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Rhododendron in Snowdonia and a strategy for its control

SNOWDONIA NATIONAL PARK AUTHORITY

Executive Summary

Rhododendron has become established over more than 2000 ha of Snowdonia National Park and poses a major threat to native plants and animals. The factors that promote and constrain the invasion are reviewed, the distribution of the Rhododendron is analysed with respect to habitat, ownership and other factors. Most of the Rhododendron occurs in six areas. Woodlands and steep sites are particularly favoured sites. The history of control over the last thirty years is reviewed. Significant progress has been made over this period particularly in Dyffryn Ffestiniog and more recently south of Beddgelert and the south side of the Mawddach estuary. Using a GIS model, it is estimated that it will cost about £10M to effectively control Rhododendron in the Park and adjoining areas (Blaenau Ffestiniog, Corris, Aberangell). An attempt has been made to identify future priority areas for control based on the threat to areas of high conservation value whose features are threatened by Rhododendron. Control of Rhododendron throughout the Park and adjacent areas is feasible in the long term.

The strategy proposes 12 recommendations. Co-operation between the main bodies that have a strategic role in land management will be more or less essential to ensure that control programmes can take place in an effective strategic manner. A key recommendation is that a Partnership is set up in order to co-ordinate future work. Several recommendations elucidate the role of the Partnership. For example, that it would maintain and share a GIS–based record of control programmes. Significant financial resources will be required in order to achieve and maintain progress and one possible role of the Partnership would be to bid for these. Amendments to government policies and grants are also recommended.

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1. Introduction

Invasive species have an enormous and often irreversible impact worldwide. They cause major economic losses and rank with habitat loss as one of the major causes of a decline in biodiversity. In Snowdonia, Rhododendron[1] is a considerable cause for concern. It was commonly planted in large gardens and estates in the nineteenth century but soon began to spread into the wild. There are now hundreds of hectares where it is the dominant species and hundreds more where it has a significant and increasing hold. A similar invasion is occurring elsewhere in the British Isles, particularly in regions with a moist climate and acidic soils such as western Ireland and Scotland. In the context of Wales, Rhododendron is very much a problem of Snowdonia; by far the majority of the invasive stands are located here.

There have been significant efforts to control or eradicate Rhododendron in Snowdonia and other regions. The methods are labour intensive and require repeated intervention over several years and are thus expensive. In some areas significant progress has been made; in others there has been significant expenditure and less progress.

This document will examine the current position of Rhododendron in Snowdonia, its impact, distribution, and history of control with the aim of recommending a strategy for the future and elucidating possible opportunities, mechanisms and constraints for future work.

2. The impact of Rhododendron

2.1 Impact on native plant and animal communities

There are few detailed studies on the impact of Rhododendron other than for birds. Batten (1976) showed that there were substantially lower populations of breeding birds in Rhododendron infested woods in Killarney. Similarly, Becker (1988) found that woods with Rhododendron supported lower populations of woodland specialists such as pied flycatcher and redstarts in Devon.

For flora, the impact is self evident. Few plants cope with the deep shade of dense stands and the ground is usually bare. The native flora of the field and ground layer and associated fauna are lost or displaced. In the long run it is even possible that woodland canopies will disappear to be replaced by a shrub layer climax composed of blanket Rhododendron. Oak, for example, requires quite high light levels for successful establishment (Shaw 1974). In Turkey regeneration and growth of beech forest is reduced as a result of the *Rhododendron ponticum* understorey (Esen et al. 2004). In the Appalachians, Lei et al. (2002) found that thickets of the closely related *Rhododendron maximum* strongly inhibited regeneration of native tree seedlings.

The main habitats threatened by Rhododendron in Snowdonia are woodlands, heaths and blanket bogs. These are of such high conservation value that significant areas have been designated at the European level as Special Areas of Conservation. The Atlantic oak woodlands are of outstanding interest particularly for their diversity and abundance of

[1] Throughout this document “Rhododendron” refers to *Rhododendron ponticum* and its invasive hybrids

mosses, liverworts and lichens. The special conditions that enable these species to thrive are also highly favourable to Rhododendron which is widely recognised as a key threat. Recent surveys of bryophytes (Newton 2004) and lichens (Orange 2003) in Snowdonia cite Rhododendron as a major threat. *Rhododendron ponticum* features in a recent list of the top twenty alien invasive species that threaten the UK's flora (Plantlife 2002).

Rhododendron is poisonous or unpalatable to most animal species. Few species of invertebrates utilise it as a food (Judd & Rotherham 1992). A food chain based on Rhododendron is likely to have a low biodiversity.

In the absence of other suitable vegetation, Rhododendron can provide shelter and cover for a variety of animals including badgers, otters, bats and various song birds (Rotherham 2002).

2.2 Impact on farming, forestry and tourism

Rhododendron invasion causes a loss of grazing area (and associated agricultural subsidies). The plant is poisonous to stock (e.g. Higgins et al., 1985; Black, 1991) and mortalities can occur in late springs when sheep return from wintering.

Competition from Rhododendron can be a problem in forestry especially at the establishment stage. There are also extra costs involved in maintaining rides.

The impact on tourism is probably positive, with some visitors coming especially to see the blooms. As public awareness increases, this attitude is beginning to change and affected landscapes are more likely to be perceived negatively. Where Rhododendron blocks paths or other access to the land, there is a loss amenity for visitors interested in walking.

2.3 Role in the spread of "Sudden Oak Death"

Phytophthora ramorum, a fungus-like organism, has recently caused major mortality of oak trees in California. It has since been found in Britain, as has a similarly pathogenic species *P. kernoviae*. Rhododendron is highly susceptible. In a few cases native trees and shrubs (including bilberry) have also been found infected. Often, the source of the infection is diseased Rhododendron growing nearby (Forestry Commission 2006). The concern is that a reservoir of *Phytophthora* could build up in Rhododendron and then transfer to native species. At the moment the likely impact these pathogens could have on native flora is not established (DEFRA 2008) Neither *P. ramorum* nor *P. kernoviae* has yet been identified from Snowdonia.

3. Ecology of Rhododendron

3.1 Origin and distribution

Rhododendron ponticum occurs as a native species in the Iberian Peninsula and also around the Black Sea. It appears to have been first imported into Britain in 1763 from Gibraltar as a garden plant. By the middle of the nineteenth century it was being widely planted in the gardens and woods of large houses and also for pheasant cover (Dehnen-Schmutz & Williamson 2006) from where it has since spread widely. Milne & Abbott (2000) undertook a DNA study which indicates that the British population has an Iberian rather than middle Eastern origin. It appears to have undergone some selective adaptation especially for cold tolerance since its introduction. This may include incorporation of genetic material from other species. Milne & Abbott (2000) found markers characteristic of the N American *Rhododendron catawbiense* in a few of their samples

The present natural range of Rhododendron ponticum is in the north Mediterranean to Black Sea. In Spain and Portugal, it is a relict species no longer well suited to the dry climate and is confined to a few damp valleys. Reproduction is largely confined to layering of branches as the climate is too dry for seedlings to survive (Mejias et al., 2002). It is similarly rare in Bulgaria, where it is classed as a Red Data Book species. By contrast, *R. ponticum* is abundant in several forest types in northern Turkey. It can also behave as an invasive species there and causes problems when attempting to regenerate woodland after felling (Colak et al., 1998).

3.2 What makes Rhododendron an invasive species?

Rhododendron has several attributes that make it a highly successful plant in Snowdonia.

- Wide climatic tolerance. The climatic extremes of heat, cold and drought experienced in Snowdonia do not cause significant mortality to established bushes. At higher altitudes, climate does appear to become a limiting factor. Few bushes have been recorded above 400m and plants growing at this elevation in exposed sites appear unhealthy with signs of leaf damage and dieback, (E.g. Fig. 1). In sheltered sites such as gullies and plantations, plants are found at up to 500m altitude. The highest record is 550m in a gully within a plantation (Cwm Esgyll/Nant Pumryd SH879193). 30% of the land area of the Park is above 400m altitude.)

Figure 1: Isolated bush at c 350m altitude Nant Gwynant (SH658505). The sparse foliage of such bushes and lack of young plants suggests that climate may be exerting a limiting factor here.

- Broad soil and habitat requirements. Most soil conditions in Snowdonia will support established Rhododendron, although permanently moist sites appear to be necessary for the seedlings to establish. Growth is most vigorous on well drained acid soils in woodlands and heaths. Waterlogged soils are less favoured and plants are much less vigorous. However, plants do occur in mires.
- Shade tolerance. Established plants can tolerate low light levels (2% daylight) but growth is much reduced in deep shade. Plants survive under a woodland canopy, especially under deciduous trees, where the evergreen Rhododendron continues to photosynthesise after leaf fall of the trees. Very heavy shading (e.g. under an unthinned conifer canopy) can kill established plants.
- Poisonous foliage. The leaves are poisonous to mammals and established plants are rarely browsed. The leaves are also unpalatable to most invertebrate herbivores.

- Longevity and vegetative reproduction. Bushes may live at least one hundred years persisting through vegetative layering of collapsed branches. (Colak et al. (1998) report 200-400 year old plants from Turkey.)
- Prolific seed production. Up to 1million seeds are produced annually in a mature plant in full sunlight. Seed production in woodland plants much reduced. Flowering begins once the plants have reached 12 years of age (3-5 years for regrowth from cut stumps)
- Outcompetition by shading. The very dense shade under established plants is inimical to most other plants.
- Mycorrhizae. Associated mycorrhizae aid nutrient uptake from infertile soils.
- Allelopathy. Exudates from leaves and roots may be allelopathic to other plants although the evidence for this is controversial, (e.g. Rotherham & Read, 1984, cf Hockley, 1989).

A detailed account of the ecology was given by Cross (1975), on which the above account is partly based.

3.3 Limiting factors to invasion

A mature Rhododendron bush can produce one million seeds per annum (Cross 1975). If the seeds from all the bushes in the Park were evenly distributed across the Park, each square metre would receive around a hundred seeds every year. In reality, the seeds are not scattered evenly and only a minute fraction develop to become established bushes, but the figures serve to illustrate that slight increases in the rate of establishment could lead to a major increase in the invasion rate. The three main limits to invasion appear to be dispersal distance, soil conditions and predation by grazing.

Detailed observations and further discussion of these aspects can be found in Appendix 1.

3.3.1 Dispersal

Wind appears to be the main agent for dispersal. Seeds have a calculated terminal velocity of 1m/sec and thus should largely fall within a few tens of metres of the parent plant. Seed release experiments broadly confirm this (Stephenson et al, 2007). However, observations from Snowdonia suggest there is a minor but significant dispersal up to several kilometres from the seed stand. On the basis of recent observations (see Appendix 1), wind transport appears to be the most likely agent involved. If so, stands of Rhododendron in elevated or exposed sites are likely to be of particular significance in promoting colonisation.

3.3.2 Soil moisture

Sites with suitable ground conditions for successful germination are quite restricted. The key requirement appears to be that the soils do not dry out. Humus-rich (acid) soils are thus favoured, and especially those in sheltered sites. Absence of competition for moisture (and to a lesser degree) for light also appear to be important. Soils with a thin layer of bryophytes are especially favoured (Cross 1981), the latter acting to conserve soil moisture rather than compete for it. Stephenson et al, (2005) studied colonisation of a felled woodland site in Scotland and found that logs and tree stumps colonised with moss were the most favoured substrate. Forestry sites are thus likely to be highly susceptible to invasion.

3.3.3 Seed viability
In some ericaceous species, seeds can survive for many years in the soil as a seed bank (e.g. see Hill & Vander Kloet 2005). This is probably not true of Rhododendron. From experimental evidence, Cross (1975), concluded that the seed viability was only six months. However, limited experiments by the author show that a significant number of seeds are still viable after 18 months. Observations of occasional germinating seedlings on sites that were cleared three seasons before (and where there are no remaining adjacent stands) suggest that a few seeds may be viable for longer periods.

3.3.4 Grazing
Recent observations from southern Snowdonia indicate that grazed sites are much less likely to be invaded by Rhododendron. A similar conclusion was reached by Thomson et al (1992) in their study of Nantgwynant. Grazing of young seedlings by sheep appears to be a key factor in controlling invasion. This is discussed further in Appendix 1.

4. Distribution of Rhododendron

4.1 Survey data
A complete survey of the National Park was carried out on horseback in 1985/86. The survey was carried out to a high standard and although twenty years old, is still a valuable source. In 2005, the south east corner of the Park around Dinas Mawddwy was surveyed. Recent detailed surveys have also been undertaken as part of the SNPA Invasive Species Project. Details of survey methodologies and data interpretation are given in Appendix 2.

4.2 Geographical Distribution of Rhododendron.
In the absence of a comprehensive new survey, the 1986 survey provides the foundation for our present knowledge on distribution. The main areas of Rhododendron are localised in the major valleys and estuaries and are generally associated with gardens or pheasant coverts of nineteenth century estates. To facilitate analysis, six main areas of infestation have been defined (Mawddwy, Mawddach South, Mawddach North, Dyffryn Ffestiniog, Glaslyn-Gwynant, Betws y Coed) (Maps 1 and 2). Over ninety percent of the Rhododendron in the Park occurs within these areas.

The remaining ten percent is composed of small stands, mainly in valleys and other lowlands associated with large houses.

Rhododendron is also present in quantity in areas bordering the Park notably Blaenau Ffestiniog, Corris and Aberangell. These areas are not included in the analysis presented below, due to lack of data, but they will be considered as part of the overall strategy.

4.3 Changes in the distribution over the last 20 years

4.3.1 Mawddwy
A straight comparison of the 1986 and 2005 surveys indicates that the area occupied by Rhododendron has increased by around 15%. Recent survey work indicates apparent systematic errors in both surveys. When these are taken into account, the best estimate of increase over this period is around 20%.
The main changes are:

- Increase due to colonisation of open land adjacent to major stands (e.g. above Cerddin and on Foel Benddin). There appears to be an increase of around 40ha, although it is likely that some areas with only small plants will have been missed in the 1986 survey.

- Increase due to colonisation in forestry plantations. Scattered plants occur, especially along track sides in plantations. Many of these plantations were barely in established at the time of the 1986 survey.
- An increase in the number of upland sites where Rhododendron occurs as isolated plants or low density stands at a distance from major stands (e.g. Fig. 2 and Fig.3). Some of these areas were probably not included in the 1986 survey.
- A decrease of around 10ha due to clearance.
- A decrease of around10ha in plantations as a result of either shading out by unthinned conifers or a combination of shading and control.

Figure 2: Isolated Rhododendron below Maesglasau, Dinas Mawddwy (SH832138). The associated rowans suggest grazing pressure has been low. Nearest major seed source Coed Foel Dinas 2.5km to E

Figure 3: Rhododendron colonising open upland, head of Cwm Cerddin (SH921203). Nearest major seed source 1km to W

4.3.2 Mawddach South

There have been major efforts to tackle Rhododendron since the 1986 survey. Over 200 ha of the 292ha recorded then have been cleared or are currently being cleared. There has been a gradual spread from the established stands (mainly set in a matrix of parkland and fields) into higher areas of rough grazing and moorland. Most of these plants are within 500m of the nearest seed source but occasional pioneers are found up to 1000m away.

