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Rhododendron survey: control costs and priority.

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Outline of Presentation

- Cost of Control in Argyll & Bute
- Stages in the spread of Rhododendron
- Setting the Control Priorities
  - Ranked priority in Argyll & Bute
  - Within site priority

Methods of control

Decision chart - to identify the recommended control methods for bushes of a specific type (see table 1).

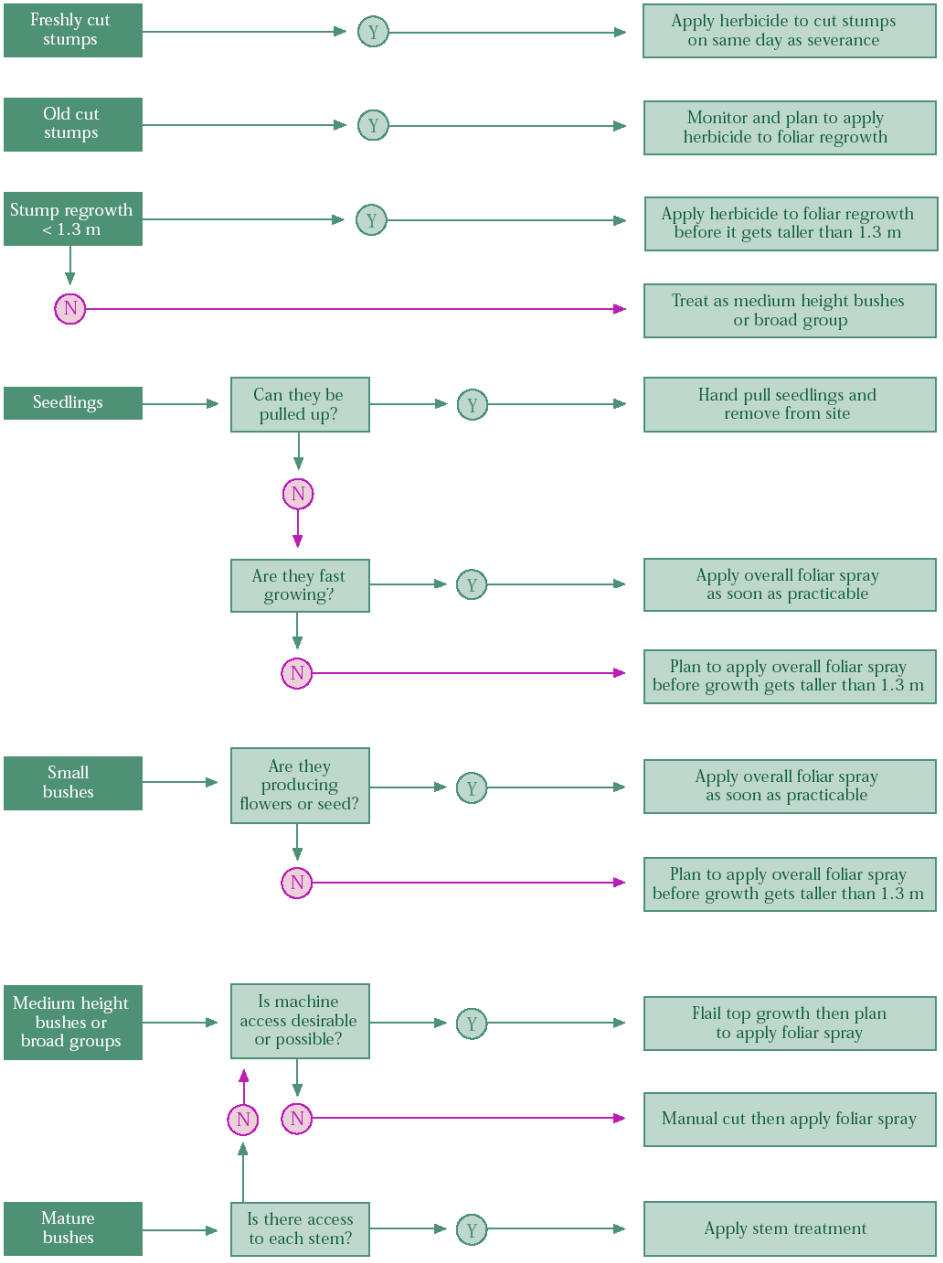

Table 3 Cost breakdown used in Argyll and Bute analysis

Cover Class	Bush conditions	Treatment to achieve bush eradication[a]
Dense	• Bush density assumed to be 100% on all sites in this class. • Bushes are all > 2.5 m tall therefore can not be treated with an overall foliar application. • We have assumed 80% of sites in this cover class must be hand cut before being treated with herbicide. • The remaining 20% of sites can be stem treated.	• On 80% of sites: Hand cut and burn [b] all live material > 1.5 m, plus immediate cut stump treatment on same day as severance for all bushes in year 1. • Follow-up foliar spray to regrowth from 20% of stumps (on 80% of sites) in year 2. • On 20% of sites: Stem treat with glyphosate (25% solution) in year 1. • Then assumes 50% of sites that have been stem treated must be cleared of dead bushes in the year following successful control. Tractor flail used at £200 ha^{-1} on 'flat' and 'slight slopes', chainsaw cutting and burning at £2,500 ha^{-1} on 'sever slopes'. • Remaining 50% can be left as dead standing wood and allowed to rot.
Sporadic	• Bush density assumed to be 80% on all sites in this class. • Bushes are all < 2.5 m tall therefore can not be treated with an overall foliar application.	• Hand cut and burn [b] all live material > 1.5 m, plus immediate cut stump treatment in same day as severance on all bushes in year 1. Plus foliar spray in year 2. • Follow-up foliar spray to regrowth from 20% of stumps in year 3.
Scattered	• Bush density assumed to be 50% on all sites in this class. • Bushes scattered over the area, so transporting water and herbicide solution will be a major factor. • Bushes are all < 1.5 m tall therefore can be treated with an overall foliar application.	• Overall foliar application to all live bushes > 0.5 m tall, but < 1.5 m tall in year 1. • Follow-up foliar spray to regrowth from 20% of stumps in year 2.
