MANAGING THE THREAT OF INVASIVE PLANT SPECIES TO IRELAND'S NATIVE WOODLANDS

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Introduction

In recent years invasive species have been recognised as a major threat to biodiversity and to the long-term future of some semi-natural habitats (Anon., 2002). Invasion by *Rhododendron ponticum* L. has been identified as one of the most serious issues affecting native woodland conservation in Ireland (Neff, 1974; Quirke, 2000). Where management plans based on critical ecological and site specific factors have been applied, rhododendron control has been successful (Barron, 2000). By taking a similar approach, strategies may be developed for the control of other invasive species. In a native Irish woodland context there are several such species that spring to mind, e.g. laurel (*Prunus laurocerasus*), snowberry (*Symphoricarpos albus*), red osier dogwood (*Cornus sericea*), beech (*Fagus sylvatica*), sycamore (*Acer pseudoplatanus*), western hemlock (*Tsuga heterophylla*). Each of these is undoubtedly 'invasive' in some sites and under some conditions. However, further information about the extent of these and their impact on Irish woodland is needed, and the National Native Woodland Survey (see Martin *et al*., this volume) will contribute greatly to this. This paper outlines the aspects of Rhododendron ecology that underlie its successful management and uses data from published sources to propose control strategies for a selection of other invasive species.
Nomenclature for angiosperms follows that of Preston *et al*. (2002).

Managing Rhododendron Ponticum
Aspects of rhododendron ecology relevant to its management

The ecology of rhododendron and the history of its introduction to the British Isles are described by Cross (1975, 1981) and its deleterious impact on native habitats is well documented (Cross, 1982; Kelly, 1981; Hayes *et al.,* 1991, Gritten, 1992; Jones, 1972). Rhododendron is a shade-tolerant member of the Ericacaea and thrives on acid soils and in areas of moist, mild climates (Cross, 1975). It is frequently naturalised close to areas of former planting and has the potential for invasion of heath, bog and woodlands over suitable substrates. Rhododendron exhibits prolific seed production, typically flowering annually from 10-12 years onwards. Each flower head can produce up to 5,000 seeds per annum, with seeds being cast from the seed pod between December and March. The majority of seed is usually dispersed within tens of metres of the parent plant but a proportion of the seed may travel farther by wind, water, and other vectors. While light is required for germination, quite low levels (2-5% daylight) are sufficient (Cross, 1973) and germination is frequently successful below an oak/holly canopy. Seedling establishment is relatively high where suitable seed beds such as bare soil and mossy carpets are abundant. While the seeds are not thought to form a persistent seed bank (Cross, 1973), observation suggests that some proportion may survive for up to two years (C. Barron, *Pers. Comm*.). Young plants of rhododendron have a considerable competitive edge over native trees and shrubs in that they are poisonous and avoided by grazers, and in grazed sites where there is a seed source and suitable seed bed rhododendron tends to replace the native shrub layer. Rhododendron regrows vigorously when cut, and the resulting regrowth can produce flowers within 1-2 years (although more usually in 3-4 years). The thick, waxy cuticles of the foliage render it relatively resilient to foliar herbicides and its multi-stemmed growth habit further complicates treatment as herbicide does not translocate laterally.