4.3.3 Mawddach North

There is no recent survey data on which to base the comparison. Major gains e.g. Dolymelynllyn estate, Farchynys, Garth Gell, and recent work around Bontddu are partly offset by increases in forestry plantations. Scattered bushes are colonising the rough grazing and heath land to the north of Bontddu.

4.3.4 Dyffryn Ffestiniog

Of the 150 or so hectares of dense or medium density infestation recorded in 1986, less than 20 remain. Rhododendron is still present at a low density in much of this area (and also around Blaenau Ffestiniog nearby). As with other areas, there has been a spread, generally at a low density or as isolated bushes, to a substantial area of the surrounding upland.

4.3.5 Glaslyn Gwynant

Major achievements here include the Glaslyn gorge, around Craflwyn and work currently underway around Plas Aberglaslyn. There have also been significant areas of colonisation covering at least 30 ha of new ground. For example to the east of Coed Eryr, the main invasion front has shifted 200m eastwards from the position recorded in 1986. In addition, much of the land previously recorded as having only a low density is now under dense cover. Few seedlings and young bushes were observed above 300m and very few bushes above 350m.

4.3.6 General trends

a) The main areas of increase have occurred adjacent to major seed-producing stands.

b) There has been a significant spread in the distribution of Rhododendron over the last twenty years. Isolated bushes and patches of low density infestation are widespread in areas of unimproved grazing and heath and especially along forestry tracks and roads. The nearest identifiable seed source may be over a kilometre away. In 1986, 28% of the 1km squares within the Park boundary were recorded as having some Rhododendron. The present figure is considerably greater. For the Mawddwy area, 50 kilometre squares were recorded as having Rhododendron in 1986. A further 30 km squares were recorded by 2005.

c) The total area of cover of Rhododendron plants has not changed greatly. Natural increase has been balanced by a similar amount of clearance.

4.3.6 Estimate of areal extent

The 20% increase recorded in Mawddwy also appears, on qualitative evidence, to hold true for other areas. On this basis, an estimate of the present areal extent can be derived by adding a nominal 20% to the 1986 data and then making adjustments for known clearance work. Only areas where Rhododendron has been effectively controlled and which have reached the “maintenance phase” (see 5.2.3) have been deducted. Substantial progress towards effective control has been achieved over much larger areas.

Only areas with “at least a light density cover of Rhododendron” have been included in the figures below. This equates to about 10% cover although the category can only be inferred for the 1986 data and was not mapped as such (See Appendix 2).

Main areas ("polygons") of Rhododendron	Area (ha) in 1986	Area (ha) in 2007 assuming 20% increase	Area (ha) effectively controlled since 1986	**Estimated area present in 2007 (ha)**
Betws y Coed	40	*49*	0	**49**
Glaslyn-Gwynant	528	*633*	50	**583**
Dyffryn Ffestiniog	212	*255*	100	**155**
Mawddach N	372	*446*	50	**396**
Mawddach S	292	*350*	20	**330**
Mawddwy	205	*247*	10	**237**
Other areas	271	*325*	0	**325**
Total	1921	*2305*	230	**2075**

Table 1: Estimate of area of land with at least a light density cover of Rhododendron in Snowdonia National Park.

4.4 Distribution with respect to habitat type

GIS analysis of the 1986 survey and the Phase 1 CCW Habitat survey provides information on the main types of habitat affected.

Habitat type	Area with Rhododendron (ha)	Percentage of total area
Broadleaved woodland	700	38%
Coniferous woodland	590	32%
Grassland (incl. Improved)	210	11%
Bracken	100	5%
Dry Heath	130	7%
Wet Heath	5	0%
Bog/Flush	20	1%
Riparian	20	1%
Garden/Built Areas	70	4%

Table 2: Habitat type of land with at least a light density cover of Rhododendron in Snowdonia National Park in 1986 using Phase 1 Survey data

The most striking finding is that 70% of the Rhododendron occurs within woodland. Grassland and dry heath account for much of the rest. A similar figure for woodland was obtained using the Forestry Commission's woodland inventory data. A more refined analysis of the data, for instance a comparison of improved and unimproved grassland, is precluded by the quality of the data.

In the field it is clear that subtle variations in habitat have an enormous effect on the probability of Rhododendron colonisation. Short-cropped grass swards with strong grazing pressure are less likely to be invaded than rough unimproved grassland. Dense bracken (despite the data above for bracken which probably includes mixed habitats) is not very susceptible to invasion. Woodland is generally readily invaded except where heavily grazed. Even here, there are subtleties: upland oak woodland (NVC W17) is far more susceptible than upland ash woods (NVC W9). These aspects are further discussed in Appendix 1.

4.5 Distribution with respect to slope and aspect

The distribution of Rhododendron (1986 survey) was also examined with respect to slope and aspect. Five 5km squares were selected in each of which Rhododendron was abundant. The land was categorised on 5m grids for slope (six categories) and aspect (eight categories). The Rhododendron distribution was then compared with each of these grids. The data is shown in Table 3.

Sample Square	**1**	**2**	**3**	**4**	**5**	**Aggregate 1 to 5**
5km x 5km	Beddgelert	Maentwrog	Bontddu-Islawrdref	Ganllwyd	Dinas Mawddwy	
Centroid X	2675	2657	2725	2603	2682	
Y	3175	3404	3225	3476	3149	
Slope						
0-10º	8	3	6	6	3	5
10-20º	10	8	16	6	3	9
20-30º	15	13	23	7	6	13
30-35º	21	18	27	10	10	17
30-40º	22	19	28	9	14	18
>40º	31	14	27	9	22	21

Aspect						
N (337.5-22.5º)	15	11	16	3	10	11
NE (22.5-67.5º)	15	11	10	12	10	12
E (67.5-112.5º)	13	8	11	9	8	10
SE(112.5-157.5º)	14	7	16	5	2	9
S (157.5-202.5º)	8	6	13	4	3	7
SW(202.5-247.5º)	5	5	12	4	0	5
W(247.5-292.5º)	10	4	8	7	8	7
NW(292.5-337.5º)	16	6	24	6	6	12

Table 3: Percentage of land occupied by Rhododendron relative to the area of land occupied by a given category of slope or aspect for each of the five study areas. An aggregate figure for all five areas is also shown.

There is a strong correlation between the steepness of the slope and the presence of Rhododendron. In general it seems that the steeper the slope the more likely it is to be occupied by Rhododendron.

Aspect also has an effect. Rhododendron favours more northerly facing slopes. The data for aspect is less consistent. This is perhaps explained by bias due to the location of the original planted Rhododendron stands in each of the study areas.

Similar correlations for slope and aspect were found by Thomson et al. (1993) in their study of the Nant Gwynant.

4.6 Distribution with respect to ownership

GIS analysis based on the 1986 survey was used to examine ownership of land infested with Rhododendron (Table 4). Land holdings of the major institutional owners are known, as are the areas under farming stewardship schemes (Tir Cymen, Tir Gofal). Woodland areas outside these ownerships are also known thus yielding a further category of ownership.

Owner	Area in 1986 (ha)	% of total
Institutional owners*		
WAG (Forestry Commission)	*406*	21%
National Trust	*158*	8%
RSPB/ Woodland Trust	*50*	3%
SNP	*75*	4%
Total	***690***	**36%**
Private woodland owners **		
Broadleaved/mixed	*197*	10%
Conifer	*306*	16%
Total	***503***	**26%**
Farmland		
Tir Gofal / Tir Cymen**	*400*	21%
Other land (assumed to be farmland)	*320*	17%
Total	***720***	**37%**

* Excludes tenanted land in TG/TC schemes

** Woodland included in TG/ TC schemes is included under farmland category

Table 4: Ownership of land with at least a light density cover of Rhododendron in Snowdonia National Park in 1986

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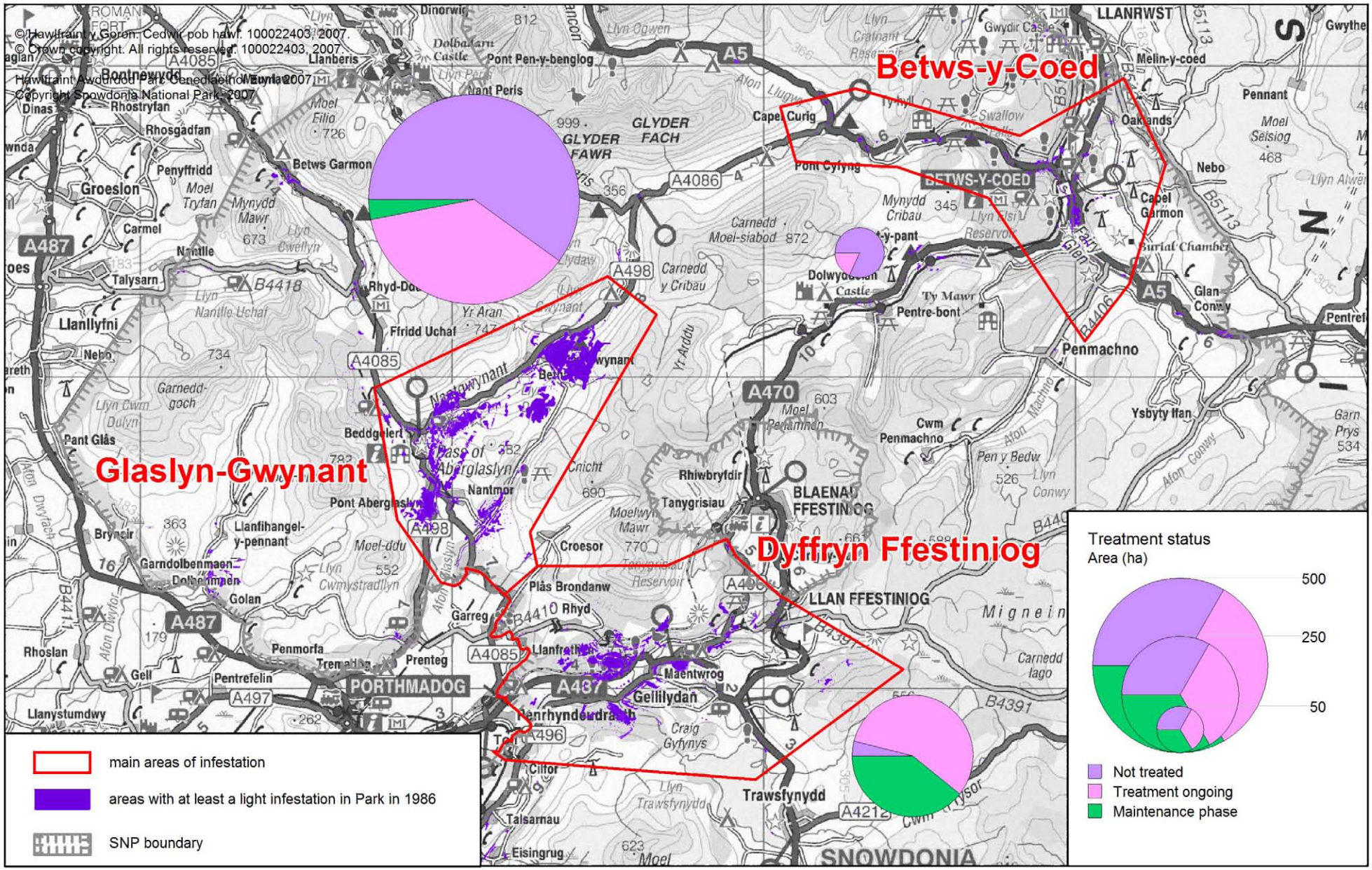
Map 1: Distribution of Rhododendron in Snowdonia National Park (North)

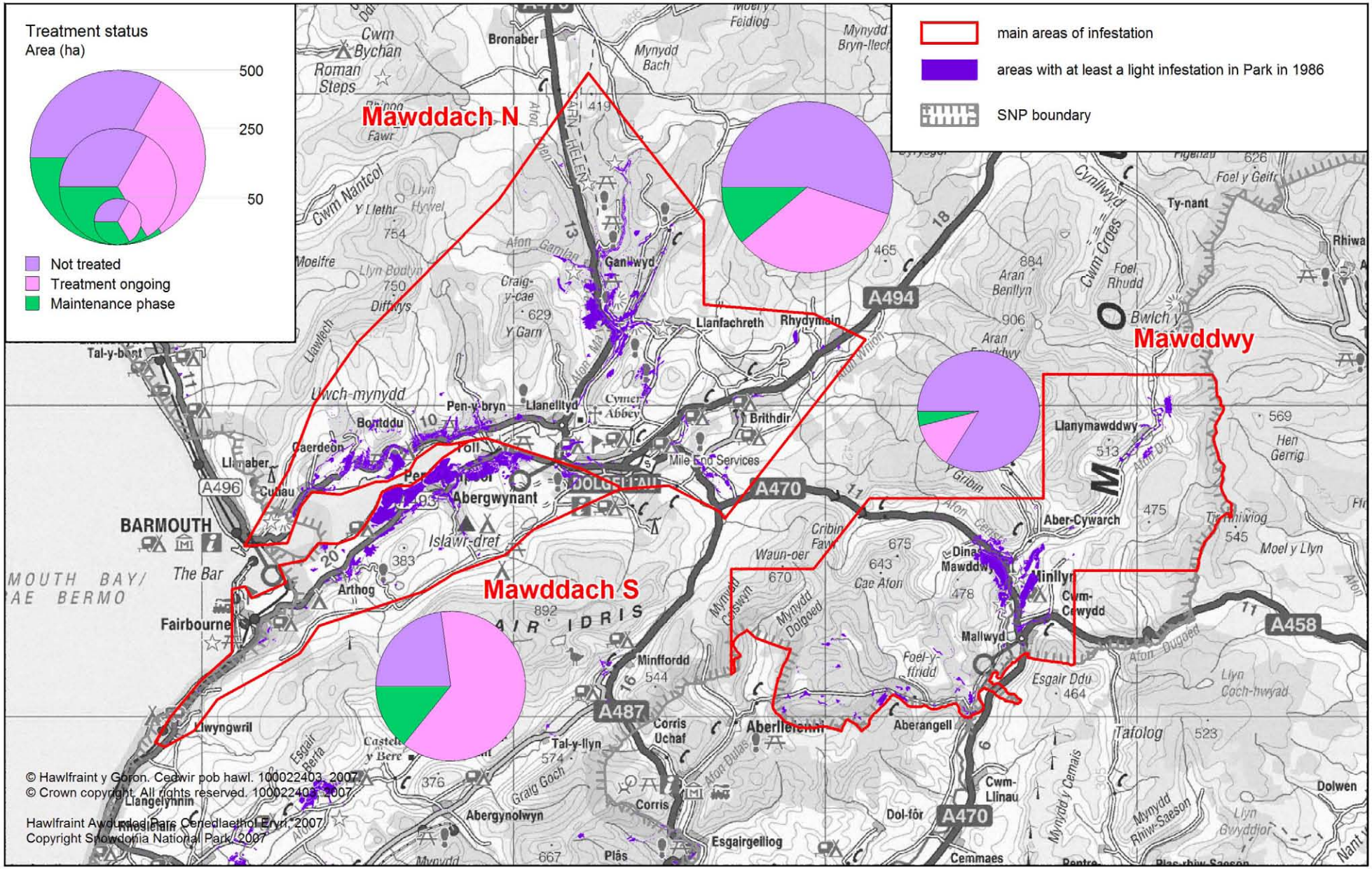
Graddfa / Scale 1:170000



Awdurdod Parc Cenedlaethol Eryri
Snowdonia National Park Authority

Map 2: Distribution of Rhododendron in Snowdonia National Park (South)

Graddfa / Scale 1:170000



The results need to be interpreted with some caution as they reflect the situation in 1986 and do not take account of subsequent clearance. However, the figures do illustrate the general picture. Over 30% of the significant stands are on institutional land; about 25% occur in private woodlands; about 20% occur on farm stewardship land.

