PROGRESS TOWARDS ERADICATION OF *RHODODENDRON PONTICUM* ON LUNDY

by

STEPHEN G. COMPTON[1], ROGER S. KEY[2] AND STEVE PRATT[3]

[1] School of Biology, University of Leeds, Leeds, LS2 9JT

[2] The Old Black Bull, Carthorpe, North Yorkshire, DL8 2LD

[3] Landmark Trust, The Quay, Lundy Shore Office, Bideford, EX39 2LY

[1] *Corresponding author, e-mail: s.g.a.compton@leeds.ac.uk*

ABSTRACT

Control of rhododendron on Lundy accelerated from the 1990s after recruitment of specialist climbers and a ranger. Rhododendron's 'Achilles heel' is a lack of a persistent seed bank and long-term prevention of flowering is therefore key to eventual eradication. Larger rhododendrons have now all been cut and herbicide-treated and any remaining plants that flower are targeted for rapid removal. No individuals are believed to have set seed for about four years and the number of plants that remain alive is being reduced each year. Eradication is now achievable if vigilance can be maintained each year for a least another decade.

Keywords: *Lundy, rhododendron, eradication, invasive species*

INTRODUCTION

'I expect if you or I could look down a hundred or two hundred years hence, we would find either that the island was one mass of rhododendron, or that … (volunteers) … were having a busy time with their machetes trying to keep it down.' (M.C. Harman, owner of Lundy in the 1950s, quoted by Gillham, 2007). In this paper we describe the efforts that have taken place to ensure that this pessimistic view does not become a reality.

ALIEN PLANTS AND ISLANDS

Invasive alien species are increasingly recognised as a significant threat to biodiversity globally (McGeoch *et al.*, 2010), and they are the most frequent cause of extinctions of endemic species on islands (Kueffera *et al.*, 2010). Invasive plants compete for light and space with native species and can also alter ecological processes such as the frequency of fires (Mack *et al.*, 2000). Invasive plants are difficult to eradicate. They often form persistent seed banks in the soil and can be very hard to find once they are reduced to low densities (Mack and Lonsdale, 2002). Plant eradication programmes also typically take ten years or more to be successful and consequently depend on long-term commitments from control agencies (Panetta, 2007). Despite this, the list of successful plant eradications is growing, especially from islands. Seven alien plant species have been eradicated from Raoul Island, New Zealand (West, 2002), as well as other islands in the Pacific. These successes have not been repeated in Europe where, apart from very

small scale clearances, no successful eradication of any alien plant has been recorded (Genovesi, 2005). Effective eradication efforts necessitate accurate mapping of target populations to determine appropriate prioritisation of search efforts, repeated cycles of efficient searches and detailed recording of both the effort involved and the numbers of plants being destroyed (West, 2002). In particular, for plants that reproduce sexually, seed production must be effectively eliminated during the eradication process, otherwise control efforts may need to continue for decades (Zamora *et al.,* 1989).

RHODODENDRON AND ITS CONTROL

Rhododendron ponticum is an introduced ornamental species, native to Spain and Turkey. At least some U.K. populations of rhododendron display evidence of hybridisation with other cultivated species, and this may have increased its cold hardiness (Milne and Abbott, 2000; Stace and Crawley, 2015). The result has been described as a hybrid swarm, for which the name *Rhododendron x superponticum* has been proposed (Cullen, 2011), although its validity is somewhat contentious (Stace and Crawley, 2015). Rhododendron has become one of the U.K.'s most virulent weeds (Dehnen-Schmutz and Williamson, 2006). It needs acid soils, growing particularly well in cool, humid conditions where it threatens acidic heath, bog, upland, moorland, maritime cliff and woodland conservation areas (Rotherham and Reed, 1988; Thompson *et al.,* 1993).