Control	• Bush density assumed to be variable in this class. • Assumed that control operations have been 75% successful on flat and slight slopes, and 100% un-successful on all severe slopes. • Bushes are all < 1.5 m tall therefore can be treated with an overall foliar application. • A delay in treating some of these sites will allow bushes to grow beyond 1.5 m threshold for foliar spray, therefore 45% will require hand-cutting before foliar spray.	• Hand cut and burn [b] all live material > 1.5 m, plus immediate cut stump treatment in same day as severance on all bushes in year 1. Plus foliar spray in year 2. • Follow-up foliar spray to regrowth from 20% of stumps in year 3.

Cost model used

Cost per treated hectare of rhododendron.

	Type of Bush Cover				
Severity of slope[a]	**Dense**	**Sporadic**	**Scattered**	**Control [b]**	**Average cost**
Flat (<15 degrees)	£4,009.09	£3,401.78	£376.89	£419.97	£2,051.93
Slight (15-30 degrees)	£4,385.76	£3,718.09	£451.67	£503.29	£2,264.70
Severe (>30 degrees)	£15,018.62	£13,031.82	£645.45	£719.21	£7,353.78
Coastal areas	£12,302.28	£5,931.56	£1,500.00	£504.13	£5,059.49
Average cost	**£8,928.94**	**£6,520.81**	**£743.50**	**£590.42**	**£4,195.92**

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Total cost to eradicate current populations

	Type of Bush Cover				
Severity of slope [a]	**Dense**	**Sporadic**	**Scattered**	**Control [b]**	**Grand Total**
Flat (<15 degrees)	£1,414,127	£1,556,964	£444,252	£226,102	£3,641,445
Slight (15-30 degrees)	£1,325,208	£1,156,361	£429,443	£78,158	£2,989170
Severe (>30 degrees)	£255,070	£373,522	£63,224	£274	£692,091
Coastal areas	£1,721,166	£113,150	£141,743	£7,177	£1,983,236
Grand Total	**£4,715,571**	**£3,199,998**	**£1,078,662**	**£311,744**	**£9,305,942**

Cost of eradication after 20 years invasion

	Type of Bush Cover			
Severity of slope [a]	**Dense**	**Sporadic**	**Scattered**	**Grand Total**
Flat (<15 degrees)	£3,261,550	£3,769,566	£1,057,786	£8,088,902
Slight (15-30 degrees)	£2,743,177	£2,352,215	£880,852	£5,976,243
Severe (>30 degrees)	£545,160	£778,308	£122,130	£1,445,597
Coastal areas	£3,103,684	£215,683	£259,626	£3,578,993
Grand Total	**£9,653,571**	**£7,115,772**	**£2,320,393**	**£19,089,735**

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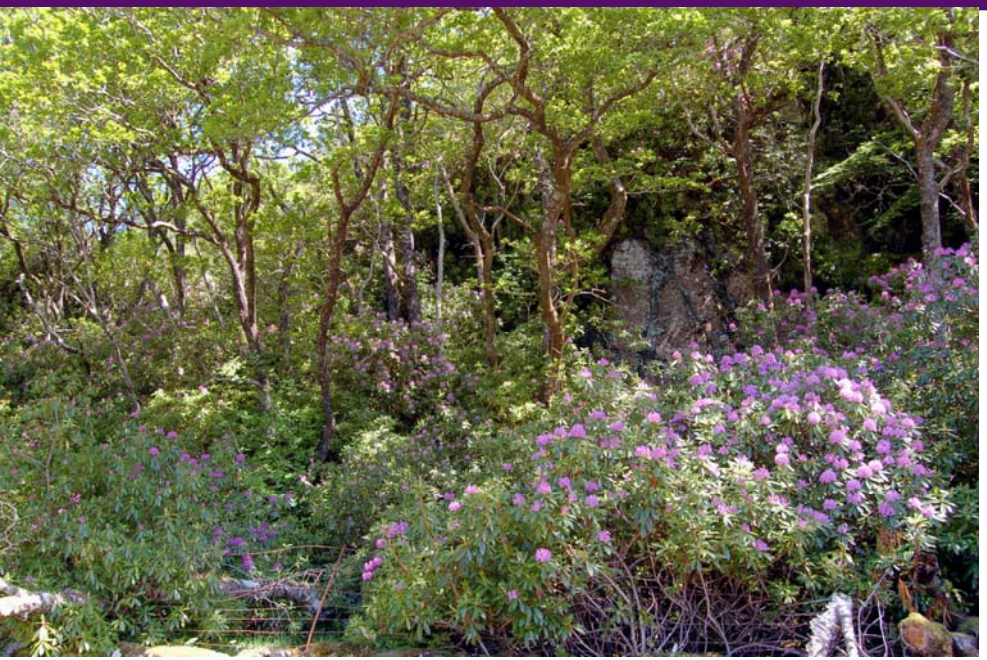
Cost of eradication after 50 years invasion