The Forestry Commission is a key landowner with over 20% of the major Rhododendron stands. Coed Eryr in the Glaslyn–Gwynant polygon and Coed Foel Dinas in the Mawddwy polygon are of crucial strategic importance in terms of both of size and landscape setting.

5. Techniques and costs of Rhododendron control

5.1 Current techniques

Control techniques are now well established and are summarised below. Nearly all require the use of herbicide. A full discussion of the techniques is given by Edwards (2006) and further method details are "*Recommended Methods and Practice for Controlling Rhododendron*" by SNPA.

5.1.1 Physical removal

Well suited for small plants that are easy to uproot but the use of mechanical excavators to uproot large bushes is rarely appropriate because of the disturbance damages habitats and creates new sites for seedling invasion.

5.1.2 Foliar spray

For bushes less than 1.5m in height and diameter foliar spraying can be very successful providing the work is done with care. Knapsack sprays are most commonly used. Even with careful technique, there is generally some damage to adjacent vegetation. Where *Vaccinium* is dominant in the field layer, the damage is evident for several years.

5.1.3 Cutting

Larger bushes can be treated initially by cutting to ground level. Cut material can be stacked, burnt or chipped depending on the volume of material and individual site. Cutting alone will not kill bushes. It needs to be used in combination with foliar spraying of regrowth or stump treatment.

5.1.4 Stump treatment

Application of herbicide to the cut stumps straight after cutting can be effective in killing bushes. This method has had a variable success rate in Snowdonia. It often causes a reduction and delay in the amount of regrowth tends rather than death of the plant. There have been instances where bushes apparently dead for two years have later recovered.

5.1.5 Stem treatment

Herbicide is applied under the bark at the base of each stem, typically by boring holes with a battery drill. The method has real advantages including economy, minimal habitat disturbance and a very high kill rate. In most situations, there is no need to cut or remove the dead standing bushes. The technique is best suited to large bushes with few but substantial stems. However it is also favoured for bushes of all sizes in highly sensitive conservation sites and sites requiring rope access.

5.1.6 Mechanical flailing

Excavator mounted flails with powerful mulching heads can be used for Rhododendron control and could possibly deliver cost savings over manual techniques. However, subsequent treatments to deal with regrowth are still required. The potential for this

technique in Snowdonia is limited by the very steep and craggy terrain on which Rhododendron typically occurs here.

5.2 Phases of a control programme

Prior to initiating a control programme, detailed surveys are required. The practical work of eradicating the plants requires repeated operations over several years. It can be considered as having three phases: an “attack phase”, a “follow-up phase” and a “maintenance phase”.

The most expensive part of the programme is the attack phase. Costs decrease with time (Fig 4). However, if control is abandoned before the maintenance phase, the costs of going back again and treating the area soon rise and in some cases can be higher than if the bushes had never been treated. Partially cleared sites typically develop a bryophyte-rich layer highly favourable to seedling establishment.

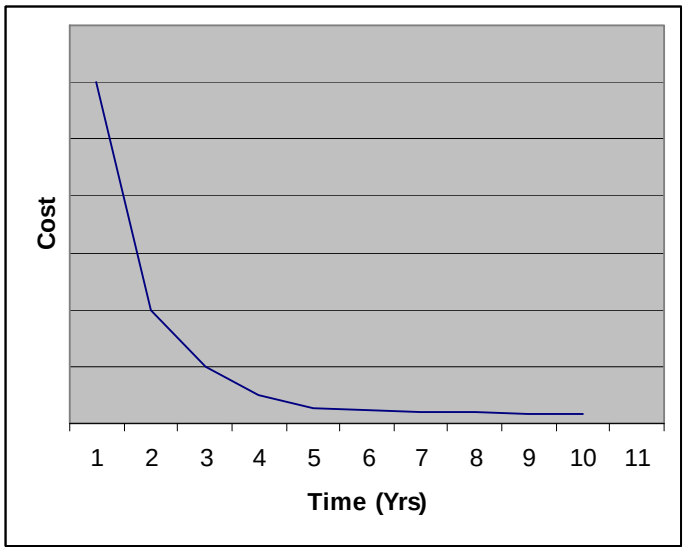


Fig. 4: Schematic costs of a Rhododendron control programme for a specific area over time

5.2.1 Surveying

Detailed surveys are necessary to identify the techniques required and the likely costs. They will also help with prioritisation of work (see 11.2) and are invaluable in delivering successful well priced contracts. The density of the stands and the form of the bushes are the main data that need to be collected. (See Appendix 2.4 for the system used in the Invasive Species Project). The cost of surveying is very dependent on the terrain but is generally in the range £5 to £20 per ha.

5.2.1 Attack Phase

The attack phase has much the highest cost as it is very labour intensive. Depending on the site, it will consist of cutting, spraying large volumes of herbicide, stem treatment.

5.2.2. Follow-up Phase

Follow up action is always necessary. Even with the high mortality stem treatment technique, a few branches are nearly always missed in, and with other techniques it can even take a third visit to finish off recalcitrant mature plants. Seedlings also need to be considered. It takes five years for them to reach an easily visible size and perhaps even ten on difficult terrain.

5.2.3. Maintenance Phase

The maintenance phase is reached when Rhododendron is reduced to a level where it no longer has an impact on conservation interest and land use, and if left untreated, significant recolonisation would take many decades. By this stage, all mature bushes will have been located and successfully treated and there will be no more than occasional seedlings (say 100/ha). Flowering Rhododendron should be absent or extremely rare (say one small bush/ha). A 5-yearly sweep to locate and treat these plants (mainly hand weeding) will progressively reduce and remove these plants. The maintenance phase will never be reached if significant seed sources remain due, for example, to uncooperative landowners.

Some areas within the Park have now reached the maintenance phase. The Dolymelynllyn estate is an outstanding example. Much of the Dyffryn Ffestiniog is now also reaching this phase. However there are still pockets of untreated bushes.
In comparison to our knowledge about the initial and follow-up phases, the best techniques for the maintenance phase are still poorly known. There is a danger that the cost of searching for the last few plants could be disproportionate to the risks of allowing the odd one of these plants to release a few seeds. The cost benefit analysis is likely to be finely balanced and will vary from site to site. Further work to evaluate the optimum frequency and thoroughness of monitor-and-treat methods are needed. There is a good potential to reduce the cost of the maintenance phase through the direct involvement of land owners and volunteers.

5.3 Costs per hectare

The cost of controlling Rhododendron is very variable. Bush density is probably the single most important factor. Bush form is also important, as is the variation in density. Site factors such as steepness, roughness of terrain, other vegetation, access, water supply, can also be highly significant. The steepest sites require rope access for safe working; here control can be extremely costly.

The spread of prices from experienced contractors, even for well specified and surveyed jobs is often considerable. Experience from Snowdonia and Ireland (R. Millar, pers. comm.) indicates that is desirable to break down large pieces of work into small well-described contracts as this produces a narrower range of prices. Under priced contracts are not likely to yield good results.

Table 5 gives indicative prices for Rhododendron control. Prices are based on current work in the National Park and others (D Oliver, C Edwards). The costs are based on easy sites (flat, good access) for bushes of medium height. Costs on difficult steep sites (frequent in Snowdonia) can be significantly more. Low densities of infestation cost more to treat per bush.

Bush type	Recommended treatment (5-year programme)	Typical contractor cost/ha in
Bushes <1.5m height with good all round access	Foliar spray, 2 follow up sprays /hand weeding	£1000
Bushes over 1.5m height/diameter or too dense to allow good access for spraying	Cut and stack branches; Foliar spray of regrowth and follow-up spray/weed	£3500
As above but where it is not acceptable to leave cut material	Cut and burn or chip arisings Foliar spray of regrowth and follow-up spray	£5000
Large stemmed mature bushes	Stem treatment 2 follow-up spray/weed	£2500
Maintenance Phase	Search and treat (hand weed /spray)	£50

Table 5: Cost of Rhododendron control

5.4 Future control techniques

Techniques have been refined in the last twenty years but the main approach, a combination of manual cutting and herbicide application, is unchanged. The adoption of stem treatment is probably the largest advance in this period. There do not appear to be any dramatically improved techniques on the horizon. However, even modest advances in efficiency would be worthwhile in view of the large costs of treatment.

Novel approaches using biological control or genetic engineering may become feasible in the future. However, there are several obstacles. Evans (2003) investigated the possibilities of biological control. He concluded there was potential to develop a mycoherbicide for stem treatment based on the indigenous fungus *Chondrostereum purpureum.* If successful, this could obviate the need to use chemical herbicides, but it is unlikely to be cheaper. The potential for finding a suitable invertebrate predator is poor. Even in its native range, *R. ponticum* has few invertebrate herbivores (Colak et al.1988). Any free release of an agent that might also attack related *Rhododendron* species in gardens is likely to be strongly opposed by horticulturists.

6 History of control in Snowdonia

Rhododendron has been perceived as a threat in the British Isles both to native plant communities (e.g. Turner &Watt 1939) and forestry (Brown 1953) for over half a century, There were various early attempts at eradication (Dehnen-Schmutz & Williamson 2006).

The first attempts at control in Snowdonia began in the National Nature Reserve of Coedydd Maentwrog at the beginning of the seventies. The work was largely carried out by volunteers using cutting and stump treatment; by 1974, contractors were being used. SNPA soon followed with work on its own woodlands. The main herbicide used in the early work was ammonium sulphamate. It was not until after 1985, that the glyphosate and Mixture B combination received approval and became the standard.

Dyffryn Ffestiniog has remained the focus of a major eradication programme which continues to this day. Much of the work has been done under the aegis of CCW (formerly NCC) who has attempted to control Rhododendron not just in the reserves but has orchestrated work on adjacent landholdings. Recent work using European funds has enabled some of outlying forestry areas to the north of the valley to be tackled.

Another major area of activity has been the Aberglaslyn Pass and Nant Gwynant valley. Early work was undertaken by SNPA and the National Trust including the joint Cynllun Glaslyn initiative which tackled around 10ha of infestation around Sygun. Work was undertaken by employment action workers and volunteers (including the Army), with follow-up spraying by contractors. Experiments were also done with mechanised flail cutting (1993). Several attempts were made to attract funding on a scale necessary to make major progress here. A £0.3M bid submitted to the Heritage Lottery Fund in 1997 was not successful. In 1998, a community-based group at Beddgelert tried to access substantial funds, again without success. More recently, the National Trust has been the major player in this area using funds from the Lottery to undertake clearance of the Aberglaslyn gorge and a large area on the west side of the Gwynant valley at Craflwyn. Use of volunteer labour is a key element of the Trust's strategy.

Elsewhere in the Park, until very recently, control work has been piecemeal. Conservation bodies (National Trust, Woodland Trust, RSPB, and SNPA) have been the most active and have achieved substantial progress on their own land. Individual owner schemes through

Tir Cymen, Forestry Commission or SNPA grant schemes have also been undertaken with varying degrees of success.

European Objective 1 funds have provided substantial funds for control since 2003. SNPA, CCW and Forestry Commission all have taken the opportunity to develop major projects. Projects by the Forestry Commission are constrained to ancient woodland sites. SNPA's project money can be used more widely and has partly been used to complement other projects in order to achieve a more contiguous control.

SNPA and the Forestry Commission set up the Snowdonia Rhododendron Group for land managers and owners. The group held its first meeting in 1982 and has continued to meet intermittently since. The group was particularly active in the 1980's and organised surveys of Rhododendron distribution and a national conference (see Gritten1987). A further national conference was organised by the National Trust at Craflwyn in 2005 (see Wong & Ambrose-Oji 2007).

6.1 Lessons learnt

1. Rhododendron control can be undertaken successfully.
2. Successful control requires a minimum of five years. Management involving an initial and two follow-up treatments is nearly always necessary. On many sites, with difficult terrain and numerous seedlings, at least ten years will be required.
3. A piecemeal approach to control is unsatisfactory. Sites adjacent to seeding stands will tend to be reinvaded.
4. Incompletely treated stands can recover rapidly. Subsequent costs of control are very high and can even exceed comparable untreated areas.
5. A long-term commitment from the landowner or land manager is necessary to achieve successful control.

7 Government Policies and grants

7.1.1 Invasive species legislation

Schedule 9 Part 2 of the Wildlife and Countryside Act 1981, as amended by the Natural Environment and Rural Communities Act 2006, lists plants that it is an offence to "plant or otherwise cause to grow in the wild" and that are banned from sale. The Schedule contains two terrestrial plants, Japanese Knotweed (*Fallopia japonica*) and Giant Hogweed (*Heracleum mantegazzianum*). In Scotland, Schedule 9 was updated in 2005 to include *Crassula helmsii* and *Hydrocotyle ranunculoides*. Further amendments, perhaps including Rhododendron, are likely to follow from the 2007consultation. Changes are also likely for England and Wales following a DEFRA consultation (closed 31/01/08). The consultation document (DEFRA 2007) included Rhododendron as a proposed addition to Schedule 9.

The Government's guide to horticultural practice on invasive species (DEFRA 2005) admits the possibility of adding further species which pose the highest risk to native wildlife to Schedule 9. *Crassula helmsii* and *Hydrocotyle ranunculoides* and *Rhododendron ponticum,* are specifically mentioned in this context.

Rhododendron is currently freely on sale in north Wales.

7.1.2 Invasive Species in the context of Government Strategies

EU and UK policy on invasive species stems from the Convention on Biological Diversity (1992). Article 8h requires signatories to control, eradicate and prevent the introduction of alien species that threaten ecosystems, habitats and species. More specifically there is an

EU commitment to halting the loss of biodiversity by 2010 (European Commission, 2006). This is embodied in the Environment Strategy for Wales (Welsh Assembly Government, 2006) which aims to bring statutorily designated conservation sites up to favourable conservation status. The Environment Strategy sets ambitious targets: 95% of the European designated Natura 2000 sites(e.g. SACs) will be in favourable condition by 2010; 95% of SSSI's will be favourable condition by 2015; and all designated sites will be in favourable condition by 2026. Many of the statutory sites in Snowdonia whose features include woodland and heath are threatened by Rhododendron.