Rhododendron is a large evergreen shrub with dense foliage that produces intense shade and an acid leaf litter, both of which suppress regeneration of most other plants (although a few species of moss can thrive in such conditions). Few other plants can co-exist with it and, under suitable conditions, it can form dense, impenetrable single-species stands. Its nectar is also reported to be toxic to bees (Tiedeken *et al.,* 2014). Chemical control of rhododendron can sometimes be effective (Tyler and Pullin, 2005), but is expensive. Control by cutting is difficult because the plant regenerates vegetatively very well and individual root-shoot connectivity means that herbicide treatment of re-growth needs to be applied to all shoots of each regenerating bush (Offwell Woodland and Wildlife Trust, 2004). Removal of smaller plants by pulling is only effective if both stem and below-ground parts of the plant are removed, because they can regenerate if any part of the stem remains, even if underground. A single flower head can produce more than six thousand seeds, and a large bush over one million seeds each year (Cross, 1975), which are tiny and wind-dispersed. Fortunately, rhododendron's post-dispersal seed longevity is low, with an almost 50% reduction in germination success within the first year, even under optimal conditions (Cross, 1975); hence it does not form a persistent seed bank (Shaw, 1984). This means that, so long as flowering is prevented, there should be little or no recruitment of new plants after a year or two. However, given the large numbers of seeds that a single plant can produce, even a small number of 'missed' plants can be responsible for large-scale recruitment and negate control efforts if they are allowed to set seed.

Decisions on whether or not it is practical to attempt total eradication, rather than just achieving control of an alien weed, are grounded mainly in economics (Panetta, 2009). Even when a plant is eradicated there is always the danger of re-invasion from elsewhere (Harris *et al.*, 2009) and complete eradication is only likely to be a viable option for isolated populations of rhododendron. A time-scale of 16 years was envisaged for the

removal of 300 hectares of rhododendron on Colonsay in the Inner Hebrides (Carrell, 2000), but only partial control had been achieved by 2012 (Cooke, 2012). Eradication is also being attempted on Brownsea Island, another National Trust reserve.

RHODODENDRON ON LUNDY

Marren (1973) and Compton *et al.* (1999) detailed the earlier history of rhododendron on Lundy. Introduced as an ornamental plant in the early nineteenth century, Lundy's sheltered eastern side, protected from the destructive Atlantic gales, is very favourable for rhododendron. Feral plants established a series of impenetrable thickets between the damper gulleys on the east side of the island after a major fire in 1926. By the 1990s, scattered plants had also colonised areas such as the Sidelands below the Castle, above the Miller's Cake, and above Quarry Bay, as well as small areas of the central plateau. Mapping in the 1990s (Compton *et al.,* 1998), showed that although rhododendron was still largely confined to the same discrete blocks as before (thanks to clearance efforts aiming to maintain fire breaks between them), the blocks had increased in size and proximity to each other since the 1970s and that there had been a general increase in rhododendron cover, particularly in the numbers of isolated bushes and incipient new patches. Total rhododendron cover was estimated at 8.9ha in 1997, of which 1.5ha had been recently cut, but not successfully cleared (Compton *et al.,* 1998), though these figures were known to be underestimates, because of the steep slopes. Of particular concern was the spread of the plant down the sea cliffs, with small plants becoming established down to just above the high-water mark. The endemic Lundy cabbage (*Coincya wrightii*) is restricted to the eastern part of the island (Compton and Key, 2000), and it is unique in the U.K. insofar as it supports endemic insects that are also restricted to Lundy. Conservation of the Lundy cabbage is therefore of national significance and its entire distribution was found to lie within areas where rhododendron was either already starting to colonise or which were vulnerable to colonisation (Compton and Key, 1998, Compton *et al*. 1998, 1999).

Eradication of rhododendron is a stated target of the Lundy Cabbage Steering Group, which is chaired by the National Trust. The economic case for eradication of rhododendron on Lundy was summarised as 'this is the only way that the need for constant, repetitive and very expensive control measures will be ended' (Compton *et al.*, 1999). The maximum extent of rhododendron on Lundy was far less than on Colonsay and both islands have the advantage that wind-dispersed seeds are very unlikely to cross the 18km that separates them from the mainland. The distribution of the plant on Lundy is also well understood – a prerequisite for success. Furthermore, the availability of a warden and ranger to co-ordinate activities and the numerous volunteers that visit the island meant that a viable long-term strategy could be developed and implemented. Lundy nonetheless offers considerable challenges to eradication of rhododendron, of which the most significant is the presence of the plant on the vertical or near vertical sea cliffs and faces in the quarries area. The section of the Sidelands immediately adjacent to the break of slope onto the cliffs also cannot be safely tackled by most land-based groups. Realistically, only specialist climbers can safely reach these plants and, given inevitable limitations on their time, small plants there and on the cliffs can easily remain undetected until they come into flower.