	Type of Bush Cover			
Severity of slope [a]	**Dense**	**Sporadic**	**Scattered**	**Grand Total**
Flat (<15 degrees)	£11,923,020	£15,388,899	£3,262,663	£30,574,583
Slight (15-30 degrees)	£8,519,395	£8,690,776	£2,448,081	£19,658,252
Severe (>30 degrees)	£1,601,303	£2,711,643	£340,389	£4,653,335
Coastal areas	£7,809,089	£700,337	£629,682	£9,139,107
Grand Total	**£29,852,808**	**£27,491,655**	**£6,680,814**	**£64,025,277**

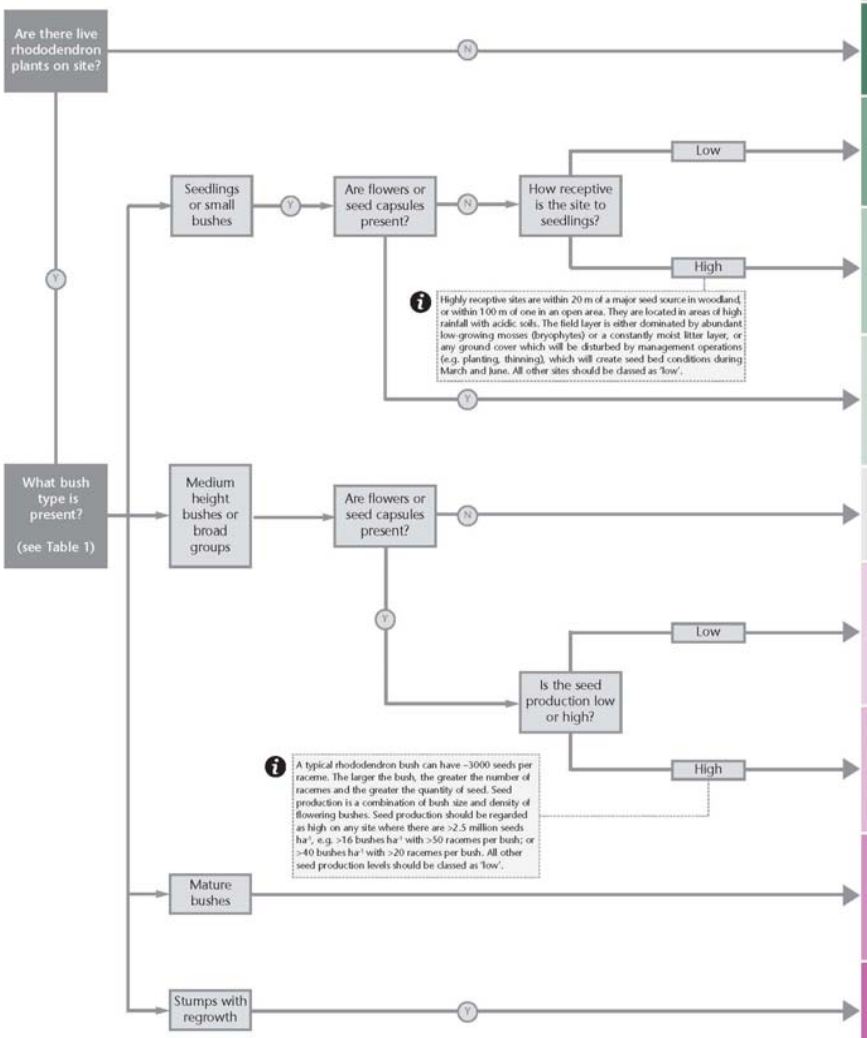
Stages in the spread of invasive rhododendron

Stages in the spread of invasive rhododendron, the factors that encourage spread, and the appropriate management responses (Adapted from Hobbs and Humphries, 1995).

Stage of invasion	Rhododendron status in habitat	Factors encouraging spread	Appropriate management response
Initial invasion of a new environment	Not present.	Seed dispersal from local seed source, or long distance assisted dispersal.	Prevent or reduce invasion by eradication of seed source. Reduce receptivity of site to minimise further invasion. Control invading plants.
Adaptation and establishment *Scattered*	Localised populations of small seedlings vulnerable to desiccation, trampling and competition from vigorous vegetation.	Adjustment to local conditions. Selection for invasive attributes. Developing links with local biota.	Early detection (eradication priority stage if within designated habitat). Later stages suitable for hand-pulling.
Exponential growth *Sporadic*	Multiple populations, exponential increases in affected area, and increases in bush size and density.	Dispersal from established plants, site disturbance. Mismanagement through inappropriate or late management/control.	Integrated chemical control, starting with seed sources. Management of ecosystem dynamics. Assessing socio-economic drivers (control priority stage).
Dominance *Dense*	Large, widespread problem, loss of natural habitat features, lowering of biodiversity.	As above, but populations approaching carrying capacity of the environment, stem layering allows expansion into areas not available to seed germination (i.e., dense bracken).	Massive inputs needed for effective control. Eradication priority stage, seed sources main target for control.