Future policy and guidance is likely to follow from the work of the recently formed Wales task-and-finish group for non-native invasive species.

7.2 Land use policies and grants

7.2.1 Agriculture

Grant aid for Rhododendron control is available under the Tir Gofal scheme. Control is not mandatory. The money for this operation comes from a limited capital works budget and not uncommonly the landowner has other priorities. The grant rate is currently £2000/ha. This is inadequate for dense stands and is less than the £2500/ha available under the preceding Tir Cymen scheme. The grant is paid as a lump sum (presumably on completion of the initial phase of clearance) and thus fails to reflect the long-term nature of any control programme. Grants are not available for farm woodlands since these are eligible for forestry grants. About 30 ha of Rhododendron affected land are currently being treated within the Park under Tir Gofal.

Areas where the Rhododendron cover is dense enough to result in loss of grazing are deducted from the farm area used to calculate single farm payments. Under cross compliance regulations, allowing the spread of invasive species is forbidden. Failure to control them could result in the suspension of single farm payments.

Control on organic holdings is severely hampered by the ban on herbicide use. There is no bar to entry of infested holdings to the Organic Farming Scheme. Post-entry deregistration of land in order to allow control incurs financial penalties.

7.2.2 Forestry (including farm woodlands)

Under the new Better Woodlands for Wales (BWW) scheme, the Forestry Commission offers substantial grants for Rhododendron control. The grants are based on standardised costs related to the type of control method used and steepness of terrain. The grant rate 75% for native woodlands and high priority planted ancient woodland sites, and 50% for plantation woodlands.

To qualify for any Forestry Commission grant, a management plan covering all woodlands in the property must be prepared. In nearly all cases the presence of Rhododendron should be regarded as a key threat to the woodland. Eradication or control would thus be a mandatory operation and must be included in the operations plan. Grant aid for other operations such as restocking or thinning would thus be contingent on Rhododendron control.

7.2.3 Conservation

Heavy grazing and agricultural improvement have led to a fragmentation and decline in condition of native woodlands, heaths and blanket bogs. CCW aims to reverse this decline and re-establish a more diverse suite of habitats including woodland extending upwards

into a natural “treeline” (Jones 2007).This would largely be achieved through reduced grazing pressure under schemes such as Tir Gofal.

8 Human factors

8.1 Landowners’ attitudes

Any strategic control will require the co-operation of multiple adjacent landowners. Based on consultations of around one hundred landowners as part of SNPA’s Invasive Species Project, their attitude to Rhododendron control can be summarised as one of passive co-operation. Less than 5% of owners were unsympathetic to the idea of control, and in half of those cases the reluctance appeared to stem from an antipathy to SNPA (or authority in general).

8.1.1 Farmers

Nearly all farmers consulted were concerned by the increase of Rhododendron on their land and were strongly in favour of control. A few have made a significant effort to control Rhododendron, in nearly all cases, with grants from Tir Cymen/ Tir Gofal or the Forestry Commission. However, few farmers would voluntarily undertake control if there were a significant cost in time or money to themselves. Control on farmland is likely to require more or less complete funding (certainly if it to take place in a strategic way) or will require some element of obligation.

8.1.2 Householders

About half the householders consulted had little understanding of the invasive nature of Rhododendron. However, once in possession of the facts, there was generally agreement to cooperate with the control programme. Help to remove (or even replace) plants is likely to be essential in most cases.

8.1.3 Commercial forestry interests

Most privately owned plantations are managed by forestry management companies. Rhododendron is not generally considered to be a priority. Control is only likely to take place if there is no net cost. In one case a manager was not content with the offer of 100% funding for Rhododendron control from SNPA but also expected to take a “profit” from the operation. In the light of the new BWW scheme (7.2.2), such attitudes are likely to change.

8.1.4 Conservation organisations

The National Trust, RSPB, Coed Cadw. CCW and SNPA all treat eradication of Rhododendron from their landholdings (and in the case of CCW, National Nature Reserves under their control) as a major management objective. On the whole there is an impressive record of implementing control.

8.1.5 National Assembly Woodlands

The Forestry Commission, as managing agent, has long recognised the need for Rhododendron control and has been carrying out work on the Assembly estate for at least twenty years. Historically, it has not been regarded as a high funding priority. Recently, European funded woodland restoration projects have given a big boost to the amount of control being undertaken. However the work is confined to ancient woodland sites which are generally small fragments in a larger matrix of plantation woodland. There is no overall policy or strategic approach, although one is currently in development.

8.2 Public attitudes

Fear of a public outcry about Rhododendron control was a major theme of the 1987 Snowdonia Rhododendron conference (Gritten, 1987). Twenty years on, this can probably be discounted as a major problem notwithstanding a few local complaints. Public understanding of environmental issues has increased over this time. Local initiatives such as the Beddgelert Rhododendron Control Group and the National Trust's annual "Megabash", involving hundreds of volunteers, have no doubt helped both locally and nationally to educate the public. Loss of public support is a significant risk and has led to the failure of control programmes of other invasive species (Hulme, 2006).

9 Predictions on the future distribution

9.1 Changes in land management

9.1.1 Farming

The number of breeding ewe in Wales as a whole underwent a large increase over the second half of the twentieth century (Fuller & Gough, 1999), and the increased grazing pressure is likely to have been an important constraint on Rhododendron expansion. Numbers have fallen back by 15% in the last decade (WAG, 2007) and this trend seems set to continue in the light of the changed agricultural grants regime. Hill farming is likely to become more extensive, with lower stocking densities and less intensive management of vegetation (e.g. silage making, topping). This would favour the spread of Rhododendron. Agri-environment schemes designed to improve the condition of woodland and heath land by stock reduction or exclusion (see 7.2.1, 7.2.3) are also likely to promote Rhododendron.

9.1.2 Forestry

Recognition of the importance of woodland for conservation, amenity, and landscape has led to changes in government policy towards management of their own estate and private woodlands. Broadleaved woodland is now considered more desirable in many sites especially where conifers have been planted on ancient woodland sites. Although this policy shift is to be welcomed, it will have the tendency to promote the spread of Rhododendron since the light levels at the woodland floor will be generally higher. Continuous cover silviculture is also being promoted. In clear-fell rotation forestry extensive areas go through a very tight young canopy phase that casts sufficiently dense shade to kill or strongly suppress Rhododendron. This is not necessarily the case for continuous cover silviculture systems. Conversely, some systems have the potential to be better at suppressing Rhododendron.

9.2 Climate Change

The local climate is predicted to become warmer and wetter (e.g. Hulme et al., 2002). With its wide climatic tolerance, Rhododendron should cope with the new conditions and could potentially expand its range. For Ireland it has been predicted that climate change is likely to favour Rhododendron (Byrne et al. 2003).

Changes in the rate of seedling survival will be an important factor as to whether Rhododendron becomes more or less invasive. Drier summers should decrease seedling survival; conversely, wetter springs should promote successful germination. Changes to other elements of the vegetation may be just as important. For example, the altitudinal limit of bracken and gorse is predicted to increase. This could act as a brake on the expansion of Rhododendron in the uplands. On the other hand, increased disturbance resulting from gales or fires would increase the opportunities for colonisation. Equally,

climate change may favour hitherto unimportant pathogens. For example, *Microsphaera azaleae*, a powdery mildew of N American origin affecting Rhododendron, has only recently become widespread in Britain, apparently as a direct consequence of warmer summers (Ing, 2005).

The various factors are too complex to make a clear prediction as to whether Rhododendron will be a winner or loser as a result of climate change. Its impressive array of survival mechanisms and propensity to occupy disturbed habitats suggests is likely to be a winner.

9.3 Invasion dynamics

Theoretical models of species invasion suggest there are three types of expansion: constant linear expansion; a two phase expansion with slow initial linear expansion succeeded by more rapid linear expansion; and exponential expansion (Shigesada et al., 1995). Expansion ends once the available suitable niches for colonisation become limited geographically or climatically. The pattern of expansion depends critically on how far the seed (or other propagule) is transported from the parent plant. Where the distances are only short, the expansion will be linear; where long-distances are involved, through vectors such as rivers or roads and animals, the expansion will be more rapid.

If there is a significant delay between establishment and seed production, the invasion will have a lag phase followed by a more rapid expansion once the daughter plants have reached maturity. This would be expected with Rhododendron which does not produce significant quantities of seed until twenty years of age, perhaps considerably more in less favourable sites.

From the changes in distribution over the last twenty years, it seems that the expansion of Rhododendron in Snowdonia has largely taken place in a linear fashion (see also Thomson et al, 1993) with most of the expansion adjacent to large established stands. If this were the sole method of expansion, a long term increase in the cover of Rhododendron at round one or two per cent per annum would be expected.

Some longer distance dispersal is also evident. Individual bushes or small groups are common on forestry tracks, roadsides and also occur occasionally in mountain gullies and crags. Although some plants were no doubt missed in the 1986 survey, the increase appears to be significant and real. There is a risk that these plants, most of which are not yet of seed producing size, constitute the lag phase of a much wider secondary invasion.

9.4 Future distribution – summary

Unless controlled, the expansion of Rhododendron will continue apace. Woodland and heath will be the main habitats affected. The rate of expansion is likely to increase both as a consequence of inherent nature of the invasion and due to changes in land management and, possibly, climate.

10 Costs of Control across the National Park

10.1 Costs up 2008

It is estimated that about £2M (inflation adjusted) has been spent on Rhododendron control since 1987. At least £0.5M of this has been spent since 2004. There is a commitment to spend at least a further £0.5M by the end of 2008. Much of this is recent funding from the EU Objective 1 fund.

10.2 Estimated of cost of control for the whole Park

In 1992 it was estimated that it would cost £45M to undertake control on a Park-wide basis (Gritten 1995). Recent work presented below suggests a significantly lower figure will be required. Any such estimates run into the problem of defining at the point at which success has been reached. In this estimate, successful control is considered to be achievement of the maintenance phase. An attempt has also been made to provide costs for the maintenance phase.

Polygon Name	Estimated future costs (i.e. taking account of known cleared areas) (£)	Maintenance Cost (first 5 years)(£)	TOTAL (£)
Betws	£ 230,000	£ 75,000	£ 305,000
Glaslyn -Gwynant	£ 2,040,000	£ 150,000	£ 2,190,000
Dyffryn Ffestiniog	£ 160,000	£ 125,000	£ 285,000
N Mawddach	£ 1,650,000	£ 200,000	£ 1,850,000
S Mawddach	£560,000	£ 50,000	£ 610,000
Mawddwy	£1,090,000	£ 100,000	£ 1,190,000
All other areas within the Park	£1,700,000	£ 250,000	£ 1,950,000
Adjacent areas (Blaenau Ffestiniog etc)	..£500000	£ 50000	£.....550000
Total	£ 7,940,000	£ 1,000,000	£8,940,000

Table 6: Estimated costs of Rhododendron control in Snowdonia and adjacent areas

The costs have been estimated using a simple model based on 1986 data and verified on the basis of known or estimated cost of control. The figures should be treated only as an indication of absolute and relative costs; there is not enough data to give accurate figures. A major uncertainty is the extent and the cost of dealing with scattered bushes away from established stands. The model assumes that landowners will be cooperative (see 8.1) and that the work is carried out with sufficient momentum to prevent reinvasion of sites from nearby sites awaiting treatment.

An attempt has also been made to estimate costs for stands in Blaenau Ffestiniog, Corris and Aberangell, which will need to be included as part of an overall strategic programme. No detailed survey data exists for these areas. The figure of £0.5M is a qualitative figure based on cursory examination of aerial photographs.

11 Rationale and priorities for future control work

11.1 Focus on conservation sites.

In view of the costs outlined above, it is believed that it is not an unrealistic goal to aim at eventual effective control of Rhododendron throughout the Park and adjacent areas. However, it is important to try to establish the order in which this should take place. Nature conservation is currently[2] the main reason for undertaking Rhododendron control. Rhododendron is either actively causing a direct significant degradation of habitats and

[2] It is possible that control related to *Phytophthora* control may become a significant driver in the future

loss of species, or it poses an immediate threat to them. It is logical, therefore, that the main efforts at control should be focussed on the areas of greatest conservation importance.

Many (though by no means all) of the sites of high conservation value are statutorily designated as SACs and/or SSSIs. It is proposed that these sites should be used as the initial framework on which to base future programmes of control. In addition, a few other small areas (worthy of designation) whose conservation interest is known to be high and whose features are threatened by Rhododendron have also been included. An advantage of this approach is the likelihood that funds will be available to undertake the work in view of the obligation to bring such sites to favourable condition (7.1.2).

However, it is vital that the management to protect individual sites is informed by the way in which Rhododendron spreads. The sites should be the foci which justify control over a larger area or even catchment. Failure to tackle stands within seeding distance will not deliver long-term control. Some of the critical areas are illustrated in Maps 3 -8. A buffer zone of 0.5km is shown around sites in attempt to indicate the limit of seeding distance. The dataset for the areas where control programmes have or are happening is not entirely complete.

11.2 Budgetary constraints and other factors

Opportunities to undertake control are constrained by the availability of finance and the willingness of landowners to cooperate. The latter is unlikely to be a major problem (see 8.1). The refusal of landowners of key stands in a particular area to cooperate should be regarded as a reason to direct resources elsewhere.

Financial resources, on the other hand are likely to be limited and of unpredictable availability. For the areas with the largest stands, an intended strategic plan will end up as piecemeal dabbling if progress is too slow. A further complexity is that the some of the available funds may be restricted to work on certain landholdings.

There are also other complexities which are likely to influence where control should take place. Not all conservation features are of equal importance. Some Rhododendron stands clearly have much higher seeding potential than others. Some habitats are much more liable to be invaded than others. Can stands that are not thought to be significant seed sources within a control area be safely left or is contiguous control necessary? Edwards (2006) attempted to address some of these issues with his categorisation of stands according priority for control. However, this approach does not take account of the conservation value and implies that the resources and timescale of the control programme are known at the outset.

In practice, the best way forward appears to be for the decisions to be agreed by the main bodies involved with land management more or less on a case by case basis. The following section is intended to provide some guidance in this process by providing maps of the key conservation areas, Rhododendron distribution and some estimate of likely costs.

11.3 Assessment of priority area by area

11.3.1 Mawddwy
A major eradication programme is a fairly low priority. The main conservation interest in the area is the Berwyn SAC and current work around Llanymawddwy is set to eliminate the main local seed sources. Real progress to clear this polygon will only be achieved if all the major stands around Dinas Mawddwy are eliminated. The cost is likely to exceed £0.5m. Much of the surrounding land is grassland and is relatively unsusceptible to rapid colonisation. However, there are also significant areas of conifer plantations. The long-term potential for colonisation is very high. Only a relatively small sum (£10K) would be required to eliminate most of the small clumps in clearings and on forestry tracks that are now starting to act as local seed sources within the woodland. This “holding operation” should be treated as a high priority.