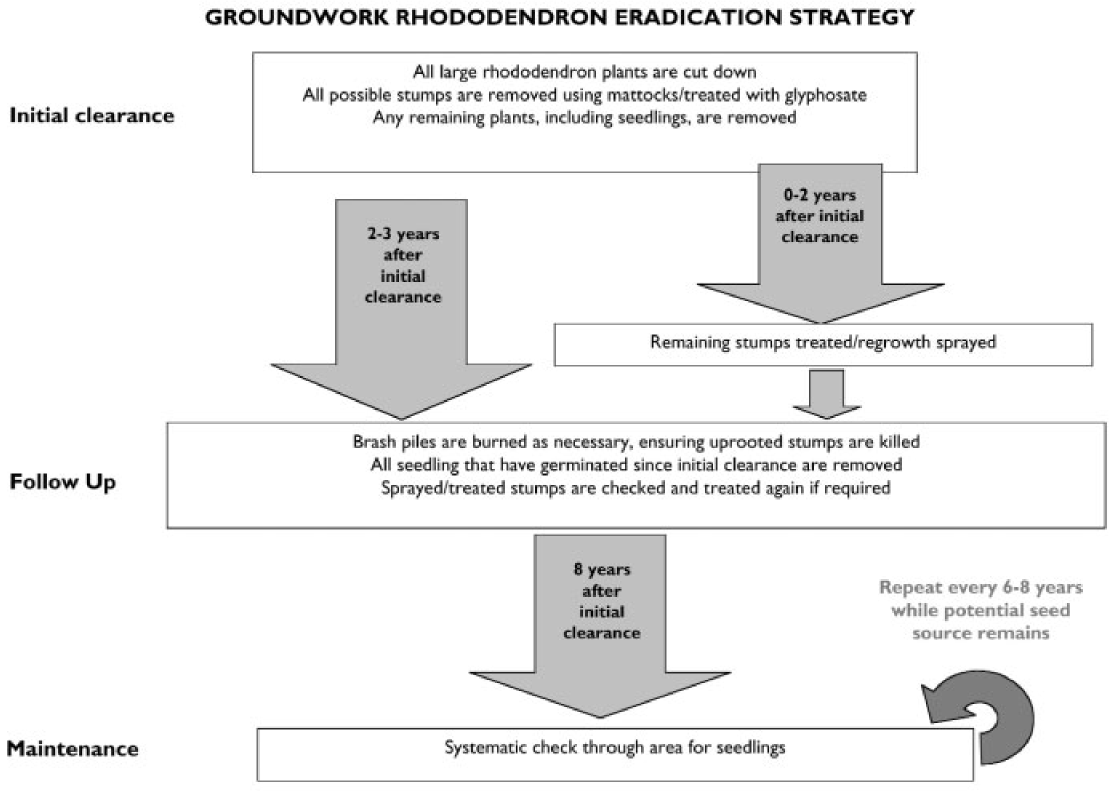

Figure 1. *Work Schedule for Rhododendron Control adopted by GROUNDWORK. Work is timed to ensure that once initial clearance has been carried out, seed production is not allowed within the cleared area.*

Rhododendron control

In vulnerable sites (with acid soils, high rainfall or humidity and abundant seed bed, e.g. heavily grazed sites) rhododendron control must be very vigorous and thorough. If *any* seed source is allowed to remain, then ongoing monitoring and seedling removal will be required *indefinitely*. The primary objective of a management plan should be to prevent seed production in an area once initial clearance has been undertaken. If it is possible, i.e. where the infested area is small or isolated or resources are unlimited, all seed sources should be eliminated first, and subsequent management must then be timed so that no plant is allowed to reach seed bearing age. In many cases, however, this will not be possible and areas will need to be prioritised for clearance. In complicated sites with varying degrees of infestation, it may be most beneficial to tackle areas of light infestation first, thereby achieving control in areas that still retain good native flora. The use of buffer zones and working with the prevailing wind will reduce reinfestation from wind blown seed. Grazing levels in cleared areas should be such that native vegetation can recover quickly, eliminating suitable sites for rhododendron germination and reducing reinfestation. Only rarely, either at the early stages of invasion, or when a very small number of plants are involved, can rhododendron management be carried out in a single work period. Usually several work phases are required. These are outlined below.