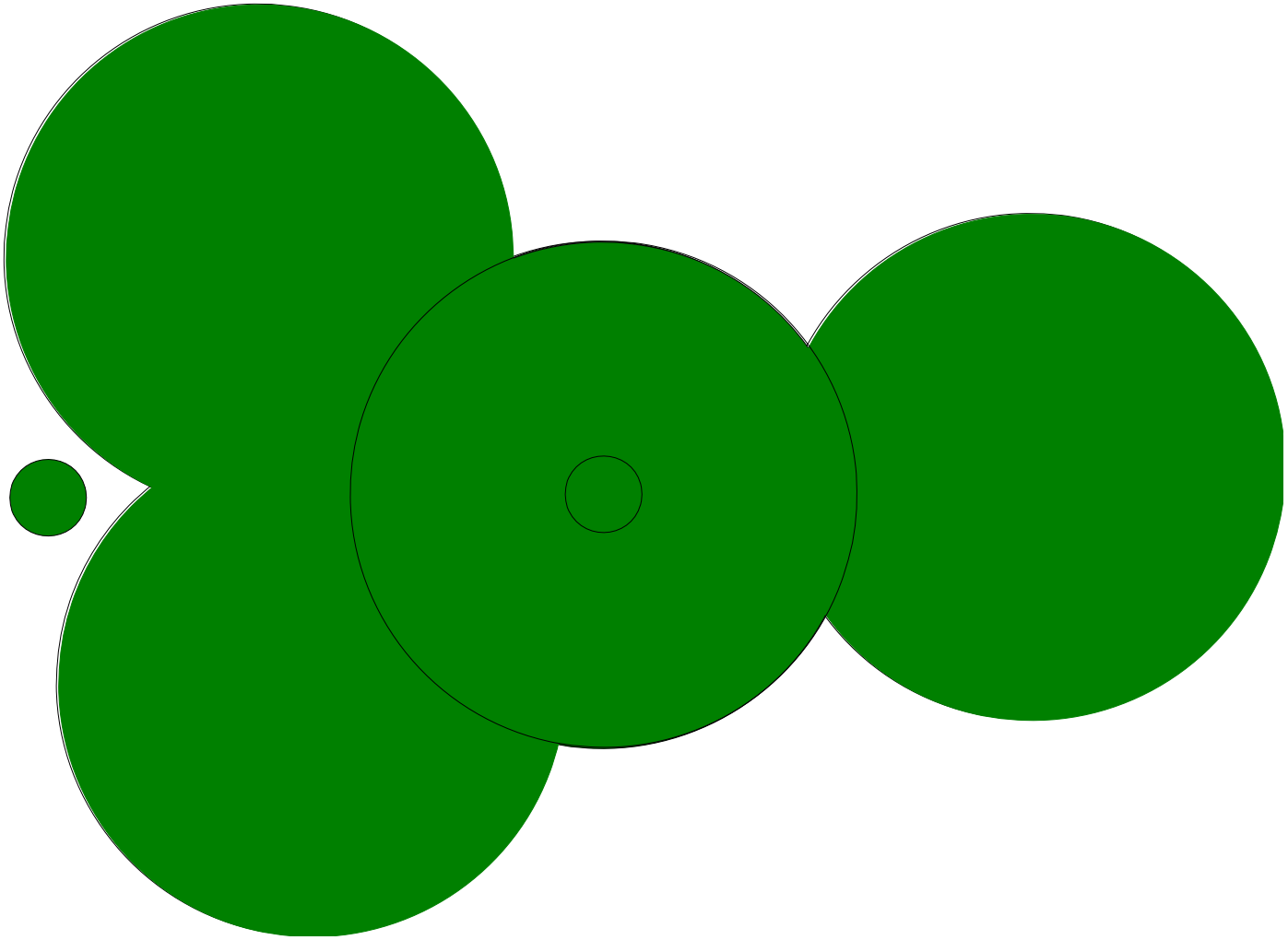
Figure 15 – deciding control priority

Figure 15 Description of the site, site class, potential site development, and suggested priority and control options.



