Systematic Review No. 6.

Do commonly used management interventions effectively control *Rhododendron ponticum*?

Review Report

Compiled by
Tyler, C. & Pullin, A.S.

Centre for Evidence-Based Conservation
School of Biosciences
The University of Birmingham
Edgbaston
Birmingham
B15 2TT
U.K.

March 2005

This review should be cited as:
Tyler, C. & Pullin, A.S. (2005). Do commonly used interventions effectively control *Rhododendron ponticum*? Systematic Review No. 6. Centre for Evidence-Based Conservation, Birmingham, U.K.

SUMMARY

Background

Rhododendron ponticum is an invasive plant of woodland, heathland, bogs and sand dunes. Suppression of native flora occurs as *R. ponticum* grows in dense impenetrable stands. Little light can penetrate its canopy; with the addition of leaf litter a near-sterile environment is created that cannot support a diverse flora and fauna. Control methods have been attempted, but many fail. This review collates accessible information and critically appraises the evidence for effective control using current management interventions.

Objectives

The primary objective is to address the question "Do commonly used management interventions effectively control *Rhododendron ponticum*?"

The question originated from UK-based organisations where *R. ponticum* control is a common problem. Therefore, although this review has not excluded information from elsewhere, it has a UK focus.

Secondary objectives

To address the following questions:

- Does habitat type modify the effectiveness of an intervention?
- Is effectiveness of control altered by the disposal of cut material?
- Can use of a follow-up treatment change the effectiveness of initial treatment?
- Are there other environmental or experimental factors that influence success of interventions?

Search strategy

Relevant studies were located through the computerised searches of English Nature's 'Wildlink database', JSTOR, ISI Web of Knowledge (comprising BIOSIS previews: 1969 to 2004, CAB abstracts: 1973 to 2004, ISI current contents: 1997 to 2004, ISI proceedings: 1990 to 2004, ISI Web of Science: 1975 to 2004), ScienceDirect, Index to Theses online (1973 to 2004), Agricola, Scopus (1966 to 2004), Digital Dissertations, www.alltheweb.com (PDF, and word doc. search), and www.google.co.uk.

A secondary search was made of bibliographies of all articles accepted at full text.

Selection criteria

1) Subject
Rhododendron ponticum populations or subpopulations.

2) Intervention

Any intervention with the objective of controlling *R. ponticum* was considered appropriate for inclusion in this review. Studies over all time scales and habitats were included.

3) Comparator

Any articles that did not include a control site/comparator were rejected.

4) Outcome

Any study reporting on the outcome of an intervention with the objective of controlling *R. ponticum* was included. Specifically, studies examining any change in the population of *R. ponticum* including cover, stand density, frequency or biomass were deemed relevant.

Data collection and analysis

Article inclusion/exclusion assessments were performed by the primary reviewer with a subset assessed by a second reviewer for verification of repeatability within the methodology; any disagreements were resolved by discussion. Data extraction and study quality were performed by the primary reviewer with the use of pre-designed assessment forms, and then entered into a spreadsheet. Meta-analyses generated the effect size of different interventions, with univariate and multivariate meta-regression used to investigate possible reasons for heterogeneity.

Main results

Application of the herbicides Imazapyr or Metsulfuron-methyl to *R. ponticum* stands, and post-cut the application of Glyphosate, significantly reduce *R. ponticum* abundance (p= 0.02, 0.0005, and 0.001 respectively) as demonstrated by the negative effect sizes generated (d= -2.83, -1.92, and -1.14 respectively). No other interventions produce significant reductions.

Potential reasons for heterogeneity were identified as pot-grown vs. field trials, length of experiment, herbicide dosage, method of application, and month of treatment. These were assessed individually in a univariate meta-regression, and then in a multivariate meta-regression for Imazapyr; no factor was significant in the univariate meta-regression, but the multivariate meta-regression demonstrated that there was a significant difference between *R. ponticum* treated in the field and *R. ponticum* treated in pots (R=19.26, p=0.034), where the effect of treatment in pots was greater. Multivariate meta-regression for Metsulfuron-methyl yielded no significant results. Length of experiment was significant for Glyphosate application post cut (R=-0.13, p=0.039), where longer follow-up monitoring produced a greater reduction in *R. ponticum* however; in further analyses of independent data this factor was no longer significant.

Secondary objectives could not be directly addressed in the review due to lack of information in included articles.

Reviewers’ conclusions

The weight of evidence suggests Metsulfuron-methyl application, and post-cut application of Glyphosate will produce short-term reduction of an *R. ponticum* stand. Only five studies provided data for analysis of Metsulfuron-methyl and are either performed in an unspecified habitat or in pots in glasshouses. The applicability of these results to field conditions with a diverse range of interacting variables is therefore uncertain. In particular, it is unclear whether short-term reduction means long-term effectiveness. Meta-analysis on post-cut glyphosate application used 11 data points; however, these data points came from only five studies, creating significant publication bias in the meta-analysis. Without further research producing more articles this problem cannot be overcome.

Imazapyr application also resulted in significant reduction in abundance but its use is now illegal in some countries (including UK). Since the majority of experimental work on the control of *R. ponticum* has been on the effect of Imazapyr, there is now a requirement for further research into the effect of replacement herbicides and other control methodologies.

The significantly greater effect of Imazapyr on pot-grown plants compared with field plants demonstrates that, whilst efficacy can be demonstrated with pot-grown trials they do not take into account ecological factors that can reduce the effectiveness of the intervention in the field. This should be considered when planning future trials.