HISTORY OF RHODODENDRON CONTROL ON LUNDY

Table 1 provides a time-line for rhododendron and its control on the island. The plant was recognised as a problem and control was first suggested as early as 1949 by the island's owner (Harman, 1950). Control efforts by island wardens and rangers, members of the Lundy Field Society and numerous teams of volunteers have taken place over the intervening 70 years and still continue. Until the mid-1990s, most cutting was by hand, and herbicides were only used intermittently. Consequently, many plants survived the clearance efforts, which succeeded in slowing, but not stopping, the spread of rhododendron on the island.

Table 1: A summary of rhododendron and its past and future control on Lundy

Dates	**Description**
Early nineteenth century	*Rhododendron ponticum* introduced as an ornamental shrub to Millcombe gardens.
1926	Gorse and peat fire along the Eastern Sidelands which enabled Rhododendron to 'escape' and colonise the mossy/bare burnt soil.
1926-1950s	Rhododendron population expansion with no recorded control efforts. Control first suggested 1949.
1950s-1998	Somewhat uncoordinated clearance of patches, cutting of bushes and removal of seedlings, including sporadic pushing back of the edges of large blocks of mature plants mainly to maintain fire breaks, (none of which actually stopped expansion). Little or no systematic use of herbicide control. Premature claim (1988) that all plants had been cleared from Brazen Ward.
1998-2013	1998 publication of rhododendron control strategy. 1998 Ropeworks with Leeds University volunteers carry out pilot studies on practicality of cliff-side clearance. 2000 Ropeworks begin annual cliff-side cutting and spraying. First ranger with control responsibilities appointed 2002. Systematic clearance and follow-up efforts lead to local removal of all mature bushes. Last easily-accessible Sidelands plant cut 2011. Last cliff-face population cut for first time (mature bushes 2012, high density regrowth 2013). Last confirmed seed set 2012, but may have set seed in 2013.
2013-2025(?)	Seedling numbers greatly reduced. Monitoring to prevent any further flowering, and removal/spraying of all known remaining rhododendron on both Sidelands and cliffs.
Post 2025	Re-invasion is unlikely, but continued vigilance will be required.

Control of established rhododendron stands during the 1980s centred on an attempt to eliminate a large but relatively young stand of the plant at the northern edge of its distribution near Brazen Ward. An indication of the labour involved was provided by Willcox (1988, 1989), who estimated that 250 and 500 man-days were spent on rhododendron control during 1987 and 1988 respectively. By 1988 the complete elimination of mature rhododendron from this area was reported (National Trust, 1991) and the area is now almost indistinguishable from other areas of the Sidelands, with a flora once again dominated by bracken, bluebells, bramble, various grasses, and hay-scented buckler fern. Until very recently, however, new rhododendron seedlings continued to appear there every year, because of a few mature plants that had persisted below the cliff edge. These were cut and sprayed in 1998, though some survived, and appear to have only finally been eliminated by 2010.

Clearance efforts targeting large thickets were concentrated in the early 1990s around areas of archaeological interest centred on Victorian quarry workings. These revealed various previously unrecorded archaeological features that had been completely hidden by the dense rhododendron. Conservation activities related to the Lundy cabbage and its associated insects, as part of English Nature's Species Recovery Programme, began in 1993, and rhododendron was recognized as a major threat. A strategy for the control of rhododendron on Lundy (Compton *et al.,* 1998) included maps of all the rhododendron, including isolated bushes, with their significance rated according to the threat they posed to Lundy Cabbage. It was suggested that, as far as possible, the rhododendron should be removed in sequence, in accordance with the priority ratings of individual blocks and bushes, with control of scattered plants away from the main blocks also emphasised because they were foci for rhododendron population expansion.

Removal of rhododendron from the steep sea cliffs, and the dangerous areas of the Sidelands immediately above the cliffs, clearly posed a particular challenge. An early visit by Calum Rankine and members of the British Mountaineering Council tested the practicability of control and a 1998 pilot study by Ropeworks Ltd., Bristol, confirmed that cutting, removing and applying herbicide to cliff-side plants using specialist rope-based techniques was a practical option. This initial study was continued by Ropeworks under the leadership of Angus Tillotson and they have been responsible for almost all of the subsequent cliff-side rhododendron clearance on the island. This work has continued almost every year since 1998.