Class	Detailed site description	Potential site development	Priority for control
0	Site clear of bushes.	Ensure sites remain clear of seedlings if adjacent to Site classes IV–VII by avoiding major disturbance events that will create favourable conditions for seedling establishment.	No control required.
I	Sites that are poorly receptive to seed influx, germination and establishment of bushes. Bush growth likely to be very slow (see Box 1) and age to flowering extended. Bush densities likely to be low, usually an expanding margin onto an unsuitable habitat for major rhododendron growth.	Unlikely to develop beyond Site class III.	Very low priority sites that are easily treated by foliar applications with herbicide. Small bushes and small seedlings can be easily pulled by hand.
II	Sites that are highly receptive to seed influx, good for germination and establishment of bushes. Probably recently disturbed sites, or sites with ground cover of thin layered bryophytes. Current bush growth rapid (Box 1), but still early in stage of bush development, >6 years before seed production and further expansion expected.	Will develop in time into Site class IV which then requires bush removal before herbicide control is possible.	Low-priority sites that are easy to treat but should not be left too long or they will be too large to treat without cutting down. Size currently within limits for overall foliar applications with herbicides, unless caught early likely to be too large to hand pull.
III	Sites that are acting as minor seed sources, dispersal and potential establishment of bushes onto adjacent sites very low. Bush growth slow (Box 1) and mainly vegetative, although a few flowers produced annually. Likely at limits for bush survival, either on excessively dry or wet soils, high pH or exposed sites. Seed production low.	Should not be left if very close to recently cleared receptive sites. Unlikely to develop into Site class V unless major site changes.	Medium-priority sites that are easy to treat, but should be left until higher priority sites cleared. Size within limits for overall applications.
IV	Sites that are highly receptive to seed influx and potentially new germination and establishment of bushes. Bush growth rapid with <4 years to flowering age likely (Box 1). Late in stage of bush development with limited time before seed production.	Will rapidly become Site class V.	Medium-priority sites with bushes that are too large to treat without cutting down. Size outwith limits for overall applications, some cutting, or flailing required before herbicides can be applied.
V	Sites that are acting as minor seed sources, dispersal and potential new establishment of bushes onto adjacent sites low. Bush growth rapid although flowering still only partial. Seed production low, but potential for increase in subsequently years. Likely to be under dense shade from a tree canopy, which if reduced or completely removed will result in rapid growth and onset of flowering.	Likely to develop rapidly into Site class VI or VII. Should not be left if very close to recently cleared receptive sites.	High priority sites that are not easy to treat, but can be left while still producing few seeds until higher priority Site classes VI and VII cleared. Size outwith limits for overall applications, some cutting or flailing required before herbicides can be applied.
VI	Sites occupied by mature bushes that are acting as a major seed source. Bush growth rapid, with a high stem density and/or complete canopy cover. Seed dispersal and potential new establishment of bushes onto adjacent sites very high. Seed production high, 750K–1.5 million seeds bush⁻¹ year⁻¹.	Expected to develop rapidly into Site class VII. Should not be left if very close to recently cleared receptive sites.	Second highest priority sites that are not easy to treat but should be cleared first along with Site class VII. Access to stems not always possible to allow stem treatment treatment. Size outwith limits for overall applications, some cutting or flailing required before herbicide can be applied.
VII	Very mature sites that are acting as major seed sources, dispersal and potential new establishment of bushes onto adjacent sites very high. Bush growth into woody stage, probably associated with an overstorey of trees. Seed production high, 750K–1.5 million seeds bush⁻¹ year⁻¹.	Should not be left if very close to recently cleared receptive sites.	Highest priority sites that are not easy to treat unless stem treated, should be cleared initially along with any Site class VI. Size outwith limits for overall applications, some cutting or flailing required before herbicide can be applied. Stem treatment application of herbicide possible on these bushes, avoiding having to cut down bushes before control.
VIII	Foliar regrowth from stumps originally classed as III, IV, V, VI or VII.	Should not be allowed to develop to a height >1.3 m or to begin flowering. Flowering will begin when regrowth is 2 or 3 years old. Shoot elongation likely to be rapid: 20–40 cm yr⁻¹ (Box 1).	High priority. Treat using a foliar regrowth application before shoots reach 1.3 m height. Once shoot regrowth is >1.3 m its size will be outwith limits for overall applications, some cutting or flailing would then be required before herbicide can be applied.

Classification system - priority classes



Classification system - priority classes

Priority category [a]	Class	Scoring system [b] A	B	C	No. meta-Populations [c]
Previous bush control	Yes	2	3	6	34
	No	1	1	1	169
Presence of roads	Yes	2	3	6	84
	No	1	1	1	119
Bush cover type [d]	Control only	6	6	6	14
	Dense	5	5	5	36
	Mixed + dense	4	4	4	19
	Sporadic	3	3	3	48
	Mixed – dense	2	2	2	6
	Scattered	1	1	1	80
Conservation status [e]	>60%	10	8	6	39
	40-59%	8	6	4	28
	20-39%	6	4	3	40
	>0%<20%	4	2	2	46
	0%	1	1	1	50

[a] Final priority score of a given rhododendron metapopulation is the product of the four priority category scores (previous bush control * presence of roads * bush cover type * conservation status).

[b] Three score weights were used to assess sensitivity of the final priority to the relative contribution of each priority category. Score A and B weight conservation status higher than the other priority categories, while score C gives equal weight to each priority category (i.e., all have maximum score of 6).

[c] Category system devised to ensure >5 metapopulations per class.

[d] Bush cover type is based on the relative area contribution of a bush cover type to the uncontrolled rhododendron area: control only (0% uncontrolled), dense (dense >60%); mixed + dense (sporadic <60%, scattered <60%, dense >0%<60%); sporadic (sporadic >60%); mixed – dense (sporadic <60%, scattered <60%, dense 0%); scattered (scattered >60%).