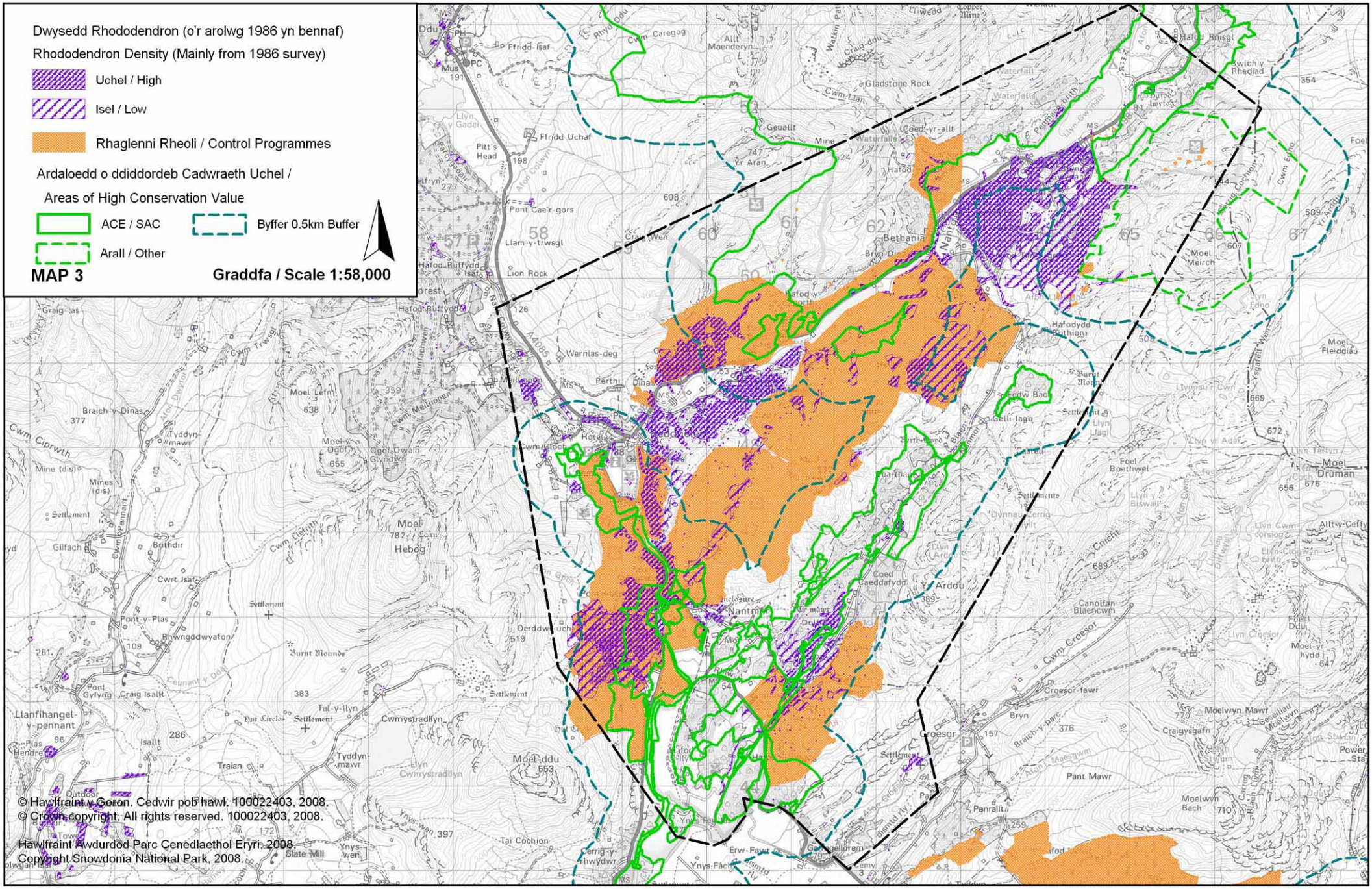
11.3.2 South Mawddach
Much of the Rhododendron in this catchment has recently been treated. Consolidation of this work is a high priority. The Gwynant valley is the area of the highest conservation value. The few remaining untreated stands in the vicinity are of high priority.

11.3.3 North Mawddach
This area contains several sites of exceptional conservation value notably around Ganllwyd and the Bontddu Gorge. Remaining untreated areas in their vicinity should be considered as very high priority. There is considerable potential to achieve major strategic gains in this polygon with budgets of £50- £100K as the area can be split into several discrete projects. A further reason to channel resources into this area is the apparent recent expansion of Rhododendron to the north of the woodland belt along the estuary. Scattered plants are appearing over several areas of heath up to several kilometres from the main seed sources. There is clearly a longer term threat to of colonisation of very large areas of heath along the southern edge of the Rhinogydd SAC. One complication of working in this area is the relatively large number of land holdings involved including numerous large gardens with mature Rhododendron between Barmouth and Bontddu. As with Mawddwy, clearance of Rhododendron along forestry tracks should also receive high priority.

11.3.4 Dyffryn Ffestiniog
The work here is at an advanced stage. The priority is to maintain these gains. Coed Hafod Boeth still requires a significant amount of work.

11.3.5 Glaslyn Gwynant.
This is undoubtedly the greatest challenge remaining in the Park despite significant gains. At the northern end of the polygon important areas of heath and woodland are threatened. Management to restore these features by reducing the grazing pressure is likely to be compromised by Rhododendron colonisation. Major projects costing hundreds of thousands of pounds will be required to achieve real progress. If resources on this scale are not available it is probably better to postpone treatment here in the short term. Consolidation of the existing work around Aberglaslyn, Craflwyn and Moelydd will be required. There are also some smaller high priority projects to complement this recent work.

In this area above all others, a strategic approach is desirable with the work taking place progressively across adjacent landholdings. Treatment of the extensive stands in Coed


Dwysedd Rhododendron (o'r arolwg 1986 yn bennaf)
Rhododendron Density (Mainly from 1986 survey)
Uchel / High
Isel / Low
Rhaglenni Rheoli / Control Programmes
Ardaloedd o ddiddordeb Cadwraeth Uchel /
Areas of High Conservation Value
ACE / SAC
Byffer 0.5km Buffer
Arall / Other
MAP 3
Graddfa / Scale 1:58,000
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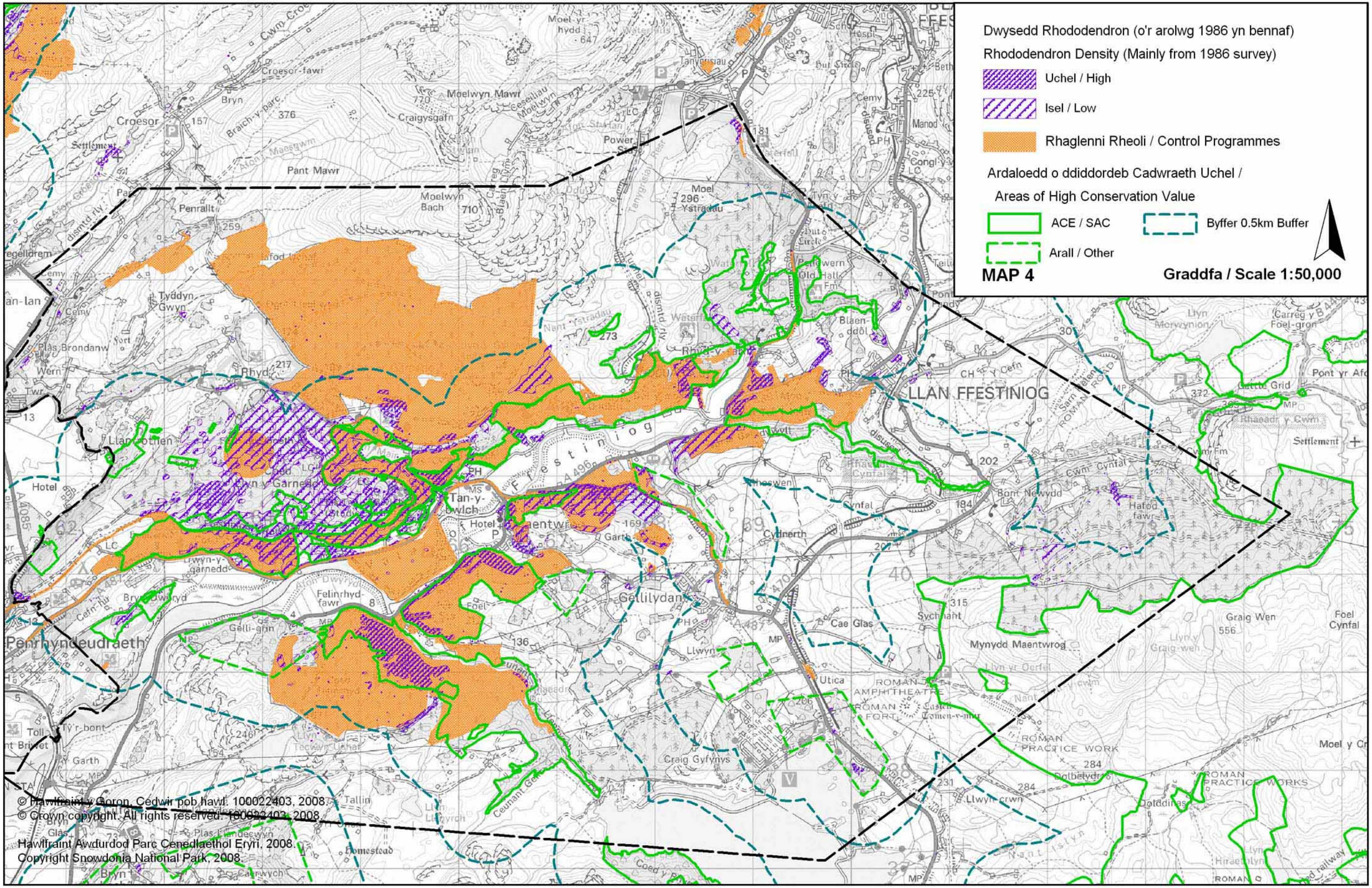