1. BACKGROUND

There has been much documentation about the problem of controlling the invasive species *Rhododendron ponticum* (Pysek *et al*, 1995); however, no definitive intervention has been established as the best control mechanism (Gritten, 1987). From the family Ericaceae, a genus of over 600 species (Cross, 1975), *R. ponticum* is a shrub first introduced into Britain in 1763 (Cross, 1975; Milne and Abbott, 2000). Many subsequent introductions have led to its naturalisation (Milne and Abbott, 2000). Within Britain, *R. ponticum* has proven to be the most prevalent threat to wildlife of all Rhododendron species, as it has few natural enemies (Milne and Abbott, 2000), and is able to grow on all acid soils, unlike other *Rhododendron* species that have more demanding cultivation requirements. It is an invasive species that threatens and suppresses native flora, often altering the entire ecosystem (Mitchell *et al.* 1997). Due to the prolific production of seeds, which are subsequently wind dispersed, (Cross, 1975; Pysek *et al.* 1995) *R. ponticum* has escaped from gardens and parks, where it was used for winter game cover or as an ornamental, into woodland, heaths, bogs and sand dunes (Thomson *et al*. 1993). The species forms evergreen vegetation that is impenetrable, underneath which there is little light, creating, in combination with leaf litter, a near-sterile environment supporting little in the way of fauna or flora (Cross, 1981).

Currently there is no standard method of control as no single method has been proven to be the most effective (Eşen and Zedaker, 2004). Practitioners therefore often follow methods used previously on the site (Pullin and Knight 2003), or use the cheapest method that requires the minimum effort. Prevalent methods of control are herbicide application, cutting, and herbicide application post cut. Method of application of the herbicide varies depending on the size of the stand and the costs involved, examples include the knapsack sprayer or the more recently developed stem injection.

Searle (1999) describes some of the problems that are associated with *R. ponticum*'s naturalisation in Britain including; the reduced access to woodland areas for harvesting timber as *R. ponticum* grows in dense thickets, reduction of native tree growth in areas that are densely colonised, and unacceptable growth in public places. Further problems include the increased sodium concentration in soils where *R. ponticum* is found (Mitchell *et al*. 1997), and the release of polyphenols into the soil that have a deleterious effect on native species (Cross, 1975). These have led to *R. ponticum* becoming a major threat to native species and a cause for concern for statutory and other conservation organisations who have to control its distribution within protected areas.

By systematic critical appraisal of the available literature on control of *R. ponticum* this review evaluates the effectiveness of commonly used interventions. Data from relevant studies are integrated into a meta-analysis to provide an overall effectiveness measure for each intervention.

2. OBJECTIVES

2.1 Primary objective

To systematically collate and synthesise published and unpublished evidence in order to address the question "Do commonly used management interventions effectively control *Rhododendron ponticum*?"

2.2 Secondary objectives

To address the following questions:

- Does habitat type modify the effectiveness of an intervention?
- Is effectiveness of control altered by the disposal of cut material?
- Can use of a follow-up treatment change the effectiveness of initial treatment?
- Are there other environmental or experimental factors that influence success of interventions?

3. METHODS

3.1 Question formulation

The question originated from UK-based organisations where *R. ponticum* control is a common problem. Therefore, although this review has not excluded information from elsewhere, it has a UK focus. English Nature representatives were contacted for guidance and advice on the specific nature of the problem to be addressed. Their input resulted in the question "Do commonly used management interventions effectively control *Rhododendron ponticum*?" The three elements of the question are:

Population: Rhododendron ponticum

Intervention: Any treatment that aims to reduce the population of *R. ponticum*

Desired outcome: The reduction of *R. ponticum* population size.

Key reasons for heterogeneity were also discussed, and led to the formulation of the secondary objectives of the review; these are addressed where sufficient data exist.

3.2 Search strategy for identification of studies

Relevant studies were located through the computerised searches of English Nature's 'Wildlink', JSTOR, ISI Web of Knowledge (comprising BIOSIS previews: 1969 to 2004, CAB abstracts: 1973 to 2004, ISI current contents: 1997 to 2004, ISI proceedings: 1990 to 2004, ISI Web of Science: 1975 to 2004), ScienceDirect, Index to Theses online (1973 to 2004), Agricola, Scopus (1966 to 2004), Digital Dissertations, www.alltheweb.com (pdf, and word doc. search), and www.google.co.uk. The search terms used were:

- *ponticum* and control
- *ponticum* and management

- Rhododendron and control
- Rhododendron and management

Bibliographies of accepted articles (full text) were searched for further studies that had not appeared in any of the computerised searches of the databases. Foreign language searches were not performed. Authors of articles in which all relevant data had not been presented, or where its existence had been inferred but not published, were contacted for the original data. Further articles were acquired through personal communication with relevant researchers in the field.

3.3 Study inclusion criteria

A single reviewer (CT) screened title and abstract of each captured article for relevance to the review question. A subset of the articles (103) was then assessed by a second reviewer (GBS); Cohen's Kappa (Landis and Koch, 1977) was calculated as 0.29 -a 'fair result'- as a measurement of the degree of agreement between reviewers for the inclusion of articles. Any disagreement was resolved by discussion between the two reviewers. Articles were accepted for full text viewing if they appeared relevant to the review, or if they had an ambiguous title/abstract that did not allow inferences to be drawn about the content of the article.

Articles accepted at title and abstract were then read at full text by a single reviewer (CT), and a subset (20) assessed by the second reviewer (ASP). Methodology of inclusion/exclusion criteria was verified with 100% agreement between reviewers. Derivation of inclusion criteria from the review question led to the requirement of the articles to report on primary studies that include a:

1) Subject

Rhododendron ponticum populations or subpopulations.

2) Intervention

Any control intervention. Studies over all time scales and habitats were included. Distinction was made between studies that had one or a combination of interventions.

3) Comparator

The control/comparator is untreated or uncontrolled *R. ponticum* that is not experiencing any type of management. Any articles that did not include an uncontrolled comparator were rejected.

4) Outcome

Any study reporting on the outcome of an intervention was included. Studies that included data on any change in the population of *R. ponticum* were deemed relevant; this may incorporate data on the change in cover, stand density, frequency or biomass of *R. ponticum*.