1. Initial Clearance - Removal of plants and killing of rootstock

Small to medium sized plants can be pulled or dug out of the ground intact. These must be disposed of in some way that ensures the plant is killed, as uprooted saplings left lying on the damp woodland floor are capable of re-rooting. Effort must be made to remove as much of the rootstock as possible as plants snapped off at ground level will grow back. Large plants should be removed by cutting the branches and dealing with the brash appropriately. While brash piles can increase habitat diversity, it must be borne in mind that access to the area for follow up work is vital for the management of rhododendron to be successful. Stumps may be dealt with by uprooting or by direct stump treatment (with 20% glyphosate within an hour of cutting and with dry conditions for 6-8 hours after application) or spraying of regrowth (20% glyphosate with surfactant, in dry conditions persisting for 24 hours after application, 1 to 3 years after cutting). Either of the first two options is preferable as they are easier to carry out and usually more effective.

2. Follow Up – Quality Control of Initial Clearance Work

In order to ensure success of initial clearance and to remove smaller plants that were missed or have established since initial clearance, systematic checking of the area is required. This should be within 2 years of initial clearance, as stumps that were not killed properly are capable of flowering in that time period.

3. Maintenance – Dealing with reinfestation such that seed production is prevented

Subsequent visits will be required approximately every 8 years to ensure that any newly established plants do not get the opportunity to flower or set seed. If seed input has been minimized, the number of saplings found should decrease with each visit.

The principles outlined above have been used as the basis for the management of rhododendron within parts of the Killarney National Park by GROUNDWORK volunteers since 1981. The work schedule used is illustrated in Fig. 1. More than 370ha have been cleared to date and are maintained clear by the method described above.

General principles for invasive species management

Experience with rhododendron has demonstrated that the management of any invasive species must be well planned before action is taken. In some sites it will be desirable to completely eliminate the problem species, while in others it may be more realistic to contain the spread of such species, or to accept their presence within defined limits. Whatever the specific target set for invasive species management, there are some general principles which, if applied, will assist in the most cost-efficient and effective management being achieved.

1. Prevention is better than cure. With many invasive species, invasion is exponential (Pysek & Prach, 1993) whereby initial colonisation is slow, and then accelerates rapidly after a certain 'critical mass' has been achieved. If the invasion can be controlled before this point, time and money will be saved and the negative impacts of the invasion on the woodland ecosystem can be averted rather than corrected later.

2. Know thy enemy. By understanding the ecology (especially reproductive ecology) of a species it is possible to predict how it will react to management within a site, thus allowing managers to maximise their return on limited financial resources. Lessons learned from some of the 'older' invasions can be used to identify important questions to ask about new invasions, the answers to which are very important in devising an appropriate management plan. Important questions that must be asked about any invasive plant species include:

- Where does the species grow/invade/potentially invade?
- How does the species invade? What is the timescale involved? What is the potential dispersal area?
- What are the site factors that facilitate/hinder its establishment?
- What management allows/promotes increase in spread?
- How can mature plants be killed?
- How does the species respond to cutting (timing, type)?
- Are there requirements for dealing with brash/litter?
- Is reinfestation an issue?

3. Look before you leap. When conservation is the primary objective, it is vital to take a holistic approach to woodland management. Certain operations that may have no direct link to invasive species may, however, have a large impact on the behaviour of such species. For example, increasing grazing pressure will create germination sites for rhododendron, thereby facilitating its spread. Similarly, removal of canopy trees will increase light levels and may allow for the rapid expansion of snowberry.

Selected invasive species and guidelines for their management

Beech (Fagus sylvatica L.)

Introduced from Europe and southern England, beech has been widely planted into woodland and parkland during recent centuries. Beech casts and tolerates deep shade, is relatively unpalatable to grazing herbivores and produces a deep, persistent leaf litter, all of which contribute to it being a very successful competitor with our native long-lived canopy species such as oak (Sydes & Grime, 1982). Beech is associated with lower plant diversity and also with a reduction in natural regeneration of native tree species (Higgins *et al*., 2004). It is widely naturalised in Irish woods, especially oak-birch-holly woods (WN1- Fossitt, 2000), and oak-ash-hazel woods (WN2 – Fossitt, 2000). In the first phase of field survey for the National Native Woodland Survey, beech was found to be present at 72% of sites (n = 215) and was deemed frequent, abundant or dominant in the canopy of 46% of sites (Higgins *et al*. 2004). In some sites, there is a clear trend of beech replacing native trees in the canopy (Quinn, 1994; Dierschke, 1982).