Organised and *ad hoc* pulling of rhododendron seedlings has not been well documented until recently but has probably been a component of rhododendron clearance on Lundy for more than fifty years. The seed rain from established blocks of rhododendron resulted in huge numbers of seedlings across the Eastern Sidelands. These were removed year after year, but the continued production of seeds meant that new seedlings were appearing each year and inevitably some managed to become established. Once the first (most southerly) large blocks were removed from the Sidelands the numbers of seedlings declined locally, but seeds blown from the remaining blocks and cliff-sides meant that seedlings initially continued to appear throughout the area where rhododendron had been cleared.

Increases in the numbers of Lundy staff with conservation responsibilities had a major influence on the rates and effectiveness of rhododendron control on the island. The

appointments of a ranger and summer (later full-time) assistant wardens coincided with the expansion of the major blocks of rhododendron being reversed, for what was probably the first time since control measures had been attempted. This was as a result of increased man-hours available for clearance, the use of chainsaws in combination with volunteer groups, and regular use of herbicides, which had hitherto been largely avoided because of environmental concerns. Ranger Rod Diamond initiated a herbicidal treatment plan which was considerably expanded and strategically developed by his successor from 2006, Chris Flower. Cutting and clearance of the major blocks subsequently accelerated (Table 2) although removal and disposal of cut rhododendron from both the cliffs and Sidelands continued to be both difficult and time-consuming. The introduction of a brushwood chipper in 2007 and a metal burning platform greatly sped up the processing of cut material. Stacking of cut rhododendron to allow natural decay was also tried, but decay rates of wood in the stacks have been slow.

Table 2: First cuts of the major Sideland blocks of rhododendron (block terminology follows Compton *et al.* 1998, starting from the South). Earlier localised temporary removal by volunteers was not documented. Repeated cycles of cutting and spraying are often required to achieve total removal, which is still not complete in all areas

Rhododendron Block Number	**Initiation of first cut**	**Completion of first cut**
3	1998	1998
5	1998	2004-05
6	Sept 2006	Mar 2007
7	Mar 2007	2007
8	2008	2008
9	2007	Mar 2008
10	Mar 2008	Feb 2009
12	Feb 2009	Mar 2012
13 (South)	2007	2007
13 (North)	2006	2006
14	2006	2006

Areas of rhododendron close to Lundy Cabbage were the first to be targeted for clearance from 1998 onwards. Cutting of the majority of large blocks of rhododendron and most of the isolated individual flowering bushes was then mainly carried out from the south northwards, starting with a small group of plants above Landing Beach, with the particularly difficult area immediately south of Quarry Bay the last area to be completed in 2012. The last large rhododendron on the more accessible upper Sidelands was cut in March 2011, and the last large established stand on the lower Sidelands/cliff-side was cut in 2012, with the last large group of regenerative cliff-side bushes cut in 2013 (Tables 1 and 2). Land- and sea-based surveys in spring 2013, 2014 and 2015 detected progressively smaller numbers of rhododendron in flower on the Sidelands and cliffs. They were all herbicide-treated or had their flowering heads removed, and it is

likely that there has been no seed set on the island in the three years since the winter of 2012. There is however a very narrow window of opportunity for the clearance of the remaining cliff-side regenerative growth and flowering. A definitive search using binoculars requires flower heads to be showing on problematic plants, whereupon they must be removed/treated within two weeks, otherwise they become much harder to find. The removal of all remaining flowers in spring 2013 was a major undertaking, with hundreds of flowering heads removed, and it is not inconceivable that some early setting heads could have set seed. A concentrated effort was made to clear the last large sections of bushes in winter 2013 and far fewer numbers of plants with flowers have been detected (and destroyed) in subsequent years. The cliff-based operations remain crucial if eradication is to remain on track, and this was reflected in an increased focus and financial drive in the years 2013, 2014 and 2015 in order to reduce future costs and increase site manageability.