3.4 Study quality assessment

All included studies underwent a methodological quality assessment. This was performed by a single reviewer (CT) using a study quality assessment instrument modified, with respect, to the review question. Weighting was given to the most important factors – primarily the study design – using a hierarchy of evidence adapted from Stevens and Milne (1997) and Pullin and Knight (2003).

Criteria for study quality assessment include:

Study design:

In descending order of quality: Randomised control trial, Quasi-Randomised control trial, Control trial, Historical control trial, Site comparison, Time series, Interrupted time series, Questionnaire and Expert opinion.

Performance bias:

Baseline comparison: Size of experimental area, Habitat type, Location/geographical area, Altitude, Stand age at time of treatment, and Soil type.

Intra-treatment variation: Stand age at time of treatment, Method for disposal of cut material, Habitat type, Location and Altitude.

Measurement of intervention and co-intervention: Burning, Grazing, Other.

Assessment bias:

Parameter of abundance: Is the measurement used to assess success of the intervention objective or subjective?

Number of replications: In descending order of quality: No replication, one or two replications, or more than two replications.

Attrition bias:

Subject units lost during the experimental/investigational period than cannot be included in the analysis (e.g. units removed due to deleterious side-effects caused by the intervention).

The studies that maintain homogeneity between the treatment and control in the experiments were awarded higher scores in comparison with those that did not, in order to receive these higher scores this information first had to be presented within the methodology of the articles.

Tables of assessment for individual studies, including justification for the scores were constructed, (Appendix 1). An overall score was awarded to each study.

3.5 Data extraction

Data sets from all studies included at full text were extracted into a spreadsheet by a single reviewer (CT), using a specifically designed data extraction form. All data that report on the effect of treatment on the *R. ponticum* stand/bush were extracted. This required a mean, sample size and standard deviation of both the experimental treatment and the untreated control to allow meta-analysis to be performed. Information regarding the treatment and methodology (e.g. method of application) were also extracted to allow the data sets to be sub-grouped for the appropriate analysis to occur i.e. different herbicide treatments were split.

Further information was extracted on variables that may be considered as potential sources of heterogeneity, this includes those factors that are specified *a priori* in the secondary objectives of the review, but also other available information that could allow *post hoc* analysis. These include variables within the methodology of the experiment (e.g. experimental area), but also population characteristics of the *R. ponticum* stand (e.g. age) and environmental features (e.g. soil type).

On occasions where there were insufficient data or where data were inferred but not presented, contact with the authors was attempted.

3.6 Data synthesis

3.6.1 *Handling of missing main outcome data*

In instances where the standard deviation was not presented in the results of the articles, it was necessary to create a dummy standard deviation (Stewart *per comms*). This was done separately for each sub-group; the largest standard deviation presented in the group was doubled and then assigned to the articles with missing standard deviations. The doubling of the standard deviation ensured that the studies with the 'dummy' variance were given less weight in the meta-analysis. Where the means and standard deviations of the studies were not presented in a format suitable for quantitative assessment, any extractable results were included in a qualitative assessment.

3.6.2 Choice of measure of effect and meta-analyses of main outcome

Objective measures of outcome were always chosen if available within the data presented in the articles. As there was no standard method of reporting effectiveness of herbicide any relevant measure was accepted e.g. % basal area reduction. Where only subjective measures were presented in the articles these were also extracted into a spreadsheet. Random effects meta-analysis based on Standardised Mean Differences was performed in StatsDirect for all relevant data. Where the data sets could potentially give a range of results, sensitivity analysis was performed to test the robustness of the results.

3.6.3 Assessment of heterogeneity and investigation of reasons for heterogeneity

Possible sources of heterogeneity were specified *a priori* within the secondary objectives of the review as method of removal of cut material, the effect of follow – up treatment and habitat. Requirement to assess the *post hoc* variables was recognised through the data extraction process. Further analysis occurred by univariate meta-regression of each variable and multivariate meta-regression where all variables were entered into a single model. Meta-regression was performed in the statistical package Stata.

3.6.4 *Investigation of publication and other bias*

Funnel plots (plots of effect estimates versus the inverse of their standard errors) were drawn. An asymmetrical funnel plot may indicate bias – either through publication bias or biases related to sample size; however, it may represent the true relationship between trial size and effect size. The degree of asymmetry within a Funnel plot was investigated by the method proposed by Egger *et al* (1997).

3.6.5 *Investigation of power*

The results from the meta-analyses may be subject to Type I errors due to potential small sample size. Power analysis was performed to inform on the sample size needed to yield reliable results (Underwood, 1997). Where the level of power within in the meta-analysis was too low a further power analysis was performed to give the sample sizes required to increase the power to 0.95. Power analysis is performed using the .sampsi syntax in Stata (Hilbe, 1993).

4. RESULTS

4.1 Review statistics

Searching retrieved 801 articles, based on the search terms specified. A further 17 were later found through searching bibliographies; three papers were obtained from personal communications with authors and libraries, increasing the total number of 'hits' to 821. Removal of duplicates reduced this figure to 511 unique articles to be assessed for relevance at title and abstract. After this initial assessment stage 196 articles required viewing at full text for relevance to the review question. The majority of these articles (161) were inapplicable to the question and 18 were unobtainable leaving 17 in the final review.

Articles were labelled unobtainable only after attempts at acquisition through contact with the author or inter-library loans services. The majority of the articles excluded at full text were irrelevant due to an inappropriate population; the population was either not *R. ponticum*, or the population was not the focus of the paper and no treatment had occurred. Lack of untreated controls also led to exclusion.

The final 17 articles generated 39 data sets across all interventions. Twelve of these articles contained data usable in meta-analysis leaving 30 analysable datasets. Thus for meta-analytical purposes only one point from each data set can be entered into the model. Sensitivity analyses were performed to measure the impact of including different points from within a data set.