Sycamore (Acer pseudoplatanus L.)

Sycamore was introduced to the British Isles from mainland Europe prior to 1500, and has been widely planted since the 18th century. Sycamore is fast-growing and is a popular broadleaved timber species (Joyce, 1998). Additionally, being very tolerant of exposure and salt, it is often planted as a shelter species. Sycamore requires relatively well aerated, deep soils, and is abundant over limestone, but also found on sands & podzols (Jones, 1944). It is widely naturalised in Irish woods, particularly oak-ash woods and base rich wet woodland. In the first phase of field survey for the National Native Woodland Survey, sycamore was found to be present at 76% of sites (n = 215) and was deemed frequent, abundant or dominant in 26% of sites (Higgins *et al.,* 2004). It is a strong competitor with native tree species, and can form a mono-culture, reducing canopy diversity.

Table 1. *Reproductive biology of three invasive tree species.*

	Seed Production	Seed Dispersal	Seed Longevity in the field	Establishment Requirements
Beech	From 40-50 yrs, mast crops 5-10 yrs	Poor	None	Tolerates shade & field layer, Needs moisture
Sycamore	From 20-30 yrs	Poor (within 85m of source)	None	Tolerates shade & field layer
Sitka Spruce	From 20-25 yrs, mast crops 4-5 yrs	Poor (within 80m of source)	None	Need open conditions – no litter/field layer

Sitka Spruce (Picea sitchensis (Bong.) Carr.

Sitka spruce was widely and abundantly planted in the last century for timber production throughout the country but especially in upland areas. This North American species regenerates freely into adjacent semi-natural woodland and in clear fell areas (von Ow, 1996). It establishes very well on poor soils, particularly peats, and is a particular problem to managers attempting to re-establish native woodland on former spruce plantation sites.

Managing invasive tree species

The removal of invasive tree species is relatively straightforward. Individuals should be felled, taking into account the conservation value of the site. The maximum amount of dead wood should be left to add to habitat diversity (see Cotton, this volume). By ring-barking some trees, standing dead wood will develop. Some very old, veteran trees that have good wildlife value could be left on the site, as long as regeneration from seed is dealt with. Felling is best carried out selectively or in small coupes (~0.5 ha) to create canopy gap rather than clear fell conditions. Felling during the winter months can have fewer negative impacts on wildlife (Murphy, 1997), but care should be taken to avoid disturbing roosting bats and hibernating mammals. Conifer stumps will not show regrowth after cutting, but sycamore and (younger) beech stems may require treatment with chemicals (e.g. 20% glyphosate applied directly to stump within 1 hour of cutting). Regeneration should not be allowed to achieve maturity and become a new seed source. Seedlings are best dealt with after the natural mortality associated with juveniles has levelled off, but while the plants are still small enough to be handled easily and before they mature and set seed. The timescales involved are outlined for some species in Table 1. If seed producing trees are being left near the area managed, e.g. veterans/adjacent stands, managers should be aware of the dispersal area surrounding that source and use either a buffer zone system or regular seedling control to prevent reinfestation.

Red osier dogwood (Cornus sericea L.)

