva was used instead of Roundup, which allowed for greatly reduced drying time in cliff sites treated. Resolva was also found to be a more potent herbicide mix, or 'kill cocktail', on giant rhubarb with >95 per

Treatment code	Chemical name	Active ingredient	Giant rhubarb % mortality
G	Garlon	triclopyr	90%
R	Resolva Weedkiller 24H Action,	3 g/l glyphosate and 0.3g/l diquat	95%
G	Monsanto, Fast Action Roundup Weedkiller	7.2 g/l glyphosate acid, present as 9.7 g/l isopropylamine salt of glyphosate	90%

Table 7 Giant rhubarb mortality 50 days after herbicide treatment.

Fig. 9 Giant rhubarb on sea cliffs and high sea cliffs around Clare Island; Ronan Lenihan of the Adventure Agency setting up ropes for the cliff survey. Photo N. Smyth.

Giant rhubarb on coastal cliffs on Clare Island	Irish grid ref.	Size of population	Treated with herbicide
1. Small harbour	L697 843	10 × 10m^2	July 2012
2. Gravel bank	L712 847	3 × 12m^2	July 2012
3. Waterfall from hills	L713 848	10 × 10m^2	July 2012
4. Behind castle	L715 851	10 × 10m^2	July 2012
5. Strand to Kinacorra Head	L713 853 – L720 859	20 mature plants and >50 seedlings scattered on cliffs and beach	July 2012
6 Harbour close to Ballytoohy	L703 874	3 large patches 5 × 5m^2	July 2012
7 Shale Gully	L682 867	150 × 50m	August 2011
8 North Cliffs (picture below)	L675 866 – L680 867	600 × 300m	150 × 500m July 2012

Table 8 Giant rhubarb on sea cliffs and high sea cliffs around Clare Island.

Fig. 10 Giant rhubarb growing on the Atlantic sea cliffs of Clare Island. Photo. N. Smyth.

cent mortality recorded after the first year with little or no regeneration (0–5 per cent). However, one year later, in 2012, plants with larger rhizomes were found with living tissue and will have to be retreated.

CONCLUSION

These two invasive non-native species hail from different parts of the world and have very different growth forms and survival strategies. They occupy sea cliffs in different parts of Ireland, and both species form dense colonies that suppress native vegetation. Results from efforts to control both species show a >95 per cent kill rate with the treatments applied and <50 per cent regeneration of native species. Given the history of botanic gardens in horticultural excellence and the experience in scientific recording often found there, there could be a new role of 'gardening the wild' for botanic gardens, where they can provide solid advice and best practice identified by pilot experiments. In order to control those species that have 'jumped the garden fence' and become weeds this role would be a welcome one. The authors suggest that botanic gardens could take on this new role which could help to fulfil many of our current obligations and aspirations under National and Global Strategies for Plant Conservation and also help alleviate some of the damage ornamental introductions have caused to the natural environment.

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