Dwysedd Rhododendron (o'r arolwg 1986 yn bennaf)
Rhododendron Density (Mainly from 1986 survey)
Uchel / High
Isel / Low
Rhaglenni Rheoli / Control Programmes
Ardaloedd o ddiddordeb Cadwraeth Uchel /
Areas of High Conservation Value
ACE / SAC
Byffer 0.5km Buffer
Arall / Other
MAP 4
Graddfa / Scale 1:50,000
LLAN FFESTINIOG
Penrhyndeudraeth
Tan-y-bwlch
Gellilydan
Maentwrog
Croesor
Moelwyn Mawr
Moelwyn Bach
Mynydd Maentwrog
Llanfrothen
Ffestiniog
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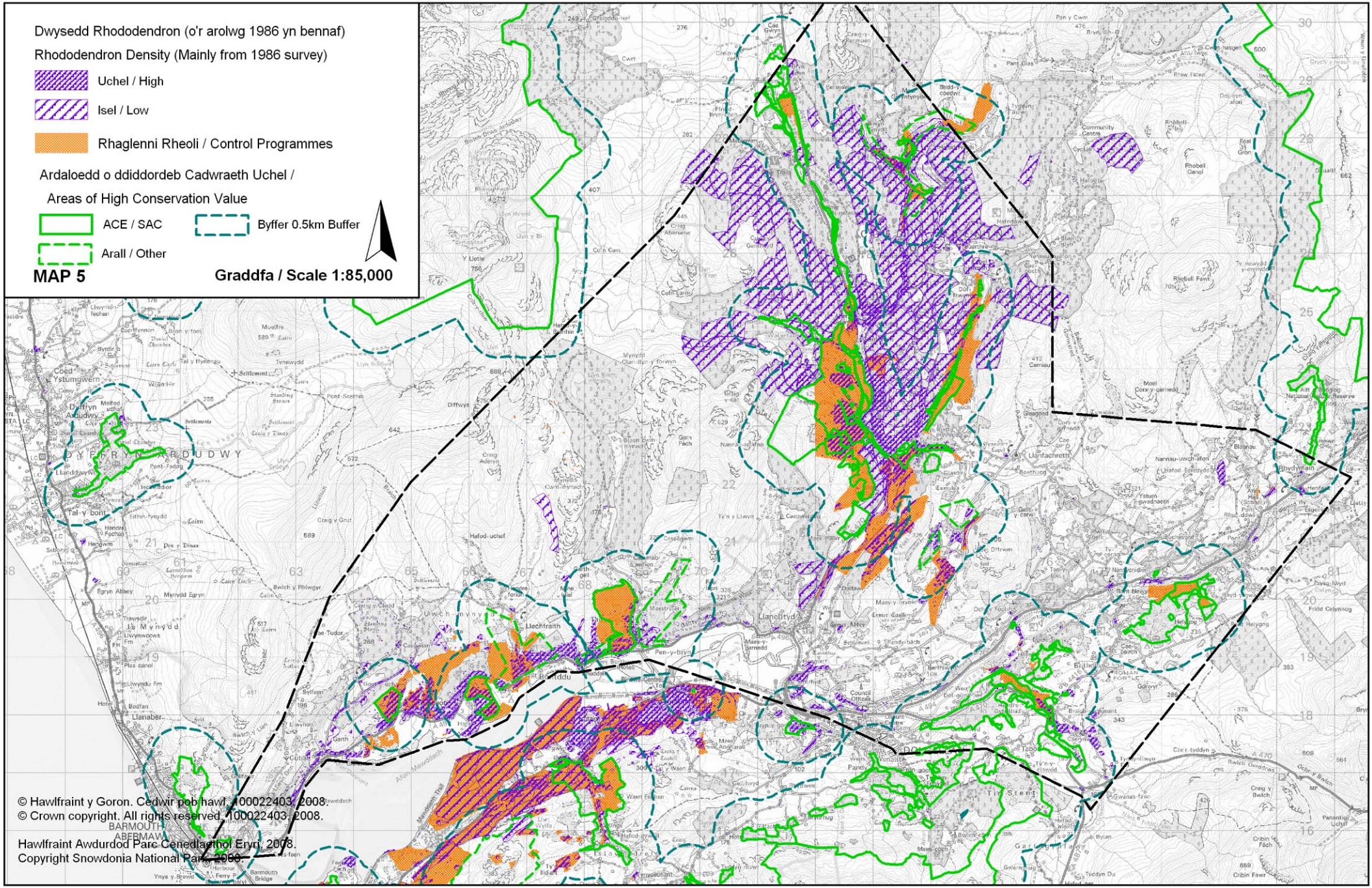
Dwysedd Rhododendron (o'r arolwg 1986 yn bennaf)
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Ardaloedd o ddiddordeb Cadwraeth Uchel /
Areas of High Conservation Value
ACE / SAC
Byffer 0.5km Buffer
Arall / Other
MAP 5
Graddfa / Scale 1:85,000
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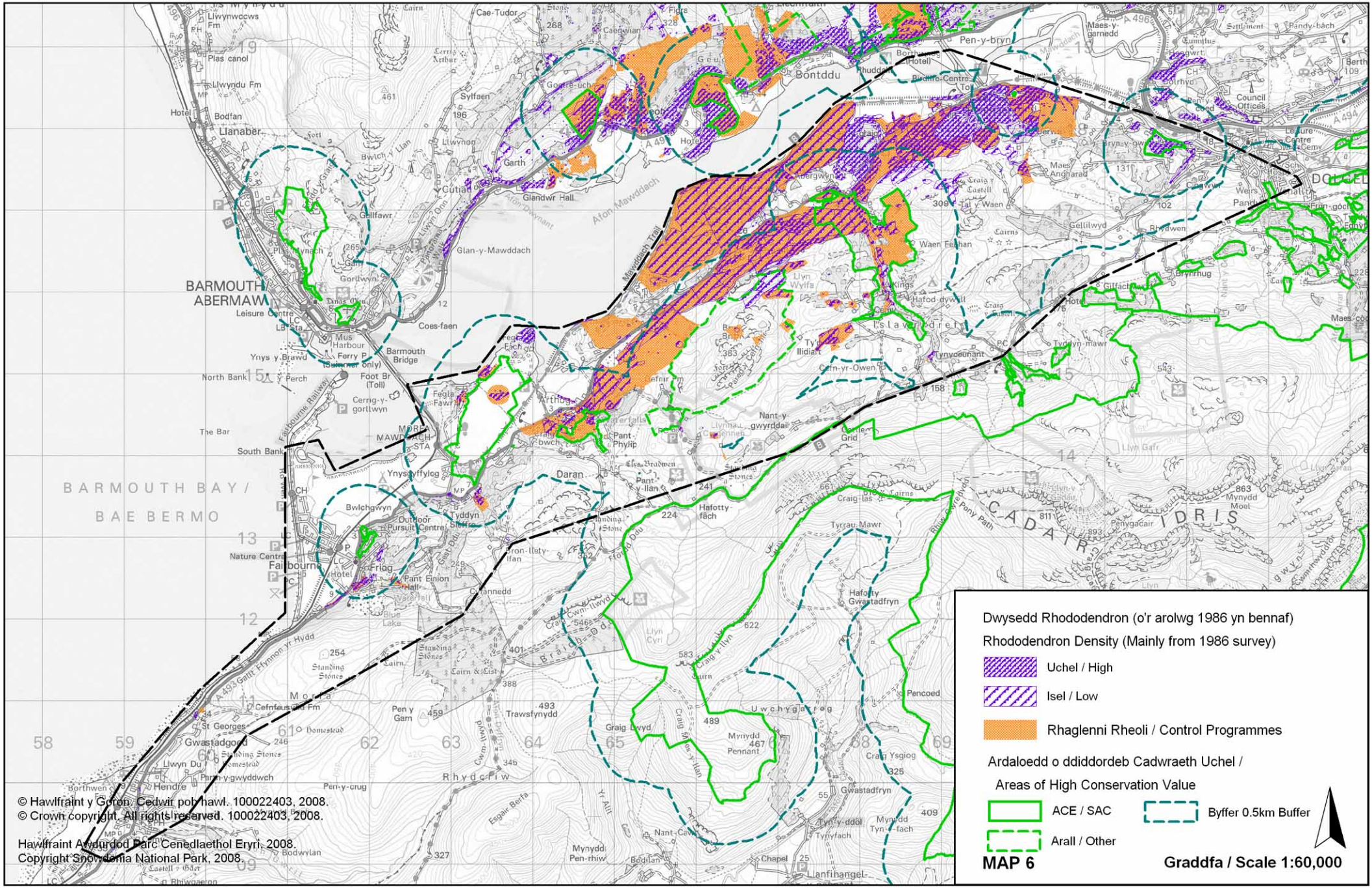
BARMOUTH
ABERMAWW
BARMOUTH BAY /
BAE BERMO
Dwysedd Rhododendron (o'r arolwg 1986 yn bennaf)
Rhododendron Density (Mainly from 1986 survey)
Uchel / High
Isel / Low
Rhaglenni Rheoli / Control Programmes
Ardaloedd o ddiddordeb Cadwraeth Uchel /
Areas of High Conservation Value
ACE / SAC
Byffer 0.5km Buffer
Arall / Other
MAP 6
Graddfa / Scale 1:60,000
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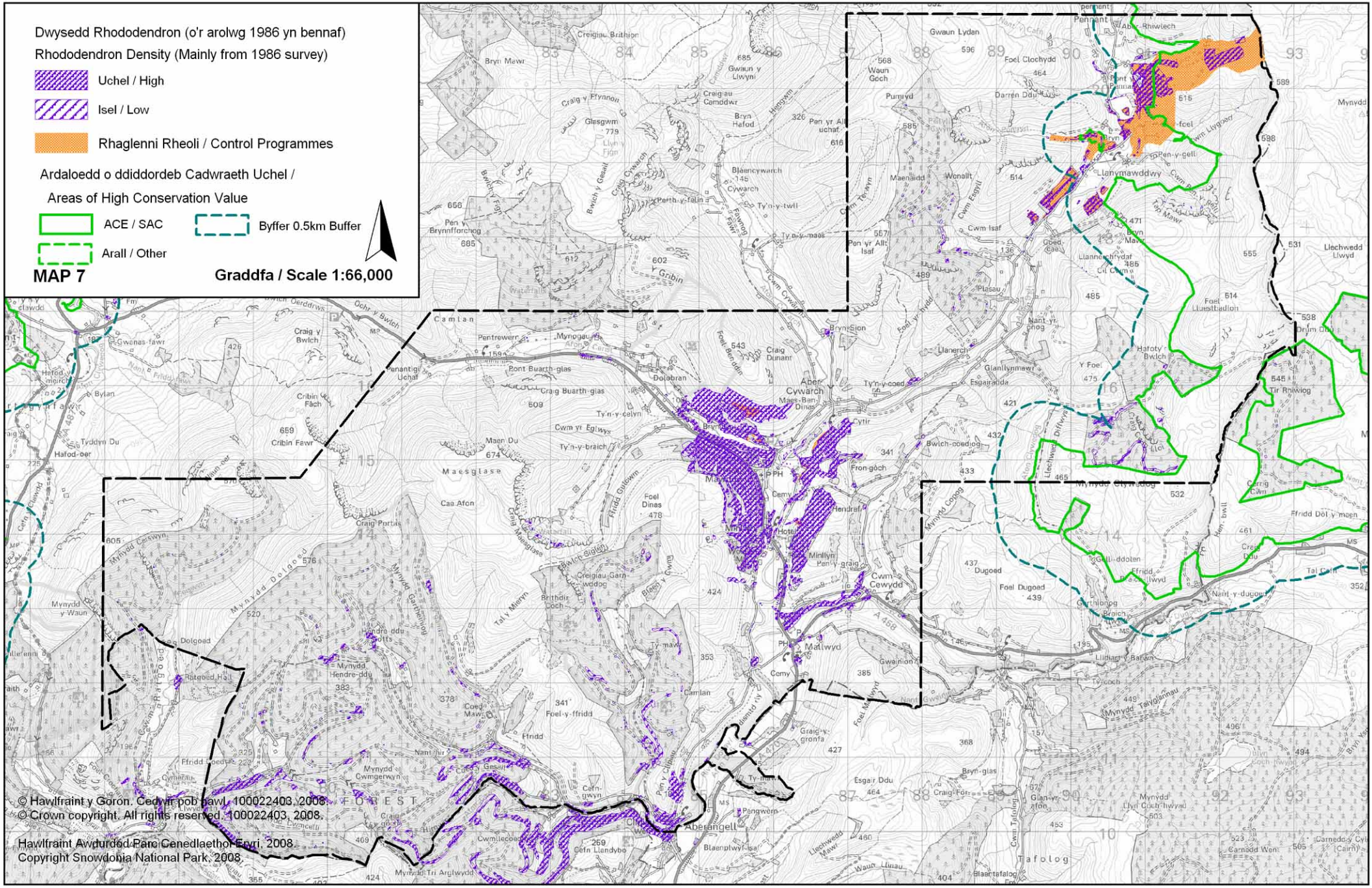
Dwysedd Rhododendron (o'r arolwg 1986 yn bennaf)
Rhododendron Density (Mainly from 1986 survey)
Uchel / High
Isel / Low
Rhaglenni Rheoli / Control Programmes
Ardaloedd o ddiddordeb Cadwraeth Uchel /
Areas of High Conservation Value
ACE / SAC
Byffer 0.5km Buffer
Arall / Other
MAP 7
Graddfa / Scale 1:66,000
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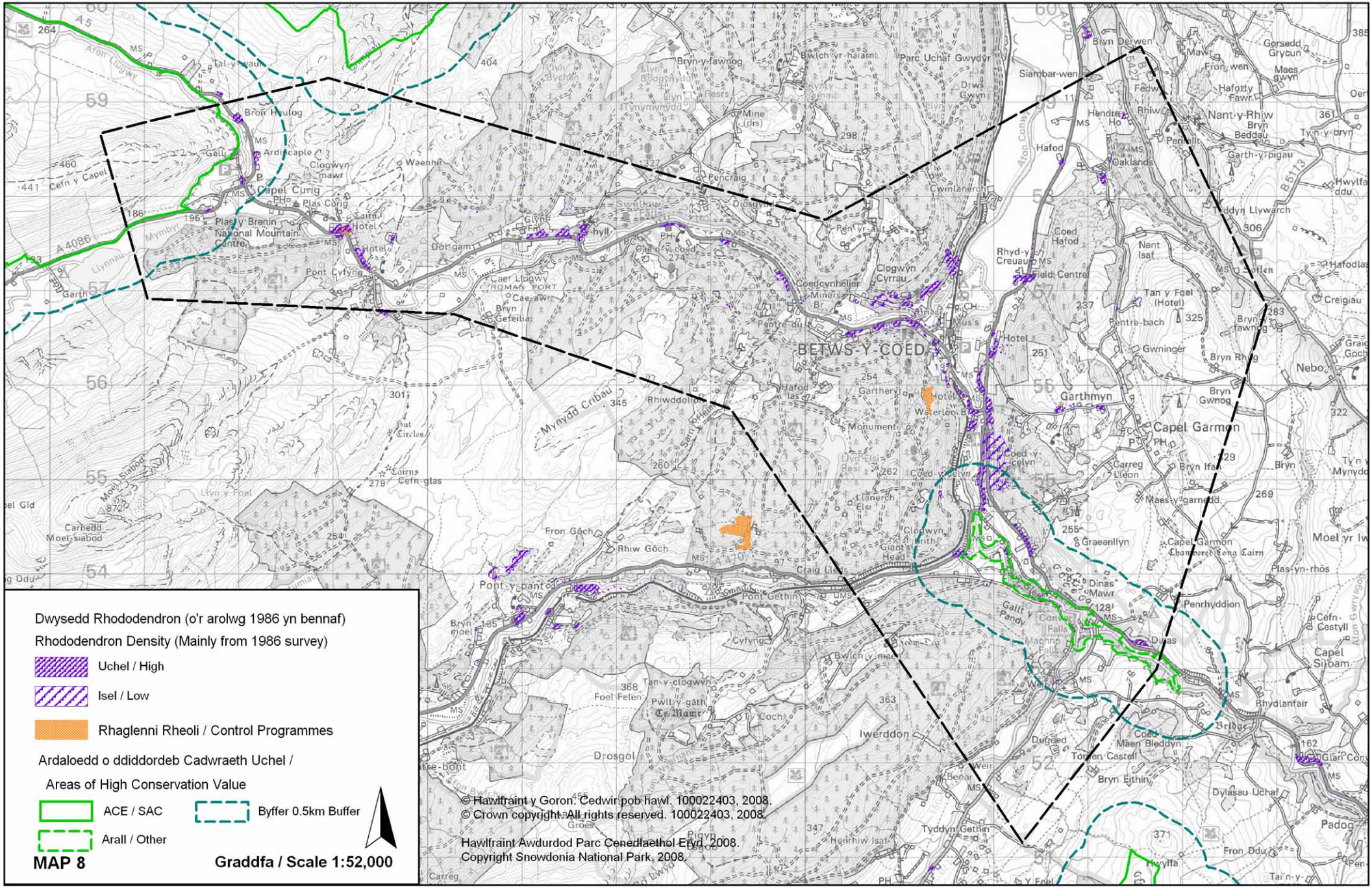
Dwysedd Rhododendron (o'r arolwg 1986 yn bennaf)
Rhododendron Density (Mainly from 1986 survey)
Uchel / High
Isel / Low
Rhaglenni Rheoli / Control Programmes
Ardaloedd o ddiddordeb Cadwraeth Uchel /
Areas of High Conservation Value
ACE / SAC
Byffer 0.5km Buffer
Arall / Other
MAP 8
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BETWS-Y-COED
Capel Garmon
Garthmyn
Nant-y-Rhiw
Pont Cyfyng
Capel Curig
Mynydd Cribau
Iwerddon
Drosgol

Eryr at the northern end of the polygon will be a key achievement. Coed Eryr's elevated position makes it a particularly significant seed source.

11.3.6 Betws y Coed

The amount of Rhododendron in this area is fairly low as is the apparent rate of colonisation. Forestry track clearance should be considered a priority

11.3.7 Other areas within the Park

Quite a few of the main stands outside the areas discussed above are associated in a lowland setting surrounded by improved or semi-improved grassland. As such the potential for significant expansion is low and these should be treated as low priority areas except where they are in the vicinity of habitats of high importance.

11.3.8 Areas adjacent to the Park

Although the stands around Blaenau Ffestiniog pose a relatively low threat to the recognised sites of high conservation value, this area should receive a relatively high priority. Colonisation of Rhododendron from the urban areas appears to be unusually rapid suggesting that the craggy and heathy hinterland is unusually susceptible to invasion. Postponing clearance here is likely to be costly as the invaded sites (old quarries, tips and crags) will be technically difficult to treat. Left untreated, this area could act as a source for the reinfestation of Dyffryn Ffestiniog in the longer term.

Corris and Aberangell, similarly, do not score highly for conservation interest and as such cannot be considered as priority areas. However, both should be treated as medium priority areas as they are surrounded by large areas of readily invaded coniferous woodland.

12. Strategy recommendations.

12.1 **A partnership should be set up in order to co-ordinate, monitor, promote and agree on priority areas for Rhododendron control within Snowdonia National Park and adjacent areas.**

The Partnership will draw its core members from the bodies that have the main strategic input into land management in the Park: Forestry Commission, CCW, WAG Agriculture Department and SNPA, and could also include others such as landowners involved in particular projects.

12.2 **The long-term aim of the Partnership should be to achieve effective Rhododendron control throughout Snowdonia National Park and adjacent areas, so that it no longer has a significant impact on or poses a threat to habitats and species of conservation interest**.

12.3 **Resources permitting the Partnership should be served by at least one full-time post**.

This is essential to maintain momentum and ensure continuity. The post should be jointly funded by the Partnership bodies and the post holder could be located within one of partner organisations.