[e] Area of metapopulation in a designated site (Ancient Woodland, SAC, SPA, SSSI, National Park)

Classification system - priority classes

- A priority score (PS) was calculated from the category scores as:

$$PS = control\ score * road\ score * cover\ score * conservation\ score$$

- Metapopulation priority scores were ranked, in five classes (Highest priority given to top 20% PS).

Priority sites: sensitivity analysis

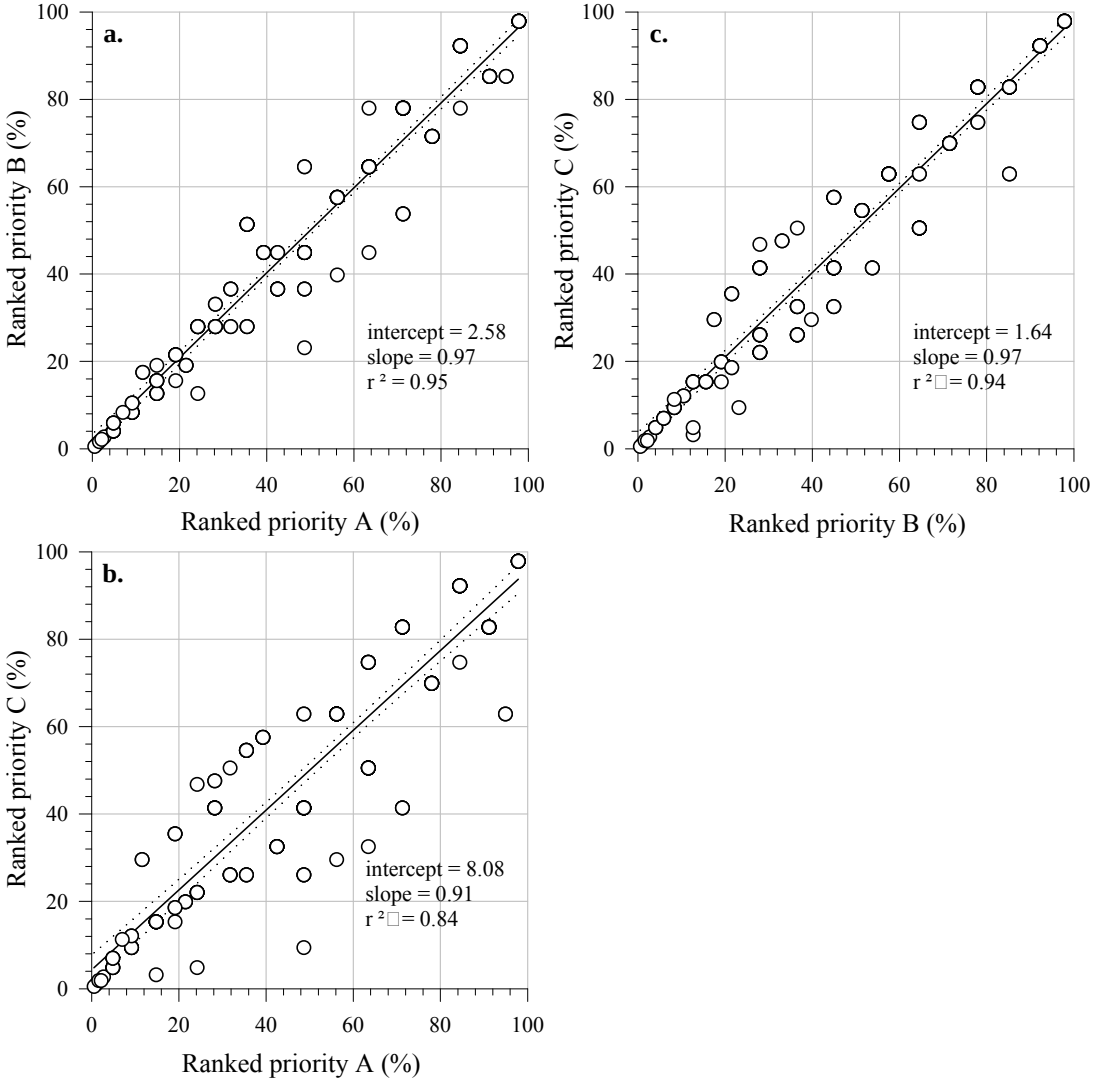
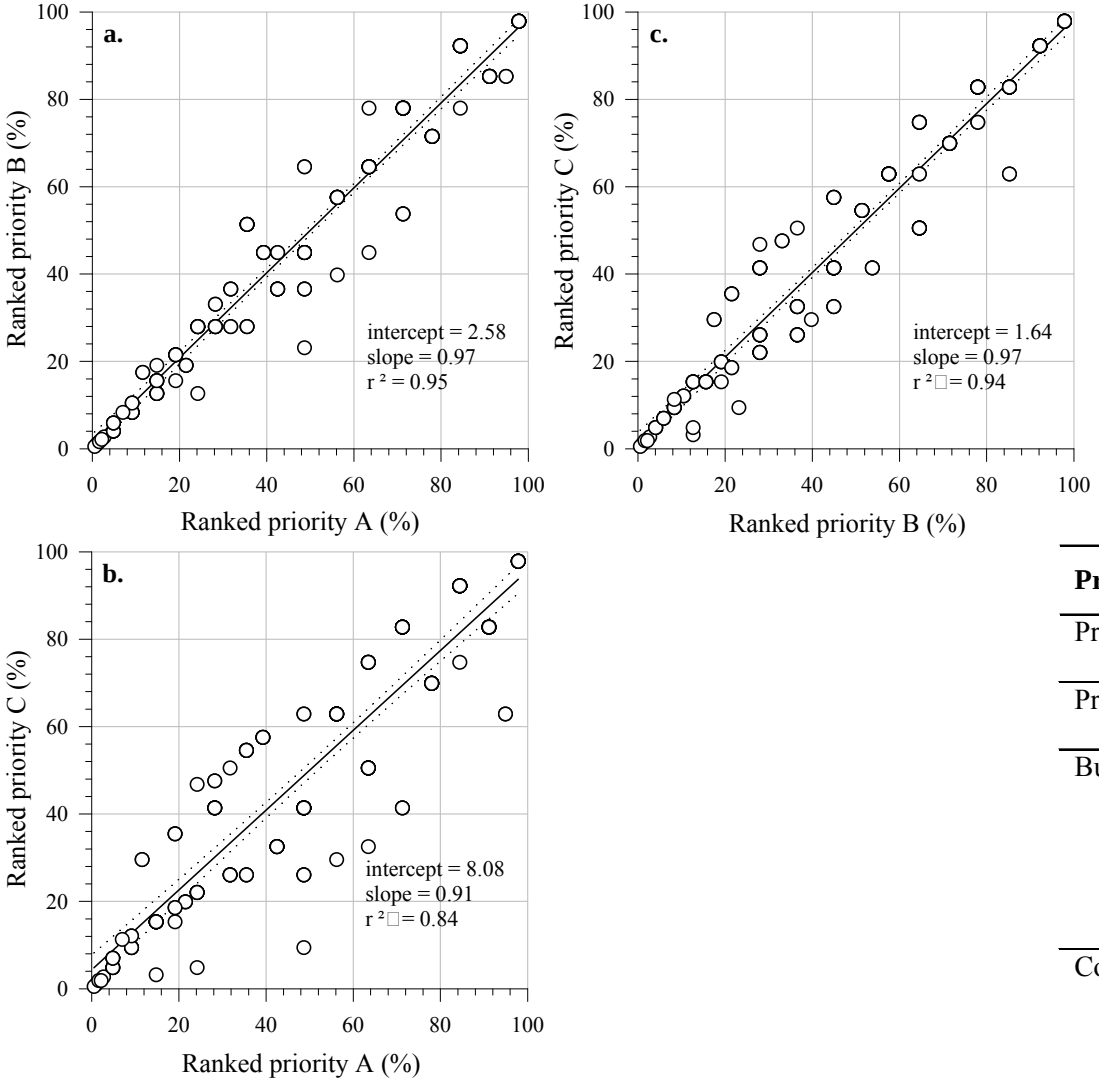