Seedling numbers started to drop dramatically once the last of the large blocks of mature plants were cleared. The workload associated with seedling clearance has dropped accordingly and effective systematic sweeps for remaining seedlings mean that large areas of the Sidelands now appear to be seedling-free. Small plants are nonetheless easy to miss, especially on the cliffs or when in dense bracken, and even quite small plants can produce one or a small number of inflorescences. Larger, established plants are also difficult to kill, with several visits sometimes needed before herbicide treatments are fully effective, and surviving older plants represent a continuing risk of seed production. Early mechanical efforts of stump removal at Brazen Ward and elsewhere (A. Gibson, *pers. comm.)* proved time-consuming, environmentally damaging and ineffective in the long-run. Correctly-applied herbicidal treatment therefore became an integral part of the control efforts. Initially, the stumps of established trees had a *Glyphosate*-based herbicide applied directly after cutting, where possible within 20 minutes of a fresh cut. This greatly reduced the likelihood of regeneration, but became a less regular practice in large-scale clearances because of difficulties encountered during adverse weather conditions and concerns over the safety of working groups on unstable slopes in proximity to harmful chemicals. Exhaustion among chainsaw operators that then needed to immediately apply herbicides was another likely factor.

On the Sidelands, stump treatment was therefore increasingly replaced from 2004 by spraying regrowth with the herbicide *Timberel* (active ingredient *triclopyr butoxy ethyl ester*), combined with an adjunctive *Mixture B*. *Timberel* is applied using a foliar mist sprayer to clear regenerative growth from untreated stumps and has proved an extremely effective method when applied at least twice in a growing season. The change in spraying methods also reflected a larger proportion of control efforts being directed towards residual scattered rhododendron and less on the progressively smaller remaining areas of rhododendron that were being cut for the first time. Stump treatments have nonetheless continued to be essential for cliff-based plant removal, where cutting and treatment are necessarily carried out at the same time. The herbicides vary seasonally in their effectiveness. Cut-stump treatments are most effective in the autumn and winter, whereas the foliar treatments are best applied to the leaves in the spring/summer growing season. Cutting and burning of rhododendron has nonetheless been concentrated outside of the bird nesting season, between 15 September and 31 March.

The last mature rhododendron stands were cut in 2012-2013, although many scattered individuals (from seedlings and small bushes to large re-growing stumps) still remained to be cleared. Following on from Chris Flower's 2006 clearance strategy and an unpublished rhododendron eradication strategy (Compton *et al.*, 2011), a new implementation strategy was created, developed and finalised by winter 2014-15, although practical work started from 2011. The aim was to implement an effective and consistent plan for completion of control phases 2, 3 and 4 (Table 1, Compton *et al.*, 2011). To achieve this, improved computerised monitoring and recording methods have been put in place alongside time-specific actions.

After the last major block had been cut, in 2013, the rhododendrons remaining on Lundy comprised seedlings, immature plants and stumps with re-growth following cutting and treatment. Plants in flower are far more conspicuous than at other times of the year, but small individuals with a single inflorescence can still be hard to detect. Late spring walks along the East side and scans from boats have picked up a small number of flowering individuals each year up to at least 2015, where 20 plants with flowering heads were located and subsequently treated. Although complete prevention of seed set cannot be proven, the dramatic reduction in seedlings and small plants suggests this has been the case.

THE FUTURE

With its attractive flowers and formation of tunnel-like paths (the 'Pink Petal Way'), rhododendron was promoted as a spring-time tourist attraction in the island's advertising literature and there were inevitable concerns about responses to its removal. However, feedback from visitors suggests that the removal of rhododendron has generated a largely positive response, though the temporary piles of cut stems were considered unsightly, as were the patches of cleared rhododendron until they re-vegetated. Visitor benefits from clearance have included the opening of new vistas out to sea and less-muddy walking conditions along the lower East-side path. Worries had been expressed about the loss of breeding areas for the island's Sika deer, but the major effect appears to have been that the deer are becoming less shy, and more visible to visitors.

The soils exposed by rhododendron clearance on Lundy are typically mainly peat, covered by varying depths of twiggy rhododendron débris. Despite claims that rhododendron can produce toxic soils (Cross, 1975), experiments have confirmed that Lundy Cabbage seed germination is not inhibited by soils collected from where rhododendron had been growing for many years (Compton *et al.*, 2010). Lundy is fortunate in that floral regeneration is rapid after rhododendron clearance, in sharp contrast to the experience at some Scottish sites, where bare peat can remain exposed for years. On Lundy, the summer following clearance can produce brightly coloured 'gardens' of foxgloves, goldenrod, sheepsbit, sea campion, sheep's sorrell and Lundy cabbage. This flora is replaced after 1-3 years by a grassier sward, with Yorkshire fog often dominant. Eventually bracken, which spreads in from the sides of cleared areas, forms the dominant post-clearance vegetation on the Sidelands, together with bluebells, bramble and gorse. A more diverse sward has begun to develop in some damper areas, with plants such as royal and hay-scented buckler ferns and primroses. The rate of sward regeneration appears to be strongly influenced by the extent of grazing pressure, particularly by rabbits, and low rabbit densities in recent years will have speeded up the process.