Red osier dogwood is a deciduous shrub, native to eastern North America which, because of its attractive red shoots and white berries has been planted for ornament in parks and demesnes throughout Ireland (Kelly, 1990) and more recently on roadsides. It is found mainly on lowland sites with varying degrees of water logging, and has been described as *'an aggressive invader of natural and semi-natural wetland habitats'* (Kelly *op cit*) along lakeshores and within riparian woodland (Cross & Kelly, 2003). Single plants of the species can grow to 4 metres in height and expand by layering to form extensive thickets, casting summer shade, thus reducing species richness and inhibiting tree regeneration. However, seed production and seedling establishment appear to be uncommon in Ireland and so dispersal of this species from the original area of planting is rare, and may result from rooting of detached fragments that have been transported by water (Kelly *op. cit*). Control by burning has proven to be ineffective in some studies in North America (Middleton, 2002) and it is likely that cutting followed by careful herbicide application (in line with recommendations for use of herbicides near water) will be the most effective method of removing established thickets of this plant.

Snowberry (Symphoricarpos albus L.)

Snowberry is a deciduous shrub, growing to 3 metres in height, and was introduced to Britain from northwest America in 1817 for cover and ornament (Gilbert, 1995). It occurs on well-drained, moist, fertile soils, and forms dense thickets by means of shallow, woody suckers (Gilbert, 1995). Where these thickets are found within woodland they are usually the result of initial planting for game cover and expansion of the thicket is slow under conditions of shade. Thickets cast deep shade that strongly suppresses the field layer below, including tree seedlings. While snowberry flowers and produces white berries annually, there has been no evidence of seed viability found in the British Isles to date: however snowberry spreads easily by seed in Germany (Gilbert, 1995) and the impact of future climate change on the plant's behaviour in Ireland is as yet unknown. Expansion of existing thickets occurs very rapidly on release from shade and this would appear to be the most likely mechanism of invasion in Irish woodland habitats. Snowberry responds to coppicing with vigorous regrowth (Gilbert, 1995) and requires herbicidal control if it is to be effectively removed (Fryer & Makepeace, 1978).

Japanese Knotweed (Fallopia japonica Houtt.)

Although it is a herb rather than a shrub, Japanese knotweed is included here because the impacts of its invasion have been widely publicised and are the subject of much debate. Although it is best documented in Britain, it clearly has the potential for invasion of semi-natural habitats in Ireland. It was introduced to Britain from Japan for ornament in the 19th century. It is a perennial herb which forms large clumps 1 to 3 meters high. Its growth is vigorous and it can grow 3 meters in 12 weeks. Japanese knotweed tolerates a wide range of soil types, but requires high light levels (Palmer, 1990). While the plant undoubtedly causes much structural damage and swamps large tracts of riverbank resulting in habitat loss and erosion, its extent and impact on Irish riparian woodland requires clarification. Control of this plant is difficult. While it does not spread by seed, fragments of the parent plant transported by water or in soil readily results in establishment of new thickets. Because of this, clearance of the plant by manual methods (strimming, flailing, cutting) must be carried out with great care as even very small fragments (down to 0.7g in weight) can give rise to new plants. Any waste that contains Japanese knotweed must be treated with care as there is potential for spread into new sites. Even after removal of shoots, the rhizome system below remains and so full eradication of the plant requires that this be targeted. Research into effective control methods is ongoing. Injection of hollow stems with glyphosate and biological control methods are showing some promise (Shaw & Seiger, 2002).

Conclusions

The management of invasive species is a challenge that will continue to face managers of Irish native woodlands. It is an issue that cannot be tackled in isolation: consideration of the relationship between invasive species and woodland processes, particularly grazing and light regime, is vital for effective management. Attitudes towards invasive species and the resultant policy adopted will vary greatly between sites, depending on local conditions. Some species, e.g. rhododendron, have such a dramatic negative effect on vulnerable sites that they are unlikely to be tolerated in sites designated for conservation. On the other hand, species like beech and sycamore may be tolerated at certain levels in some sites. However, I feel strongly that where the opportunity exists to maintain some sites as wholly 'native' then this should be the objective. We will be in a much better position to make policy decisions such as these once baseline data regarding the extent and condition of our native woodland and the abundance of invasive species are available. It is clear that the ecology of each species must be considered when formulating a control policy. The dissemination of the results of different control attempts among policy makers will increase the success and efficiency of management. While general guidelines should be developed for each invasive species, these must always be applied on a site by site basis and time spent planning management will increase efficiency in the long term.