Figure 12. Sensitivity of ranked priority to modifications of the priority category scores:
(a) A vs B, (b) A vs C, and (c) B vs C. Grey gridlines denote 20% ranked priority classes
(b) used for comparative analysis in figure 13. See Table 13 for the scoring system.

Priority sites: sensitivity analysis



Priority category [a]	Class	Scoring system [b] A	B	C
Previous bush control	Yes	2	3	6
	No	1	1	1
Presence of roads	Yes	2	3	6
	No	1	1	1
Bush cover type [d]	Control only	6	6	6
	Dense	5	5	5
	Mixed + dense	4	4	4
	Sporadic	3	3	3
	Mixed – dense	2	2	2
	Scattered	1	1	1
Conservation status [e]	>60%	10	8	6
	40-59%	8	6	4
	20-39%	6	4	3
	>0%<20%	4	2	2
	0%	1	1	1

Figure 12. Sensitivity of ranked priority to modifications of the priority category scores:
(a) A vs B, (b) A vs C, and (c) B vs C. Grey gridlines denote 20% ranked priority classes
(b) used for comparative analysis in figure 13. See Table 13 for the scoring system.

Ranked Priority in Argyll & Bute

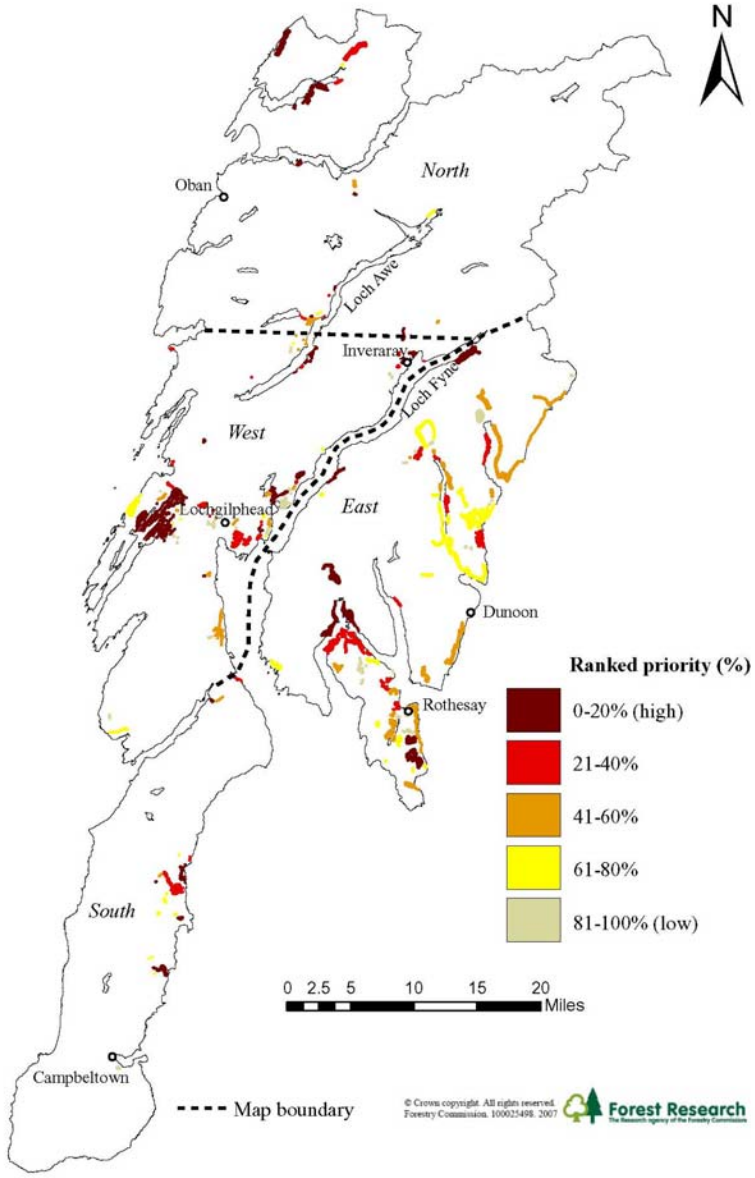
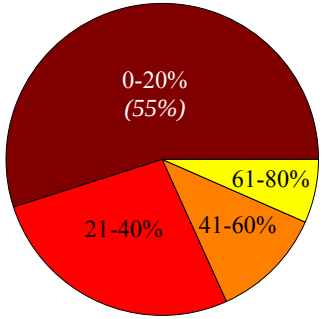


Figure 14. The distribution of rhododendron metapopulations by ranked priority across mainland Argylll and Bute. Based on the information in scoring system B of Table 13.

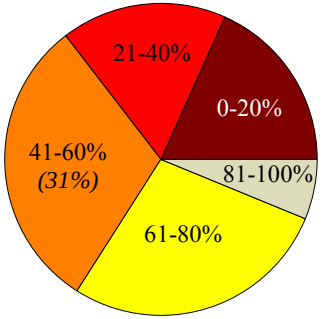
a. *North*

(1279 ha metapopulation with 415 ha rhododendron)



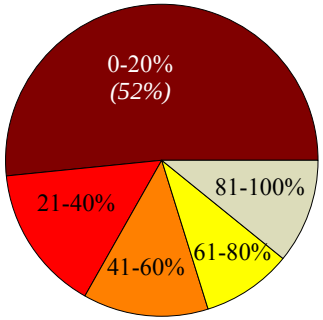
b. *East*

(8808 ha metapopulation with 2950 ha rhododendron)



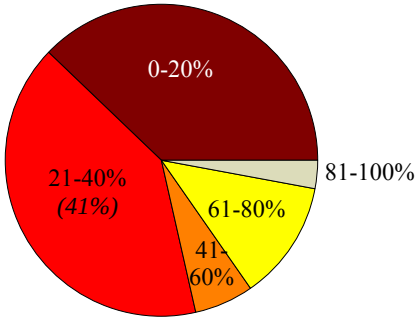
c. *West*

(4070 ha metapopulation with 960 ha rhododendron)



d. *South*

(848 ha metapopulation with 84 ha rhododendron)



Priority within individual control programmes

First order sites: - **those with recently cut stumps**.

Second order sites: - **designated woodland habitats (i.e., SSSI's, SPA's, and SAC's) that have mature flowering bushes within them.**

Third order sites: - **mature seed sources in any strategic eradication area. The tallest/oldest bushes should be treated first.**

Fourth order sites:- **bushes within 10 m of any transport routes, especially those that connect areas of seed producing bushes with sensitive habitats.**

Final order sites: - **minor seed producing sites, or non-flowering bushes**.

We recommend that where possible in sensitive sites or habitats only, seedlings younger than 10 years (or < 60 cm height) should be eradicated before they can cause damage to the native vegetation sward.

Conclusions

- To eradicate current 4,600 ha = > £9.3 million
- Increasing to > £19 million in 2028
- Increasing to > £64 million in 2058
- Priority Score *(previous bush control * presence of roads * bush cover type * conservation status)* would benefit from addition of other factors not available at time of survey (e.g. location of *Phytophthora* outbreaks, non-woodland *rhododendron*,).