12.4 **The Partnership will maintain GIS-based record of control programmes and surveys carried out by the partner bodies.**
The Partnership will have a commitment to cooperation and sharing information. This will foster a strategic approach, reduce the possibility that areas are overlooked, and will facilitate synchronisation of work where this is advantageous. Information gathered will also help clarify costs and identify best practice

12.5 **The Partnership should ensure that the consolidation and maintenance of the projects currently being undertaken with Objective 1 money are a priority in the next three years.**

12.6 **The Partnership should canvas/lobby to ensure that future grant structures and policies on Rhododendron control promote a strategic approach**.
Grants are a major driver of land management and an essential source of funds for Rhododendron control. The current system does not represent the most effective use of resources and has inconsistencies. Some suggested amendments are given in Table 7.

12.7 **The Partnership should try to secure financial assistance from Welsh Assembly Government in order to complement national grant schemes.**
Adequate resources for Rhododendron control are essential. It is unrealistic to expect that enough landowners will undertake voluntary or part funded work to achieve strategic control. The targets in the Environment Strategy cannot be met unless control is undertaken on a strategic basis.

12.8 **The Partnership should ensure that its constituent bodies each have a clear policy on Rhododendron.**

12.9 **The Partnership should encourage research on the effect of land management (e.g. stocking rates and silviculture) on Rhododendron spread, and this knowledge should be used, where appropriate, to ensure land management does not favour the spread of Rhododendron** .

12.10 **The Authority should make representations that Rhododendron (i.e. *Rhododendron ponticum* and its invasive hybrids) is added to Schedule 9 Pt 2 of the Countryside and Wildlife.**

12.11 **The Partnership should provide publicity and educational material about the threat posed by Rhododendron, guidance on control techniques, and information on the control programme.** The emphasis should be on inhabitants of the Park (especially those in the open countryside) although material should also be available to visitors.

12.12 **The SNPA, as a planning Authority, will provide advice on the control of Rhododendron and request a landscaping scheme when granting permission for development in areas where Rhododendron is known to be a problem.**

Table 7: Suggested amendments to Government grants and policies

Agriculture

Grant Scheme	All areas of Wales	Rhododendron Control Areas*
Tir Gofal	◙ Grant rate should reflect true costs and should be staged over 10 years with clearly defined performance targets ◙ No stock exclusion in woodlands where significant seed source is within 500m ◙ Landholder is expected to undertake maintenance phase control. Failure should be subject to financial penalty ◙Consider special project payments and use of contractors where cost of control is likely to exceed £10K unless landowner has proven experience ◙Provide advice for farmers undertaking control	◙ Rhododendron control should be mandatory ◙ Stocking level prescriptions should flexible (potential to use temporary high stock level as tool in control) ◙ Stock reduction should not be contemplated if there is a significant seed source within 1000m
Single Farm Payments		◙ Enforce GAEC rules about not allowing the spread of invasive species
Organic Conversion Scheme		◙Prior control and agreed rhododendron management plan before entrants are accepted ◙Stocking level prescriptions should flexible (potential to use temporary high stock level as tool in control)

Forestry

Grant Scheme	All areas of Wales	Rhododendron Control Areas*
Better Woodlands for Wales	◙ Clarification needed on rules about when Rhododendron represents a threat ◙ Grant payments should be reflect long-term nature of control and should be staged over 10 years with clearly defined performance targets. Separate category of “maintenance phase” operation should be introduced with clearly defined performance target.	◙Rhododendron control should be mandatory for all BWW grant recipients
Felling licences		◙ Presence of Rhododendron should be treated as a constraint when issuing felling licences.

* The impact of Rhododendron is localised even within Snowdonia, which is the worst affected region in Wales. Some policy and grant changes need only to apply to limited “Rhododendron control areas”. Ultimately, all severely affected areas should be so defined but the concept is flexible and could be restricted only to those areas where strategic control is being attempted.

Table 7: Suggested amendments to Government grants and policies

Appendix 1: Observations and discussion on factors controlling the spread of Rhododendron

A1.1 Effect of grazing

Study of the distribution of Rhododendron in the field reveals numerous instances where it is present on one side of a farm boundary and entirely absent on the other.

A1 Boundary between two holdings at Llanymawddwy (SH 914199). Frequent Vaccinium to the left of the fence suggest this side has a prolonged history of lighter grazing

A2 Boundary between two holdings at Arthog (SH 671161) Land on the right has had reduced stocking under Tir Cymen/ Tir Gofal

The obvious explanation for this is that the level of grazing is different on the two sides of the boundary. Some caution is necessary: present levels of grazing may be different from those that prevailed when the Rhododendron became established. Moreover, other aspects of management that are now longer obvious such as burning, reseeding or even control of Rhododendron may have occurred. However, there is supporting evidence to suggest that grazing is indeed the main factor. Rhododendron plants can occasionally be found in otherwise uncolonised land but only in places where sheep cannot reach such as islands, crags, upturned rootplates and stream margins.

Further evidence comes from observing the fate young seedlings in the winter. In a grassy sward, they show clear signs of being nibbled or disappear entirely. Not uncommonly, the uprooted seedlings or their stems are left on the surface of the grass. In experiments, in March 2006, seedlings were planted on either side of a fence, where one side was side was heavily grazed, the other very lightly grazed (occasional deer and trespassing sheep). All the Rhododendron seedlings (up to 3 years age) were eaten or uprooted from the grazed area within a few weeks of planting; most of the plants on the lightly grazed survived. It appears that the sheep graze the seedlings along with the palatable material (grasses, bilberry etc). The uprooted seedlings suggest that the shoots are not necessarily ingested.

A3 Abundant Rhododendron on sheep-free island at Llyn Wylfa, Arthog (SH671163). Major seed source at Garth Angharad 1km to W, smaller source Pant Hir 300m to N.

A4 Isolated Rhododendron on edge of steep stream. (SH913194) Llanymawddwy. Nearest seed source 500m to N.

A5 Rhododendron protected from grazing by adjacent rocks. Islaw'r Dref (SH676158)

A6 Browsing of mature Rhododendron along fence line, Llanymawddwy (SH906196)

Stock poisoning is a complex subject. Often, animals appear to learn which plants are poisonous and thus to avoid them. On this reasoning, grazing may play a particularly important role in holding back the colonisation front. A few seedlings appearing on otherwise unaffected holdings are perhaps more likely to be predated as the avoidance reaction has not been learnt by stock. The impact of grazing predation is greatest in acid grassland and degraded heath where the sward is short. Where the vegetation is taller and composed of heather, bilberry or *Molinia*, grazing appears to be a much less significant factor. Here, the seedlings tend to be below grazing height or are hidden until they become larger and thus more likely to be avoided by sheep.

Other authors have also reported a negative correlation between grazing and the establishment of Rhododendron. Thomson et al. (1993), who looked at factors affecting Rhododendron distribution in Nant Gwynant, similarly noted that sheep grazing and improved pasture inhibited the spread of Rhododendron. From the Pennines, Rotherham (1989) cites several examples where the invasion is apparently restricted by grazing (sheep, rabbits and fallow deer). Conversely, others regard grazing as an agent of disturbance a factor promoting Rhododendron expansion (Cross ,1981, Fuller & Boorman 1977, Shaw 1984, Gritten 1995) and thus a potential catalyst for invasion. Cross, in particular, regards overgrazing by deer as important.

Grazing animals have three distinct actions that have a potential impact on Rhododendron establishment:
1. Direct grazing and browsing on Rhododendron tissue.
2. Modification of the height and structure of the vegetation.
3. Creation of disturbance (trampling, dislodging of vegetation).

The first clearly has a negative impact on colonisation, the latter two potentially have a positive impact. Seedlings are more likely to be shaded out and their roots fail to reach a secure moisture source if the vegetation is rank. However, trampling could also obliterate seedlings.

In Snowdonia, there is no doubt that grazing has a negative impact on establishment and plays an important role in reducing the rate of spread of Rhododendron.

The implications for Rhododendron control are clear. In areas susceptible to invasion, grazing pressure should not be reduced. The impact of the change is likely to be greater where the sward is short. There is also potential to use increased grazing pressure to reduce seedling establishment in areas where Rhododendron control is being undertaken.

A1.2 Substrates and microsites

Rhododendron seeds are small with little in the way of food reserves. They require persistently favourable conditions in order to become established Cross (1973). The key requirements appear to be a continuously damp substrate. Reasonably high light levels are probably also important although seedlings are occasionally observed under a conifer canopy. Where there is competition from surrounding vegetation, the young plants, which remain small for several years, are likely to perish due to shading and or lack of

moisture. Observations in the field show that suitable conditions are very limited. Seedlings are abundant on some substrates at a site and rare or entirely absent on all others. In the Killarney woods, Cross (1981) found that germination only occurred successfully on bryophyte mats of less than 1cm depth. He surmised that desiccation of seedlings occurred where there was bare soil or the bryophyte layer was deeper. The present author's observations from Snowdonia broadly confirm this. Successful germination can occur on much deeper bryophyte mats notably *Leucobryum glaucum* and *Sphagnum* spp but these genera have remarkable water retaining capacities. Cushions of *Leucobryum glaucum* are a very highly favoured substrate.

A7 Two cohorts of seedlings on *Leucobryum glaucum*, near Afon Morfa (SH633134)

Successful germination can also occur on bare soil, in minute rock fissures and on damp tree bark. In each case, the microsites are appear to have permanent moisture and are reasonably well lit. Old tree stumps (see also Stevenson et al 2005) root plates and Molinia tussocks are also favoured sites. Grass sward (especially improved grassland), bracken, deep heather and woodland litter (conifer or broadleaved) are not favourable substrates. However, where there is an exceptionally high seed rain, seedlings can even become established in these sites.

A8. Seedlings establishing in acid grassland adjacent to major seed source, Llanymawddwy (SH194198)

A1.3 Slope and Aspect

Steeper sites are more likely to be colonised by Rhododendron (see 4.6). Various explanations may be adduced for this. In general steep sites are less likely to have intensive land use (improved pasture etc). They may also be other particular attributes e.g. local shade or shelter, inaccessibility to stock, bryophyte mats, continuous supply of soil moisture due to flushing, that increase the number of microsites.

One class of particularly favoured steep sites is steep banks along highways and forestry tracks. These commonly have Rhododendron even though the nearest seed sources are distant. Lack of grazing may be part of the explanation as to why these sites are favoured but the substrate of the presence of subsoil with a

thin bryophyte layer with constant soil moisture and good illumination is probably also important. In most cases the road engineering has occurred in the last twenty or thirty years. Once grasses, heather etc. become established these sites are likely to become less easily colonised.

.

A9 Rhododendron in gully, Nant y Benglog, Talyllyn (SH742122). Nearest seed source is 1200m to the SW at Dol-y-cae

Gullies and ravines are clearly favoured sites but whether this is primarily because they offer more niches protected from grazing, more shelter from desiccation, or contain more flushed soils is not clear.

The influence of aspect is less obvious in the field. However, occasionally, as at Cefn Hir (SH670160) an area just beginning to be colonised, slopes with a northerly aspect do seem to be the sites where pioneer plants occur. Northerly aspects are presumably favoured since they are less prone to desiccation by the sun. There may also be more shelter from prevailing winds.

A1.4 Dispersal

A1.4.1 Wind

Wind is likely to be the main vector in seed spread, as described in 3.3.1. The distances involved appear to be greater than those theoretically calculated. Some seedlings occur over two kilometres from any known seed source. In the Mawddwy area there are numerous examples of isolated bushes occurring on sites in plantations that are away from tracks and are free from stock (e.g Photo A10). Transport by wind appears to be the most likely explanation.

A10: Isolated Rhododendron in (stock-free) plantation, Llechwedd y Lloi, Mawddwy (SH911161). Nearest seed sources 3 km to NW or 4 km to W.

Simple seed dispersion models do not fully take account of the long tail in the distribution curve. The relative role of extreme winds is not easily incorporated into models. For a rugged landscape like Snowdonia, local topography is also a factor, producing local turbulence and thermal uplift that will tend to promote dispersal.

It is a reasonable assumption that there will be greater dispersal from stands high on the valley side compared to those in the valley bottom in sheltered woodlands. However, the data from Snowdonia presents a complex picture. For example, scattered bushes occur in Nant Iago and the scree of Mynydd Cedris (SH69850775) at 250m altitude. The nearest known seed sources are in the valley bottom in village gardens in Abergynolwyn 2km to west or 2km to the east at Ty'n y Gornel.

The prevailing wind direction has often been invoked to explain the distribution pattern of spread. While it undoubtedly must have some influence, the evidence in the field is quite mixed and shows spread taking place against the prevailing direction as well.

A1.3.2 Stock
Transport of seeds by farm stock is possible but there is no evidence that it is of major significance.

A1.3.3 Vehicles
It is plausible that vehicles travelling under seed shedding stands will be a vector in dispersing seeds. Where the road surface is unsealed such as forestry tracks, the mud collected and then lost on the underside of the vehicle is even more likely to be a significant vector.

There is little evidence as to the importance of this vector. There are a few instances of roadside Rhododendrons very remote from any known (even minor) seed source, where vehicular transport is the most plausible explanation.

A1.3.4 Water
Linear riparian stands of Rhododendron are common. Fluvial dispersal of seed is highly likely.

Appendix 2: Surveys of Rhododendron distribution in Snowdonia National Park.

A2.1 Early surveys

An initial survey of the Park was carried out at the beginning of the eighties using park wardens and volunteers. Presence/absence was noted for each one-kilometre**.**

A2.2 1986 (Horseback) Survey

A Park-wide survey undertaken by Lucy Rees in the winter of 1985/1986 on horseback with aid of binoculars at a 1:25000 scale. Red dots were drawn on the map to indicate location of individual bushes or clumps. More extensive areas of Rhododendron appear to be represented schematically by the density of the dot pattern**.** The survey protocol no longer exists**.**

This data was visually digitised in 2006. Four classes of Rhododendron infestation were inferred on the on the basis of dot density:
3 (very dense): dots at < 25m spacing (almost contiguous dots)
2 (dense): dot spacing 25-50m (20%-75% of area covered with red dots)
1 (low density): dot spacing over 50m (typically 20% of area covered with red dots)
I (isolated plants), dot spacing >150m

The survey provides a remarkable overview of Rhododendron distribution in 1986. The data should be regarded as a conservative estimate. Kilometre squares where not identified in the early survey were not necessarily surveyed. The surveyor believed that many young plants in mountain areas and those in impenetrable conifer plantations must have been missed (Gritten 1987). More detailed recent surveys confirm this to be the case, however they also demonstrate that the survey data is of generally of high quality and accuracy and includes all the major stands.

A2.3 Mawddwy survey

The area around Dinas Mawddwy, Aberangell and Llanymawddwy was surveyed at a 1:10000 scale using a mountain bike by Ashley Gauton in 2005.