4.2 Study quality

For the purpose of study quality all studies that were accepted at full text were subjected to assessment, independent of whether the data was suitable for meta-analysis (Table 1). Low scores were assigned to: Andrews (1990), Becker (1988), and Gritten (1981) because of inferior study design and lack of information about methodology and experimental area. The highest scores were assigned to Edwards (2005), Dixon and Clay (2002), Eşen and Zedaker (2003), Edwards *et al* (2000), Clay *et al* (1992), Lawrie *et al*(1993), Edwards and Mason (1999), and Edwards and Morgan (1996) as they were all randomised controlled trials with potential reasons for heterogeneity clearly stated.

Table 1: Summary of the study quality assessment review for each paper accepted at full text. RCT = randomised control trial, SC = site comparison, CT = controlled trial, TS = time series.

Reference	**Study design**	**Baseline comparison**	**Intra treatment variation**	**Measurement of co-intervention**	**Parameter of abundance**	**Replication**	**Notes**
Dixon and Clay (2002)	RCT	Habitat type, location, altitude, age of stand and soil type are homogenous	Stand age, habitat type, location and altitude are all homogenous	No information	Shoot weight (g plant^{-1})	Eight	Results are also given on a health scale of 0 (dead) to 7 (healthy)
Andrews (1990)	SC	No information	No information	No information	% kill	No information	-
Eşen and Zedaker (2003)	RCT	Experimental area, habitat, longitude and latitude are all homogeneous	Experimental area, habitat, longitude and latitude are all homogeneous	No information	Basal area reduction (%)	Three	-
Edwards *et al* (2000)	RCT	Experimental area, habitat type, location and altitude are all homogeneous	Experimental area, habitat type, location and altitude are all homogeneous	No information	Health score scale, different for each trial	4 to 6	-
Pysek *et al* (1995)	CT	Location is homogenous	Location is homogeneous	No information	Qualitative	No information	-
Becker (1988)	SC or TS	Location is homogeneous	Location is homogeneous	No information	% regrowth	No information	-
Gritten (1981)	SC	No information	No information	No information	% kill	No information	Study is a collection of information from questionnaires
Clay *et al* (1992)	RCT	Experimental area, habitat, location, altitude, stand age and soil type are all homogeneous	Experimental area, habitat, location, altitude, stand age and soil type are all homogeneous	No information	Health score scale	Two or more	-
Lawrie *et al* (1993)	RCT	Experimental area, habitat, location, altitude, stand age and soil type are all homogeneous	Experimental area, habitat, location, altitude, stand age and soil type are all homogeneous	No other intervention is occurring	Fresh shoot weight (g plant $^{-1}$)	Three to four replicates	-
De'Ath (1988)	RCT	Experimental area is homogenous	Experimental area is homogeneous	No information	% control	Four	-
Tabbush *et al* (1984)	RCT	Habitat, location and altitude are all homogeneous	Habitat, location and altitude are all homogeneous	No information	% kill	Three	-
Edwards and Mason (1999)	RCT	Experimental area, habitat, location, altitude and soil type are all homogeneous	Experimental area, habitat, location, altitude and soil type are all homogeneous	No information	% regrowth	Five	-
Edwards and Morgan (1996)	RCT	Experimental area, habitat type, location, altitude and soil type are all homogeneous	Experimental area, habitat type, location, altitude and soil type are all homogeneous	No information	% regrowth	Five	-
Edwards (2004)	CT	Habitat, location, altitude and soil type are all homogeneous	Habitat, location, altitude and soil type are all homogeneous	No information	% cover	No information	-
Edwards *et al* (1993)	CT	Habitat, location and altitude are all homogeneous	Habitat, location and altitude are all homogeneous	No information	Health score scale	No information	-

Stables & Nelson (1990)	CT	No information	No information	No information	% live cover	No information	-
Edwards, C (2005).	RCT	No information	No information	No information	Health score scale	No information	-

5. OUTCOME OF THE REVIEW

Studies were sorted according to treatment type. DerSimonian-Laird chi squared values are used to estimate the p-value, DerSimonian pooled d values generate effect size (Egger *et al,* 2003) negative results indicate a reduction in *R. ponticum*. Confidence intervals are presented for individual studies (Table 2).

Table 2: The effectiveness of different herbicides on reduction of *R. ponticum*. + and – against herbicide name refer to sensitivity analyses carried out. Effect size (d) relates to the difference between the treatment and control, presented with their respective 95% confidence intervals. P value is significant at 0.05. A significant q value (0.05) is indicative of heterogeneity within the results. A significant bias indicator value (0.05) suggests a possible publication bias.

Treatment	Effect size (d)	95% confidence interval	p-value	q (heterogeneity)	Bias indicator
Herbicide only					
Imazapyr +	-0.51	-1.88 to 0.85	0.46	**<0.0001**	0.83
Imazapyr -	-2.57	-4.65 to -0.49	**0.0154**	**<0.0001**	**0.0005**
Glyphosate +	-0.16	-1.52 to 1.20	0.82	**<0.0001**	0.33
Glyphosate-	-1.10	-2.59 to 0.40	0.15	**<0.0001**	**0.001**
Triclopyr+	0.005	-0.86 to 0.87	0.99	0.26	0.32
Triclopyr-	-0.96	-2.15 to 0.23	0.16	0.06	**0.02**
Metsulfuron-methyl+	0.55	-0.35 to 1.46	0.23	0.89	**0.001**
Metsulfuron-methyl-	-1.92	-3.01 to -0.83	**0.0005**	0.71	**0.0003**
Cutting followed by…					
Imazapyr+	0.95	-0.13 to 2.02	0.08	0.49	**0.02**
Imazapyr-	0.09	-0.93 to 1.11	0.86	0.44	0.99
Glyphosate+	-1.01	-1.67 to -0.34	**0.0029**	0.51	**0.0002**
Glyphosate -	-1.14	-1.81 to -0.46	**0.001**	0.45	**0.0002**
Triclopyr	-0.55	-1.75 to 0.65	0.37	0.42	-

5.1 Effect of single herbicide treatments.

The analyses demonstrate that whilst most of the herbicides reduce the abundance of *R. ponticum* only Imazapyr and Metsulfuron-methyl (when used in a sensitivity analysis) produce significant reductions (p=0.02 and 0.0005 respectively). Both Imazapyr and Glyphosate show significant heterogeneity within the results as shown by q values in Table 2. Significant bias appears within five of the analyses, Triclopyr (most negative) and Metsulfuron-methyl.