In winter 2015 we stand at a point where regenerative growth by rhododendron on both more accessible land and the cliffs is still the major focus of attention. The ability of vigorous plants to flower within two seasons of ineffective treatment makes vigilance essential. The clearance area of the island has been divided into manageable sections which can be effectively worked, monitored and recorded to be sure that they pose no threat; this also provides valuable information on whether herbicidal treatment has been more effective in one area than another, with the experience gained thus increasing overall kill rates.

The next large cliff clearance is expected in March 2016 with a target of clearing all remaining regenerative growth from the cliff-sides. This will mean that we are left with managing a site only a quarter of its original size. Land-based operations are now focused on higher levels of vigilance and herbicide treatment bespoke to each site, and increasingly the basis for treatment is being dictated by access levels, operator safety and the presence of bracken (which obscures smaller rhododendrons). Year on year, more plant treatment is taking place in the winter to reduce the spring foliar treatment work-load and thus giving more time to locate flowering plants at that time.

Beginning in the growing season of 2015 a decision was made that no more small plants should be pulled by hand on the Sidelands and that all remaining plants should be treated with herbicide. This is necessary because even relatively small plants can leave roots behind when they are pulled-up and the plants can regenerate. The resulting small plants are then initially hard to find and eventual eradication is postponed. There are still some areas on the cliffs where pulling of seedlings/small plants will continue for now, because the numbers of plants present make herbicide work difficult and costly.

There remains a continuing risk of plants coming into flower on the cliffs for years to come, until all the plants have reached sufficient size to be seen more easily, and have been destroyed. Any breaks in vigilance that allow the rhododendron to flower will re-set the clock and inevitably greatly increase the eventual costs. Rhododendron is often quoted as first coming into flower at an age of 10-12 years (Cross, 1975), but the windswept and salty conditions of the cliffs are likely to slow rhododendron growth and an even longer period may be required before the risk of further young plants coming into flower will be over. This time period will be extended even further if plants are treated, but not killed. A 12-year period from the final (hopefully) cessation of successful seed-set (2012) is therefore a minimum estimate of the time required for continued monitoring of the rhododendron on Lundy. As a consequence, monitoring of the cliffs by boat and from the Sidelands will need to be continued until at least 2025 (or 12 years after whenever the last flowering individual is recorded). It is often extremely hard to know when a plant has been finally eradicated (Regan *et al.*, 2006) and this will certainly be the case for rhododendron on Lundy.

If successful, the removal of rhododendron from Lundy may become the first example of a large scale eradication of any alien plant species in Europe (Genovesi, 2005). And if eradication is eventually achieved, and the previous owner's prediction proves to have been wrong, it will be a testament to the determination, perseverance and sheer physical effort of the many volunteers and professionals who have contributed to 'rhodi-bashing' on Lundy.

REFERENCES

Carrell, S. 2000. Tiny island battles to cut, spray and burn rhododendrons down to size. The Independent. Available from: http://www.independent.co.uk/environment/tiny-island-battles-to-cut-spray-and-burn-rhododendrons-down-to-size-621933.html

Compton, S.G. & Key, R.S. 2000. Biological Flora of the British Isles. *Coincya wrightii* (O.E. Schulz) Stace. *Journal of Ecology* 88, 535-547

Compton, S.G., Key, R.S. & Key, R.J.D. 1999. *Rhododendron ponticum* on Lundy - beautiful but dangerous. *Annual Report of the Lundy Field Society 1998*, 49, 74-81

Compton, S.G., Key, R.S., Key, R.J.D. & Parkes, E. 1998. Control of *Rhododendron ponticum* on Lundy in relation to the conservation of the endemic plant Lundy cabbage, *Coincya wrightii. English Nature Research Reports* 263, 1-67

Compton, S.G., Norton, R., Straker, R., Walker, C. & Key, R.S. (2010). Lundy cabbage seed dispersal, seed banks and seed germination after rhododendron clearance. J*ournal of the Lundy Field Society 2,* 45-52