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Table 2 shows the astonishing array of services provided by forests and other ecosystems, many of which are often taken for granted. Until recently, it has been common practise to value only those services that can be sold through the marketplace, i.e. the products. These are classified with a 'D' for direct pricing in the table above. The limitation of this type of valuing is that many contributions of natural ecosystems are sold indirectly, such as a landscape that attracts tourists, or represent benefits which accrue to the general population, such as flood prevention. In these cases, estimating the cost of replacing the function is the only way to assign a financial value. There are currently movements both to expand the valuation of services beyond the traditional marketplace valuation (see Alcamo *et al*., 2003) and to acknowledge the growing interest in the purchase of previously non-market services (see Pukkala, 2002 and http://www.forest-trends.org/whoweare/pdf/bc2000/bc2000_proceedings2.pdf). This means that consideration of what NTFP could be harvested from Irish woodlands may include broader, indirect services, such as maintenance of the diversity of life.

A broad range of ecosystem services should always be kept in mind with regard to NTFP in Ireland. Cultural services, such as education, heritage, and artistic inspiration, are important services of nature. Medieval Irish nature poetry abounds with examples of artistic and spiritual inspiration from ecological processes:

> *The music of the woodlands is like the playing of harps; the melody brings perfect peace; a haze rises from every hill-fortress, a mist from the full-pooled lake.*
> *(Old Irish poem dated at around the 7th century, trans. Carney 1971 quoted in Smyth 1996: 308-9; see also poems in Jackson 1935).*

Another example of the cultural significance of natural processes in the past in Ireland is auguring: an early lawgiver describes how a just king brings benefits to his people, including a good crop of tree fruits, fertile women and crops, full milk in the cows, many fish in the rivers, and peace in the country; an unjust king brings catastrophe such as defeat in war and famine on the people of his nation (Kelly, 1997; MacNiocaill, 1988). In the 12th century, Connaught leader Rory O'Connor was supported in his bid to become high king, at least in part because omens of good fortune were seen in the abundance of nuts and other things created by God in 1168 (Ó Cróinín, 1995).

Although these support and cultural functions may arguably be the most important services provided by ecosystems, owners are more likely to consider direct products that can be sold in the marketplace. One way to consider these is to look at what products were derived from Irish woodlands in the past.

Products – direct harvest in the past

Food, medicine, dyes, and fibres from woodlands were used in the past in Ireland, and this may give some indication of potential NTFP today. For example, wild garlic (*Allium ursinum*) was a common food, and an annual garlic feast in the early spring, consisting of wild garlic with cheese and milk was part of the rent given to the lord (Kelly, 1997: 309). Other food plants were pignut (*Conopodium majus*; the tuber is what is eaten), nettle (*Urtica dioica*), and sorrel (probably *Oxalis acetosella*), although the last two were eaten primarily when other food was not available (Kelly, 1997). Hazelnuts (*Corylus avellana*), which can be kept over the winter, were sold, while acorns (*Quercus* sp.) may have been eaten when other food was hard to get (Kelly, 1997). A wide variety of woodland fruits were collected for food, including cherry (*Prunus avium*), rowan berries (*Sorbus aucuparia*), crab apples (*Malus sylvestris*), elderberry (*Sambucus nigra*), hawthorn berries (*Crataegus monogyna*), sloes (*Prunus spinosa*), rose hips (*Rosa* sp.), blackberry (*Rubus fruticosus* agg.), bilberries (*Vaccinium myrtillus*), and strawberries (*Fragaria vesca*; Kelly, 1997). Apples were highly valued, as they provided a source of vitamins during the winter, and the wild plant was brought into cultivation by the 8th century (Kelly, 1997). Bilberry (*Vaccinium myrtillus*) was found in Dublin excavations of Viking and Anglo-Norman times, while Irish language documents show that it was considered so valuable that it was included in the gifts presented to kings (Kelly, 1997). An 18th century physician noted that many plants were sold on the streets of Dublin for medicine, including bilberries, and also royal fern (*Osmunda regalis*) for obstructions of the liver (Nelson, 1991). Many of these products are still in use today. For example, herbal treatments including hawthorn, birch leaves, and nettle can be found on the shelves of many contemporary Irish herb shops.