5.2 Effect of cutting followed by herbicide treatment

Application of glyphosate post cut significantly reduces *R. ponticum* (p= 0.0029 or 0.001). Although there is no significant heterogeneity in the results, there is significant bias (p=0.0002) due to the small number of studies contributing to the data sets available for the meta-analysis.

Only three studies contained data that were meta-analysable on cutting followed by Imazapyr or Triclopyr treatment. None of these treatments resulted in significant reductions in *R. ponticum*. Imazapyr did not produce a negative effect size, Triclopyr did, but was non-significant. There is no significant heterogeneity within these results; Imazapyr meta-analysis shows significant bias (p=0.02). No bias indicator could be generated for Triclopyr due to the small sample size. Small sample size and insignificance of the results prevent further data analysis.

5.3 Qualitative analysis

There were four studies not included in meta-analysis; Andrews (1990), Pysek *et al* (1995), Becker (1988) and Gritten (1981). Andrews (1990) and Becker (1988) both report on the herbicide Amcide as being successful in control, they could not be meta-analysed though because no other study tested Amcide. Pysek *et al* (1995) and Gritten (1981) qualitatively state that cutting followed by a herbicide treatment is most effective in reduction of *R. ponticum.* These studies neither support nor undermine the findings within this systematic review.

5.4 Heterogeneity

Tests for heterogeneity were performed on application of Imazapyr, Metsulfuron-methyl, and post-cut application of Glyphosate. *A priori* reasons for heterogeneity, stated above as secondary objectives, could not be investigated due to lack of information within the studies. *Post hoc* reasons for heterogeneity were recognised as: field experiments vs. pot-grown experiments, length of experiment (from time of treatment to collection of results), herbicide dosage, and method of herbicide application (Table 3).

Imazapyr

Univariate meta-regression on all variables proved insignificant (p>0.05) i.e. independently, none of the variables influence the effectiveness of the treatments. On entering all the variables into multivariate meta-regression, outcomes of field trials and pot-grown trials were significantly different (p=0.034, Table 4), demonstrating that there is a difference between treatment effectiveness in pot-grown and field experiments when the effect of all variables is accounted for. No other variable showed significance.

Metsulfuron-methyl

Due to the small number of studies available (five), a multivariate meta-regression was performed using both independent and non-independent data for exploratory analysis on length of experiment and month of treatment. There was insufficient information on other variables to allow analysis to occur. Neither variable proved to be significant.

Glyphosate post cut

An exploratory multivariate meta-regression analysis was performed on all independent and non-independent data for the variables, 'length of experiment' and 'month of treatment'. Length of experiment demonstrated significance (p= 0.039, Table 5). Further multivariate meta-regressions were performed on all non-independent data to assess the significance of length of experiment and month of treatment in a more robust analysis. Neither variable proved to be significant.

Table 3: Potential reasons for heterogeneity within studies suitable for meta-analysis. Within each study letters refer to the separate data-sets extracted

Study	**Treatment**	**Ecological characteristics**			**Methodological characteristics**					**Notes**
		Habitat	**Month of treatment**	**Age of stand**	**Length of experiment**	**Cutting tool**	**Herbicide**	**Herbicide dosage**	**Method of application**	**-**
Dixon and Clay (2002)	Herbicide application	Pot-grown	July	3 years	12 months	N/A	Imazapyr	0.75 kg/ha	Track sprayer	-
Edwards *et al* (2000)	Herbicide application	Pot -grown	**A to E)** December; **F to J)** June; **K to O)** March; **P to U)** July	No info	**A to E)** 21 months; **F to J)** 29 months; **K to O)** 31 months; **P to U)** 12 months	N/A	**A to E)** Imazapyr or glyphosate; **F to J)** Glyphosate, Imazapyr or Triclopyr; **K to O)** Imazapyr or Glyphosate; **P to U)** Imazapyr	**A)** 0.75%, **B – C,F)**3.00, **G,L,O)**5.00%, **H)**3.75%, **I,M)**2.5%, **J)**4.8%,, **K)**3.6%,**N)** 20%, **P,R,T)**0.25kg ha a.i^{-1}, **Q,S,U)**0.75kg ha a.i^{-1},	**A to E)** Injection; **F to J)** Injection; **K to O)** Injection or basal stem application; **P to U)** Foliar spray or injection	Four independent data sets were generated.
Clay *et al* (1992)	Herbicide application (for all)	Pot-grown	February	**A to J)** 12 months; **K to M)** Young; **N to P)** Old; **Q to J1)** 12 months	**A to J)** 2 months; **K to J1)** 3 months	N/A	Imazapyr		Track sprayer	-
Lawrie *et al* (1993)	Herbicide application	**A to N1)** Unknown; **O1 to D7)** Pot-grown	**A to N1)** July; **O2 to T3)** August; **U3 to D7)** July.	**A to P)** 24 months; **Q to N1)** 12 months; **O2 to D7)** unknown	**A to P)** 13 months; **Q to N1)** 12 months; **O2 to T3)** unknown; **U3 to I6)** 5 months; **J6 to D7)** 9 months	N/A	Combinations of Imazapyr, Glyphosate, Metsulfuron methyl and Triclopyr.	**D2)**125g a.i. ha^{-1}, **I2)** 250g a.i. ha^{-1}, **N2)** 500g a.i. ha^{-1}, **J6,M6,S6,**	Track sprayer	3 independent datasets extracted.