Compton, S.G., Feather, C., Saunders, N., Wheatley, S., Key, R.S., Key, R.J.D. & Appleton, D. 2011. *A strategy for the eradication of Rhododendron ponticum on Lundy*. Unpublished consultation document

Cooke, K. 2012. Scottish island wages war against purple-flowered coloniser. *The Irish Times* May 8, 2012. Available from: http://www.irishtimes.com/news/scottish-island-wages-war-against-purple-flowered-coloniser-1.529352

Cross, J.R. 1975. Biological Flora of the British Isles. *Rhododendron ponticum* L. *Journal of Ecology* 63, 345-364

Cullen, J. 2011. Naturalised rhododendrons widespread in Great Britain and Ireland. *Hanburyana* 5, 11-29

Dehnen-Schmutz, K. & Williamson, M. 2006. *Rhododendron ponticum* in Britain and Ireland: social, economic and ecological factors in its successful invasion. *Environment and History* 12, 325-350

Genovesi, P. 2005 Eradications of invasive alien species in Europe: a review. *Biological Invasions* 7, 127-133

Gillham, M.E. 2007. *A Naturalist on Lundy: The Island Wildlife Over 50 Years.* Halsgrove, Somerset

Harman, M.C. 1950. Owner's letter. *Annual Report of the Lundy Field Society 1949*, 3, 42

Harris, C.M., Park, K.J., Atkinson, R., Edwards, C. & Travis, J.M.J. 2009. Invasive species control: Incorporating demographic data and seed dispersal into a management model for *Rhododendron ponticum*. *Ecological Informatics* 4, 226-233

Kueffera, C., Daehlera, C.C., Torres-Santana, C.W., Lavergnec, C., Meyerd, J-Y, Rüdiger, O. & Silvaf, L. 2010. A global comparison of plant invasions on oceanic islands. *Perspectives in Plant Ecology, Evolution and Systematics* 12,145-161

Mack, R.N. & Lonsdale, W.M. 2002. Eradicating invasive plants: hard-won lessons for islands. In C.R. Veitch & M.N. Clout (eds) *Turning the Tide: The Eradication of Invasive Species,* 164–172. New Zealand Invasive Species Specialist Group of the World Conservation Union (IUCN), Auckland, New Zealand

Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M. & Bazzaz, F.A. 2000. Biotic invasions: Causes, epidemiology, global consequences, and control. *Ecological Applications* 10, 689–710

Marren, P.R. 1973. The Lundy rhododendrons. *Annual Report of the Lundy Field Society 1972,* 23, 46-51

McGeoch, M.A., Butchart, S.H.M., Spear, D., Marais, E., Kleynhans, E.J., Symes, A., Chanson, J. & Hoffmann, M. 2010. Global indicators of biological invasion: species numbers, biodiversity impact and policy responses. *Diversity and Distributions* 16, 95-108

Milne, R.I. & Abbott, R.J. 2000. Origin and evolution of invasive naturalised material of *Rhododendron ponticum* L. in the British Isles. *Molecular Ecology* 9, 541-556

National Trust. 1991. Biological Survey - Lundy, Devon. *National Trust Biological Survey*. Spitalgate Lane, Cirencester

Offwell Woodland & Wildlife Trust. 2004. Rhododendron. A killer of the Countryside. Available from http://www.countrysideinfo.co.uk/rhododen.htm

Panetta, F.D. 2007. Evaluation of the performance of weed eradication programs: containment and extirpation. *Diversity and Distributions* 13: 33-41

Panetta, F.D. 2009. Weed Eradication - An Economic Perspective. *Invasive Plant Science and Management* 2, 360-368

Regan, T.J., McCarthy, M.A., Baxter, P.W., Panetta, D.F. & Possingham, H.P. 2006. Optimal eradication: when to stop looking for an invasive plant. *Ecology Letters* 9, 759-66

Rotherham, E.D. & Read, D.H. 1988. Aspects of the ecology of *Rhododendron ponticum* with reference to its competitive and invasive properties. *Aspects of Applied Biology* 16, 327-335

Shaw, M.W. 1984. *Rhododendron ponticum* – ecological reasons for the success of an alien species in Britain and features that may assist in its control, *Aspects of Applied Biology* 5, 231-242

Stace, C.A. & Crawley, M.J. 2015. *Alien Plants*. New Naturalist 129. HarperCollins, London