Woodland plants were not only used as human food but also to feed domestic animals. Fodder plants included elm (*Ulmus* sp.) and holly (*Ilex aquifolium*), which was used in winter and scorched to remove the prickles (Kelly, 1997; Neeson, 1991; Lamb & Bowe, 1995). Other NTFP included the production of game and domestic stock: pigs (but not cattle) were grazed in medieval Irish woodlands with acorns being a prime pig-feed, and some birds found in or near woodland were hunted, including woodcock, snipe, wild duck, red grouse, and wild goose (Kelly, 1997).

Plants were also used for fibre and dyes. Bracken (*Pteridium aquilinum*) was used for making soap, bedding, and bleaching linen (Neeson, 1991), while elm bark was used to make ropes (Kelly, 1997). Pine resin was used for caulking boats (Kelly,1997; Neeson, 1991). Although social norms dictated the colours people could wear, plants provided the colours: bracken for a yellowish green, lady's bedstraw (*Galium verum*) for grey, and juniper (*Juniperus communis*) for brown (Kelly, 1997).

NTFP in the temperate zone today

Another way to explore possible non-timber products from Irish woodlands is to look at products currently being extracted from other temperate forests. Ciesla (2002) reports many different types of NTFP in use in temperate Europe, mostly for food and drink, including:

- beer, wine, spirit and vinegar made from birch sap (*Betula* sp.),
- jam and cider from the red berries of the whitebeam and rowan genus (*Sorbus* spp.),
- preserves, wines, salad dressings, and desserts from hawthorn berries (*Crataegus mongyna*),
- wine, pie, lemonade and herbal teas made from elderberries (*Sambucus nigra*)
- jelly and liqueurs made from the fruit of the strawberry tree (*Arbutus unedo*) in the Mediterranean region,
- coffee substitute and food from the acorns of the pedunculate oak (*Quercus robur*),
- oil for cooking, coffee substitute, and fodder for pigs from the nuts of the beech tree (*Fagus sylvatica*),
- nuts, nut chocolate, flour for bread, and edible and industrial grade oil from the hazelnut tree (*Corylus avellana*), and
- edible mushrooms including truffles (*Tuber melanosporum*, *T. magnatum* and *T. aestivum*) and morels (*Morchella* spp.).

Considering the range of NTFP produced in the past in Ireland and those which are still being harvested from temperate forests, what can we conclude? The potential NTFP for Ireland today are luxury items, like wild forest mushrooms or ornaments which remind us of either the relaxation from being in nature or the inspiration one can find in natural forms. Possible products include mushrooms and herbs, ferns and holly for decorations, bryophytes and lichens for floral arrangements, and cloth dyes from plants and lichens. Additional products might be identified by considering the broad list of forest functions listed by De Groot (1992), including ornaments, energy and raw materials for fabrics. Large-scale, cost-effective production is not the aim, as the likely customer for NTFP in Ireland is someone who is willing to pay more for ecologically sensitive or local products. They are likely to be concerned about the environment and to seek and be reassured by quality labels such as a certification standard label. This is because these environmentally conscious customers may be aware that harvesting components of a forest ecosystem could affect the balance of processes within that ecosystem.