								Y6) 22g a.i. ha^{-1}, **K6,N6,T6, Z6)**67g a.i. ha^{-1}, **L6,O6,U6, A7)**200g a.i. ha^{-1},		
De'ath (1988)	Herbicide application	Unknown	No info	No info	9 weeks	N/A	Triclopyr	2.8kg a.i.kg/ha	**A and B)** Copper peglar knapsack sprayer **C and D)** Micron Herbi CDA sprayer	Anon-independent data set extracted
Tabbush *et al* (1984)	Herbicide application	Unknown	No info	No info	10 months	N/A	2,4,5-T, Hexazinone, glyphosate, Triclopyr, DOWCO, AMS Tebuthiuron or Buthidazole.	No informatio n	Soil injection	-
Edward s and Mason (1999)	Cut and herbicide spray	Woodland	July	No info	36 months	Menzi muck flail	Imazapyr, glyphosate, triclopyr or Ammonium sulphamate	**A)**0.5%, **B)**7.2%) ,**C)** 3.8%, **D)**300g ha^{-1} a.e.,**E)** 150g ha^{-1} a.e.,, **F)** 50g ha^{-1} a.e.,, **G)** 25g ha^{-1} a.e.,, **H)**12.5g ha^{-1} a.e.,, **I)**32.8g ha^{-1} a.e.,, **J)**3.84g ha^{-1} a.e.,, **K)** 40%	**A to C)** Spray cut stump; **D to K)** spray foliar regrowth	Two independent data sets generated.
Edward s and Morgan (1996)	Cut and herbicide spray	Woodland	July	No info	24 months	Menzi-muck flail	Imazapyr, Triclopyr or Glyphosate	**A)** 5%, **B)** 1%, **C)**0.5%, **D)** 3.8%, **E)** 7.2%	Spray cut stump	-
Edward	Cut and	Woodland	No info	No info	36 months	Menzi-	Glyphosate or	**A)** 20%	Spray cut stump	-

s (2004)	herbicide spray					muck flail	imazapyr			
Edwards *et al* (1993)	Herbicide application	Unknown	**A)** February **B)** March **C)** April **D)** May **E)** June **F)** July **G)** August **H)** September **I)** October **J)** December	No info	**A)** 21 months **B)** 20 months **C)** 19 months **D)** 18 months **E)** 17months **F)** 16months **G)** 15 months **H)** 14months **I)** 13months **J)** 11 months	N/A	Imazapyr	750 g $a.e.ha^{-1}$	Knapsack sprayer	-
Stables & Nelson (1990)	Herbicide application post cut	Unknown	**A to D)** May, **E to H)** July, **I to L)**September, **M to P)** November, **Q to T)** January, **U to X)** March	Unknown	**A to D)** 51 months, **E to H)** 49 months, **I to L)** 47 months, **M to P)** 45 months, **Q to T)** 43 months, **U to X)** 41 months	Unknown	Glyphosate	36% glyphosate	Paintbrush	-
Edwards, C (2005).	**A to H)** Herbicide application post cut **I to B1)** Herbicide application	Unknown	**A&B)** November, **C,J,K)** May, **D,L,M)** June, **E, N)** July, **F,O)** August, **G,P,Q)** September, **H,I,R)** October, **S to W)** March	Unknown	**A&B)** 36 months **C to F, R, X to B1)** 12 months, **G&H)** 6 months **I to Q)** 18 months **S to W)** 54 months	Mechanical flail	**A, C to S, Z to B1)** Glyphosate **B, T to W)** Imazapyr	Unknown	**S to W, Z to B1)** Stem injection	-

Table 4: Results of multivariate meta-regression of *post hoc* reasons for heterogeneity for Imazapyr.

	Coefficient of Regression	Z	p	Confidence interval
Pot grown vs. field	19.25528	2.12	0.034	1.417768 to 37.09279
Month of treatment	-1.323324	-1.22	0.223	-3.452191 to 0.8055421
Herbicide dosage	-5.542219	-0.91	0.362	-17.45917 to 6.374735
Method of application	-4.708543	-1.23	0.219	-12.22441 to 2.807326
Length of experiment	.6812254	1.15	0.251	-0.4813279 to 1.843779

Table 5: Results of multivariate meta-regression of *post hoc* reasons for heterogeneity for glyphosate post cut

	Coefficient of Regression	Z	p	Confidence Interval
Length of experiment	-0.1246893	-2.06	0.039	-0.243102 to-0.006275
Month of treatment	-0.8428409	-1.70	0.089	-1.813474 to 0.127792

5.5 Power analysis

The current meta-analysis of Metsulfuron-methyl has a power of 0.6278. By increasing the sample size from five to 14 there would be sufficient power to reduce the probability of Type I errors to less than 5%. This would allow there to be a more definitive conclusion on the effectiveness of Metsulfuron-methyl for short-term control of *R. ponticum.*

Recommendations for future research were derived from Lawrie *et al.* (2004), as this study investigates the effect of Metsulfuron-methyl (the only legal herbicide that significantly reduced *R. ponticum*). It is a randomised control trial with a high level of homogeneity between the experimental and control plots. However, this study is underpowered. Power analysis based on the mean and variance resulted in 1-ß of 0.08, considerably lower than the accepted power levels of 0.8-0.95 (Crawley, 2002). If the power of the study were to be increased to 0.8 or 0.95 then sample sizes of 274-479 individual plants would be required. Although such a sample sizes are impractical, sample sizes should be increased as much as resources allow in order to reduce the probability of generating type I errors.

6. DISCUSSION

6.1 Primary objective

The purpose of this review was to determine the effectiveness of commonly used methods of controlling *R. ponticum*. Meta-analysis demonstrates that significant reduction of *R. ponticum* is evident when the stand is sprayed with Imazapyr (negative sensitivity analysis) or Metsulfuron-methyl (negative sensitivity analysis). As there are only small samples for each meta-analysis there is a risk of generating a Type I error. With more research studies the effectiveness of other herbicides on *R. ponticum* control may also prove significant. Imazapyr is now an illegal herbicide within Europe, banned for sale on 24th June 2003, by the EC, so further research on other herbicides is needed.