Thomson, A.G., Radford, G.L., Norris, D.A. & Good, J.E.G. 1993. Factors affecting the distribution and spread of rhododendron in North Wales. *Journal of Environmental Management,* 39, 199-212

Tiedeken, E.J., Stout, J.C., Stevenson, P.C. & Wright, G.A. 2014. Bumblebees are not deterred by ecologically relevant concentrations of nectar toxins. *Journal of Experimental Biology* 217, 1620-1625

Tyler, C. & Pullin, A.S. 2005. Do commonly used management interventions effectively control *Rhododendron ponticum*? Systematic Review No. 6. Available from http://www.environmentalevidence.org/SR6.htm

West, C.J. 2002. Eradication of alien plants on Raoul Island, Kermadec Islands, New Zealand. In C.R. Veitch & M.N. Clout (eds), *Turning the Tide: The Eradication of Invasive Species,* 365-373. New Zealand Invasive Species Specialist Group of the World Conservation Union (IUCN), Auckland, New Zealand

Willcox, N. 1988. Warden's report for 1987. *Annual Report of the Lundy Field Society 1987*, 38, 6-7

Willcox, N. 1989. Warden's report for 1988. *Annual Report of the Lundy Field Society 1988,* 39: 5-6

Zamora, D.L., Thill, D.C. & Eplee, R.E. 1989. An eradication plan for plant invasions. *Weed Technology* 3, 2-12

APPENDIX

The individuals and organisations that we know of that have contributed to rhododendron control (since 1993) are listed below. The listing is alphabetical by surname. We apologise to anyone whose name we have omitted.

Lundy Wardens

Liza Cole, Andrew and Lorna Gibson, Emma Parkes, Ben Sampson, Nicola Saunders, Beccy MacDonald, Sophie Wheatley.

Other Lundy Staff

Rod Diamond, Chris Flower, Derek Green, Steve Pratt, Jo Ramsey, Ian Reach.

NCC/English Nature/Natural England

David Appleton, Jeremy Barker, Lynne Farrell, Roger and Rosy Key, Roger Mitchell, Rob Wolton.

Funding bodies/schemes

NCC/English Nature/Natural England, MAFF schemes (Countryside Stewardship and Wildlife Enhancement Scheme, Higher Level Scheme).

Organisations

Landmark Trust, National Trust.

National Trust (science, conservation and ecology and SW local teams/individuals)

David Bullock, Lucy Cordrey, John Harvey, Rob Joules, Janet Lister, Steve Mulbery.

Ropeworks

Angus Tillotson and his staff from *Ropeworks.*

Universities

Steve Compton, students from the University of Leeds.

Volunteer work parties

Accenture group, BTCV, Callum Rankine and BMC, Lundy Field Society, National Trust, the other work parties for which we have no records.

Plate 1: Eastern Sidelands of Lundy 1993 with rhododendron at its likely maximum extent. Note the rhododendron descending the cliffs beyond the flowering Lundy cabbage and the 'Cabbage's Last Stand' pinnacle surrounded by rhododendron. Photo © R.S. Key

Plate 2: Eastern Sidelands of Lundy 2003. The southern blocks of rhododendron have been cut. Photo © R.S. Key

Plate 3: Eastern Sidelands of Lundy 2006. Rhodondendron growing between the lower eastside path and the cliff edge has all been cut, except in the most northerly patch. Photo © R.S. Key

Plate 4 (above and opposite page, top): View of the Eastern Sidelands of Lundy in 2007 showing stacked lines of rhododendron brash from areas where rhododendron has been cut and areas of intact rhododendron, further north, still to be cut

Plate 5: Eastern Sidelands of Lundy 2013. All major rhododendron blocks cut. Photo © R.S. Key

Plate 6: Celebrations at the cutting of the last large accessible rhododendron on the Eastern Sidelands (March 2011). But note the 'wall' of rhododendron at the cliff edge behind

Plate 7: Volunteers burning freshly cut rhododendron

Plate 8: Professional climbers descending cliffs to cut rhododendron

Plate 9: Lundy cabbage and foxgloves flowering in an area previously cleared of rhododendron (June 2009). This 'garden' effect is brief, with rapid succession to a grass sward and bracken. Photo © R.S. Key

Plate 10: The densities of rhododendron seedlings that were present at the side of the path leading down to Quarry Bay. Photo © R.S. Key