Rhododendron was mapped according to classes devised by Edwards (2006) to prioritise areas for treatment based on bush form and treatment. Some additional data on accessibility, land use and bush morphology were also recorded. This data has been subsequently digitised. Density and treatment attributes have been inferred from the Edward's classes, additional data and subsequent limited field observations. Each record has been assigned to one of four nominal density classes as in the horseback survey. Unfortunately, density of stands was not directly recorded.

Recent field work has shown this survey contains several minor inaccuracies and omissions. Isolated bushes occur over a wider area than recorded.

A2.4 Invasive Species Project

Survey work carried out by Peter Jackson in 2006-2008 with the aim of getting a detailed understanding of likely costs and pattern of distribution in areas selected for treatment. Mapping was undertaken, largely on foot, at a 1: 5000 scale. Seven density classes were recorded:
A: over 75% cover
B: 50-75% cover
C: 25-50% cover
D: 10-25% cover
E: 2-10% cover
F: Scattered (typically 10-20 plants per ha)
I: Isolated bushes.
(Absence also recorded)

Information on the bush form/ favoured treatment type was also collected:
1: Bushes suitable for foliar spraying
2: Bushes too large for foliar spraying, where initial cutting is required
3: Bushes too large for foliar spraying, where initial cutting is required and where the cut material needs to be dealt with by burning or chipping
4: Bushes (typically large) well suited to stem treatment
5: Bushes on sites requiring roped access.

Whether or not the area had been previously treated was also recorded. Photographic records were also made.
This survey covers only limited areas where work under the Invasive Species Project is currently taking place or is proposed. A few additional records of isolated upland plants collected by Park staff have also been included. Further sample surveys elsewhere in the Park for monitoring purposes are currently being undertaken.

A2.5 Other surveys

Smaller areas of the Park, notably the Nant Gwynant – Beddgelert area have been the subject of academic studies on Rhododendron distribution and spread (e.g. see Thomson et al. 1993).

Appendix 3: Model of costs of control

A3.1 Basis of model
This model is based on the 1986 survey. Despite subsequent changes and shortcomings, the data is considered to give a good indication of the overall distribution and density of Rhododendron throughout the Park. The model simply analyses the total area of Rhododendron infested land of each inferred density class and multiplies this by a nominal cost. The mode assumes there has been some increase in Rhododendron over the twenty years since the survey, so that the nominal costs below are slightly higher than typical contemporary clearance costs.

Density Class	**Nominal Cost per hectare (to achieve initial clearance and consolidation phases)**
1 (low)	**£2000**
2 (medium)	**£4000**
3 (high)	**£7000**
I (isolated) Each dot	**£500** (assumes that several scattered plants are present)

The six major polygons (areas) of infestation have been analysed separately.

Gross costs based on the 1986 survey are shown in Column I. These have been adjusted to take account of the clearance work already undertaken whose cost (inflation adjusted) is known (Column E) or estimated (Column G). Column E includes sums for longer term contracts for period 2008-2013.

Maintenance phase costs. These are based on a nominal cost of £50 per hectare to search for and treat Rhododendron. The search effort would be concentrated in areas which are most likely to be invaded, i.e. woodland (70% of rhododendron occurs there). The figure for the search area is based on the total area of woodland within 500m of any area or point recorded for each polygon in the 1986 survey with Rhododendron (Column C). Where there are major areas of Rhododendron away from woodland areas (e.g. Glaslyn - Gwynant), the area to be included in the maintenance phase has been increased by a nominal amount based on field observations (Column D).

A 3.2 Validating the model
For some areas, it has been possible to gather detailed information on the historical and recent costs of control. The area of the remaining untreated stands is also known, or is small. It is thus possible to test the validity of the model. The fact that the area of Rhododendron has increased since 1986 is not important, this can be allowed for in the costs. However, it is has to be assumed that relative increase has been reasonably uniform.

A3.3 Results of validation
The results are shown in the table below.

Comparison of the model costs with cost data for cleared areas gives a good match. The Dyffryn Ffestiniog polygon where the clearance programme is the most complete gives a very close match. For other areas, the cost from the model is slightly higher than “actual” costs.

A3.3 Limitations
The model should be regarded as indicative only. There are several areas of uncertainty.
1. The 1986 survey is dated and not entirely comprehensive. The density classes have been inferred from the data and were not mapped as such.
2. Knowledge of costs and areas treated is incomplete.
3. Some historical costs are based on grants rather than actual costs. Actual costs may be more or less than the cost specified in the grant.
4. There is no survey information some significant stands outside the Park boundary (e.g. Blaenau Ffestiniog, Corris)

A3.4 Conclusions
The costs provided by the model agree well with the available information on historical costs and suggest that the total cost of control is likely to be under £10M. This is a significantly lower figure than previous estimates. The greatest area of uncertainty concerns the cost of maintenance phase.

Column	A	B	C	D	E	F	G	H	I	J	K	
Polygon Name	Total Area of Polygon (ha)	Area of Rhodo 1986 (ha)	Maintenance area (0.5km buffer for woodland area) (ha)	Nominal area requiring maintenance (ha) corrected for non-woodland areas	Documented Historical Cost (at 2008 prices) and current contracts(£K)	Estimate of Additional (Undocumented) Historical Cost (£K)	Ground Estimate of cost of treating remaining areas (£K)	Total Cost (£K) *(Columns E+F+G)*	Estimated Cost from Model (£K)	Estimated intial and follow-up costs taking account of known cleared areas(£) *(Columns I-(E+F))*	Maintenance Cost (first 5 years)(£K) *(Column D*£50)*	TOTAL (£K) *(Columns J+K)*
Betws y Coed	4250	40	1400	1500		20			250	230	75	**305**
Glaslyn -Gwynant	4930	528	800	3000	158	300			2,500	2,042	150	**2192**
Dyffryn Ffestiniog	6730	212	2000	2500	793	200	85		1,150	157	125	**282**
N Mawddach	12670	372	3850	4000	100	300			2,050	1,650	200	**1850**
S Mawddach	3670	292	800	1000	583	61	310		1,200	556	50	**606**
Mawddwy	9301	205	1640	2000	113	50			1250	1,087	100	**1187**
All other areas		271		5000					1,700	1,700	250	**1950**
Total		1920			1747	931			10,100	7,422	950	**8372**
Model validation								*"Actual" cost*	*Model cost*			
S Mawddach		*292*			*583*	*61*	*310*	*954*	*1,200*			
Dyffryn Ffestiniog		*212*			*793*	*200*	*85*	*1078*	*1,150*			
Aberglaslyn/Oerddwr ISP		*41*			*158*	*10*	*2*	*170*	*209*			
Llanymawddwy		*25*			*131*	*26*	*2*	*159*	*171*			
FC land in S Maw		*75*			*84*	*25*	*20*	*129*	*169*			
SNPA land in S Maw		*33*			*122*	*30*	*5*	*157*	*196*			

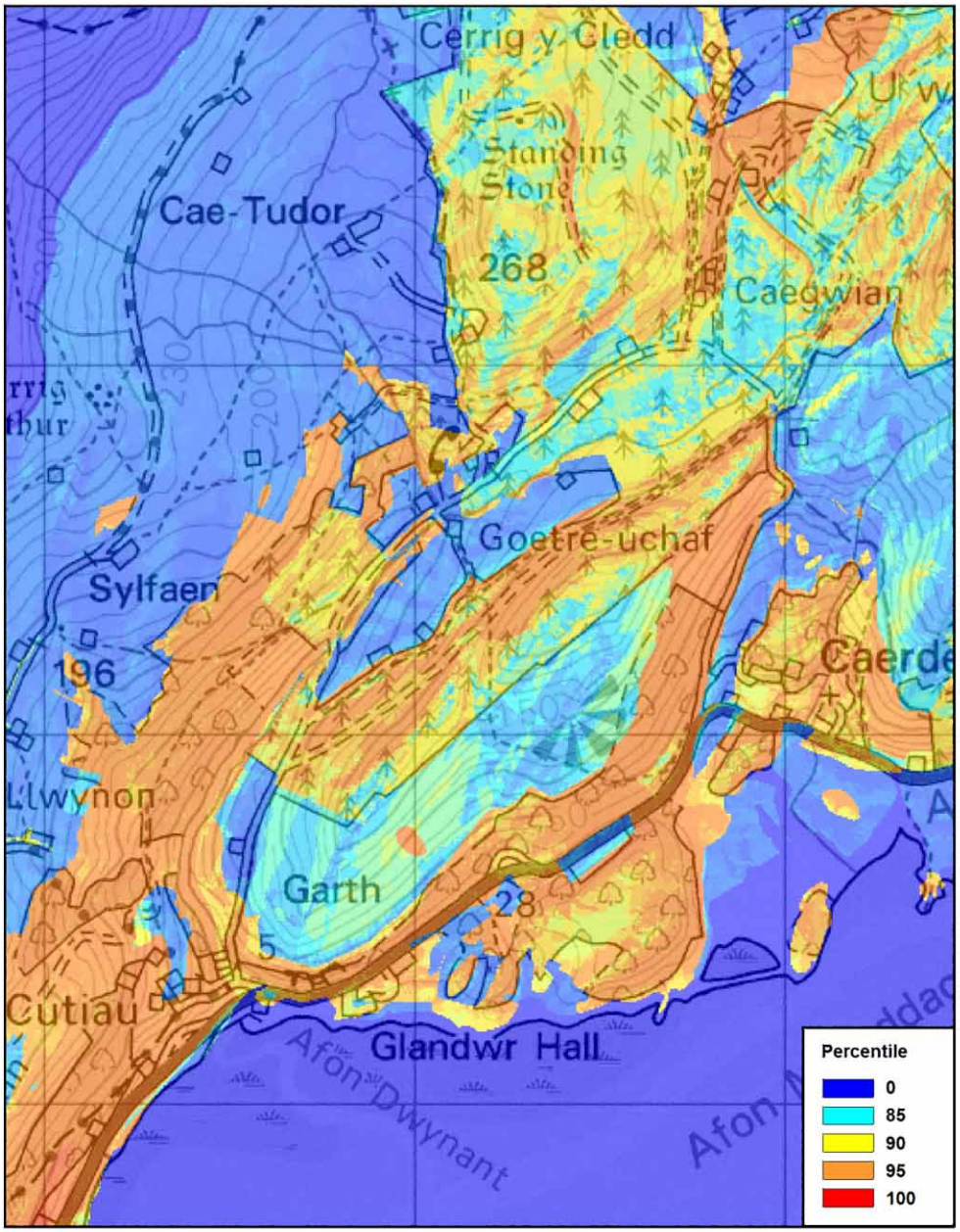
Table of historical, estimated and predicted costs of Rhododendron control in Snowdonia

Appendix 4 GIS Modelling of Susceptibility to Rhododendron Invasion

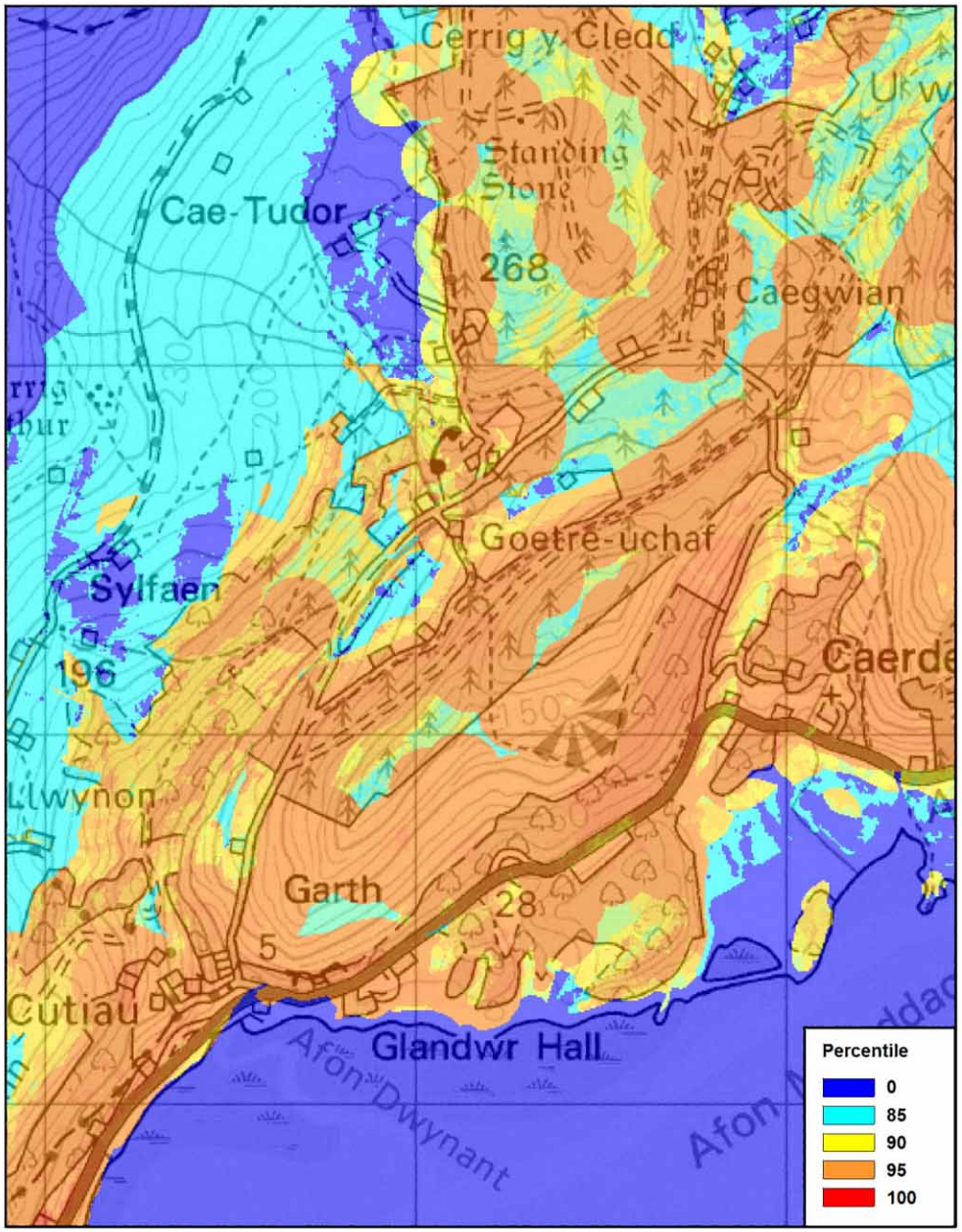
The relationship of the distribution of Rhododendron with respect to landscape variations of vegetation, slope and aspect can be used as a tool to predict which areas are most susceptible to invasion by Rhododendron. A numerical weighting or probability can be assigned for each attribute based on the data in Tables 2 and 3. The product of these figures gives an overall score which shows the susceptibility of the landscape to invasion by Rhododendron. This model can also be used to predict where Rhododendron is likely to spread by combining the susceptibility data with models of local seed rain based on surveys of present Rhododendron distribution.

Maps showing the results are potentially useful in deciding priorities for work programmes. Examples are shown below.

Susceptibility of habitat to invasion by Rhododendron



Predicted pattern of spread by Rhododendron



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