The significant reduction seen with post-cutting treatment with glyphosate suffers from significant study bias. These data, from a small number of studies, would have experienced similar habitats and ecological features, which could have potentially biased the result. As imazapyr alone significantly reduces *R. ponticum* abundance, it may be expected that significant reduction would be demonstrated when the stand was cut prior to herbicide application. This is not the case; applying Imazapyr post cut did not cause a significant decline in *R. ponticum* abundance.

There is no information within the studies on how the cut material is disposed of. If it remains at the site then seed may set and re-invasion rather than failure of treatment may be the reason why the stand is not cleared. Also, buried roots may be the cause of regrowth. These possibilities need to be taken into consideration when there are experiments carried out as they have implications for practice and management.

6.2 Secondary objectives

Habitat type, disposal of cut material, and follow-up treatments were all defined *a priori* as possible reasons for heterogeneity that require further analysis. These objectives were specified by practitioners and the lack of information available on them is of concern. Hence they are considered within further research (below).

6.3 Heterogeneity

Imazapyr
Differences between the pot-grown vs. field trials demonstrate that laboratory experiments in artificial conditions cannot be directly translated into results for a 'real' environment, and overall effectiveness is dependent on other factors, such as those entered into the meta-regression. When maintained in a pot in a greenhouse the plants are protected from environmental factors that they would experience outside, this also holds true for the herbicide. Environmental factors that may negate the efficacy of the herbicide include time of rainfall since herbicide application, and the size of the plot treated. When herbicide is used to treat a single *R. ponticum* in a pot there is no chance of re-invasion from other areas. In a field situation it is important to consider the size of the experimental area and its proximity to other stands. Within a greenhouse the herbicide will not experience any drift from the wind thus the herbicide will remain within the vicinity of the plants for longer. Outside, the plants

are essentially experiencing reduced doses of the herbicide and are subjected to them for a shorter time period.

Metsulfuron-methyl
Due to lack of information only length of experiment and month of treatment could be investigated. Even within these reasons for heterogeneity there was little variation, which may explain the non-significant result produced. Further experiments documenting all ecological and experimental variables need to be performed to assess under what conditions this herbicide would be at its most efficacious.

Glyphosate post cut
In the initial multivariate meta-regression incorporating all data points whether independent or non-independent, length of experiment was shown to be significant. The result demonstrated that the longer the experiment the more likely the *R. ponticum* stand was to be reduced. Potential explanations for this may be that the herbicide had not had time to be effective in shorter experiments therefore producing less of a reduction. The longest experiment lasted for 54 months; by performing longer experiments we may better understand for how long a treatment will remove *R. ponticum*, and the best time to re-treat if required.

6.4 Bias

Bias exists in the meta-analyses of Imazapyr and Glyphosate, and post-cut Glyphosate application. The Egger *et al* (1997) test for asymmetry examines publication bias; however the inclusion of grey literature should reduce this bias indicating that other biases may exist within the results.

There are two main methods of reporting the outcome and these may introduce measurement bias (differences in comparison groups on how outcomes are ascertained). For example, Clay *et al* (1992) measure the fresh weight of the shoot (g plant $^{-1}$), in comparison to Edwards *et al* (2000) who assess the health of a plant on a scale on 0 (dead) to 7 (fully healthy). Combining these objective and subjective methods of measuring effectiveness may introduce bias into the results. Selection bias is introduced when the control and experimental groups are unequal i.e. the basis on which the plants were assigned to groups was not random, thus the best way to reduce this bias is to conduct randomised control trials. Edwards *et al* (1993) is the only controlled trial included in the meta-analysis, all others are randomised controlled trials; it may be possible that bias is present because of this study.

The presence of bias in the meta-analyses is not certain, but the asymmetrical funnel plot indicates that there is a strong possibility of it existing, exaggerating or underestimating the overall effect size (Khan *et al*, 2003). With so many potential reasons for bias existing it is difficult to conclude the actual reason for such bias even if it is present.

7. REVIEWERS' CONCLUSIONS

7.1 Implication for conservation practice

The best available evidence suggests that Metsulfuron-methyl and glyphosate application post cut significantly reduces *R. ponticum*. The evidence for Metsulfuron-methyl effectiveness is based on five short-term studies leaving considerable uncertainty over its real effectiveness, particularly in the long-term. Further, these studies are either performed in an unspecified habitat or in pots in glasshouses. The applicability of these results to field conditions with a diverse range of interacting variables is therefore uncertain.

As significant bias is present in the post-cut Glyphosate application meta-analysis, this result also has to be treated with caution. The 11 data sets come from five studies; therefore the applicability of these results to all habitats, experiencing different ecological conditions, is unclear. There is qualitative evidence that post-cut glyphosate application is effective (e.g. Gritten, 1981) but there are no further formal statistics to back up this claim.

The available evidence on other commonly-used interventions is insufficient to test their effectiveness for the control of *R. ponticum*.

7.2 Implications for research

7.2.1 Interventions

Exploratory Power analysis suggests that a minimum of 14 randomised control trials are needed to rigorously test the effectiveness of application of Metsulfuron-methyl. Many reports are written on the effect of the treatments on sites, but experimental controls are rarely used, rendering these reports inadequate for the systematic review process. We recommended that further trials are undertaken on a range of interventions for the control of *R. ponticum*, and that the plots should be randomly allocated to treatments and controls. When only one treatment plot is used an equivalent control plot should also be monitored for comparison. Reports should preferably be stored on an accessible database (e.g. www.conservationevidence.com).

7.2.2 Ecological factors

Ecological factors form reasons for heterogeneity, it is therefore essential that any factors that could influence the outcome are explicitly stated, such as the amount of rainfall on the day of application. These can then be incorporated into the analyses and accounted for as suggestions for management.

An important factor that needs to be taken into consideration is the habitat in which *R. ponticum* was treated. Unfortunately many studies failed to report this. Measuring the efficacy of the herbicide on the pot-treated *R. ponticum* does not ensure effectiveness in a field situation, there is greater advantage in continuing with studies that are based on real populations as they have more relevance for management practices.