Harvesting NTFP

One of the misconceptions often held about NTFP is that they are 'greener' or their harvest is inherently less damaging to the ecosystem than harvest of other products, such as timber. Transport is an environmental cost: Irish grocery stores are currently selling bouquets of flowers which contain greenery from the Pacific Northwest of the US ('salal'). The use instead of local material would keep income local and reduce the environmental cost of ships or planes carrying floral material around the world. In addition, NTFP can be overharvested, and their harvest can affect the abundance of other species. The amount of harvest that will not damage the continuation of the population depends on the population dynamics of the target species, the proportion harvested, and whether the other components of the environment continue to be suitable for perpetuation of the population. In the forests of northwestern North America, bryophytes are harvested for the floral trade, and the target species include some which also occur in Ireland such as *Isothecium myosuroides* (Brid.) and *Rhytidiadelphus loreus* (Hedw.; Peck, pers. comm.). One could thus conceivably harvest these species in Ireland. However, the standard method is to remove the entire mat of epiphytic bryophytes, including bryophyte species that are not used by the floral industry, and later sort the material, discarding the unwanted species. A comparison study also found that these bryophyte mats contain nearly 200 species of macro invertebrates (Peck, pers. comm.). These species, some of which may be rare, are being removed from their habitats and then discarded as they are not of use to the florists (Peck, pers. comm.). In addition, a study monitoring recovery of the mats (Peck, pers. comm.) found that the epiphytic bryophyte mats have regrown after five years to cover the branch but not as thickly. The volumes of the five-year-old mats average about 1/5th of the pre-harvest volume. These results indicate that expected recovery time, or 'rotation', is fifteen to twenty years (Peck, pers. comm.). In the Irish context, with low woodland cover, these results imply that the quantity of bryophytes that could be sustainably harvested in Ireland is low. In addition, loss of rare species remains a concern in any removal of large amounts of material, especially that containing many species that are small and therefore easily overlooked.

Conclusions

Potential NTFP in Ireland today include mushrooms, foliage and mosses for floral arrangements, wildlife photographs, and dyes made from higher plants and lichens. The very broad range of services that ecosystems provide should be considered when searching for new potential NTFP. The potential customers should also be considered: they are likely to be people who are concerned about environmental issues and have the finances to pay for a luxury products. Implementation of a quality label such as the Forest Stewardship Council (FSC) standards for NTFP would help increase the marketability of Irish NTFP (see, for example, http://www.rainforest-alliance.org/programs/forestry/smartwood/certification/non-timber-forest-products.html).

It is important to recognise that non-timber forest products cannot be harvested in bulk from forests without consideration of population dynamics, effects of accidental removal of non-target species, and the ability of both target and non-target species to replenish themselves. The bryophyte harvesting for the floral industry currently taking place in the large forests of the Pacific Northwest of the US, for example, may be unsustainable and would be untenable in the smaller forest areas of Ireland. Biodiversity is a key concept in forest policy today; therefore, harvesting any component of the forest, whether trees or other components of the ecosystem, should be undertaken carefully and at sustainable levels of harvest. The quantity and frequency of harvesting must be based on the ecology of each species and its place in the ecosystem. Small organisms, such as the bryophytes mentioned above, may have very limited dispersal mechanisms, making the reinvasion of a 'cleared' site difficult. Fungi, however, may be more resilient to harvesting (see Dowding, this volume) and luxury mushrooms for consumption may be the most suitable NTFP available from Irish forests.

Harvesting, whether of timber or non-timber products, is only sustainable if it avoids damage to the continued functioning of the whole ecosystem. Relatively little is known about many of the small organisms in our woodlands, and therefore use of any NTFP must follow the principles of 'adaptive management', collecting data continually and using it to tweak the management (see http://www.iucn.org/themes/cem/ea/docs/ecosystem_approach.doc). Continued unimpaired functioning of the whole ecosystem should be the primary objective in management and harvesting in Irish woodlands today.

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