7.2.3 Methodological characteristics

An important question in the control of *R. ponticum* is the length of time between treatments required to prevent encroachment into previously cleared habitat. Many of the studies analysed have a short time span and therefore make it difficult to suggest a practical time between treatments. In the exploratory analysis of Glyphosate post-cut, length of experiment was significant, but not in the more robust analysis, therefore there is a requirement for more studies to investigate this variable.

7.3 Implications for policy

Many conservation organisations operate a policy of control of *R. ponticum* on some sensitive sites. Given the degree of uncertainty surrounding the effectiveness of the various control options, it is important that resources allocated to this task and the consequent work programmes incorporate good experimental design and careful monitoring of outcomes. The resulting datasets should enable further review of effectiveness leading to more cost-effective control.

8. ACKNOWLEDGEMENTS

This project was supported by English Nature. We would like to thank John Bacon (EN) and Tony Robinson (EN) for their help in formulation of the question, and Colin Edwards and the Forestry Commission for providing articles. We are grateful for comments on the manuscript from, John Bacon (EN), David Burton (EN), Colin Edwards (FC), Keith Kirby (EN), and Doug Oliver (CCW) and support throughout the review from Gavin Stewart, Zoe Davies and Phillip Roberts.

9. REFERENCES

Andrews, J. (1990). Management of lowland heathlands for wildlife. *British Wildlife* 1(6): 336-346.

Bausall, R.B. and Li, Y. (2002). *Power analysis for experimental research: a practical guide for biological, medical and social sciences*. Cambridge University Press, Cambridge.

Becker, D. (1988*). Control and removal of Rhododendron ponticum on RSPB reserves in England and Wales*. Royal Society for the Protection of Birds (RSPB)

Clay, D. V., Goodall, J.S. and Nelson, D.G. (1992).The effect of imazapyr on Rhododendron ponticum. *Aspects of Applied Biology* 29: 287-294

Crawley, M. J. (2002). *Statistical Computing: An Introduction to Data Analysis Using S-Plus.* John Wiley and Sons, Ltd.

Cross J.R. (1975). Biological Flora of the British Isles: *Rhododendron ponticum* L. *The Journal of Ecology*. 63(1): 345-364.

Cross J.R. (1981). The establishment of *Rhododendron ponticum* in the Killarney oakwoods, S.W. Ireland. *The Journal of Ecology*. 69: 807-824.

De' Ath, M. R. (1988).Triclopyr - a review of its forestry and industrial weed control uses. *Aspects of Applied Biology* 16: 183-188.

Dixon, F. L. and D. V. Clay (2002). Imazapyr application to Rhododendron ponticum: speed of action and effects on other vegetation. *Forestry* 75(3): 217-225

Edwards, C. (2004) Effective herbicide control of Rhododendron ponticum (L). *Forest research.*

Edwards, C (2005). Effective herbicide control of *Rhodododendron ponticum*. *Pers comm*

Edwards, C. and. Morgan. J. L. (1996). Control of Rhododendron ponticum by stump applications of herbicides following mechanical clearance. *Proceedings Crop Protection in Northern Britain*: 213-218.C

Edwards, C., and Mason W.L (1999). Herbicide control of Rhododendron ponticum following mechanical clearance by hydraulic flail. *Proceedings Crop Protection in Northern Britain II*: 145-150

Edwards, C., Tracy D. R. and Morgan J. L. (1993). Rhododendron control by Imazapyr. *Forestry Commission Research Information Note*: Note 233.

Edwards, C., Clay D.V. and Dixon, F.L. (2000). Stem treatment to control Rhododendron ponticum under woodland canopies. *Aspects of Applied Biology*: 58

Egger, M., Smith, G. D., and Altman, D. G., (2003). *Systematic Reviews in Healthcare: Meta-analysis in context*. BMJ Publishing Group, London.

Esen, D. and S. M. Zedaker (2004). Control of rhododendron (Rhododendron ponticum and R-flavum) in the eastern beech (Fagus orientalis) forests of Turkey. *New Forests* 27(1): 69-79

Hilbe, J. sg15: Sample size determination for means and proportions. *Stata Technical Bulletin*. 11: 17-20.

Khan, K. S., Kunz, R., Kleijnen, J., and Antes, G., (2003). *Systematic Reviews to Support Evidence – based Medicine. How to review and apply findings on healthcare research.* The Royal Society of Medicine Press Limited, London.

Landis, J.R. and Koch, G.G. (1977). The measurement of Observer Agreement for Categorical data. *Biometrics*. 33(1): 159-174

Lawrie, J. and Clay, D. V. (1993). Effects of herbicide mixtures and additives on Rhododendron ponticum. *Weed Research* 33: 25-34.

Milne R.I and Abbott J. (2000). Origin and evolution of invasive naturalized material of *Rhododendron ponticum* L. in the British Isles. *Molecular Ecology*. 9: 541-556.

Mitchell R.J., Marrs R.H., Le Duc M.G and Auld M.H.D (1997). A study of lowland heaths in Dorset, southern England: changes in vegetation and soil chemical properties. *Journal of Applied Ecology*. 34: 1426-1444.

Pullin, A.S., and Knight, T. M. (2001). Effectiveness in conservation practice: Pointers from Medicine and public health. *Conservation Biology*. 15(1): 50-54.

Pysek, P., and others, eds (1995). "Plant invasions: general aspects and special problems."

Serle S. (1999). Controlling Rhododendron at Windsor. ENACT. Volume 7, No. 4

Stables, S., and Nelson, D. G. (1990). *Rhododendron ponticum* control. Forestry Commission Research Information Note 186.

Stevens, A., and Milne, R., (1997). The effectiveness revolution and public health. In: Scally, G. (Ed.), Progress in Public Health, Royal Society for Medicine Press, London, pp 197-225.

Tabbush, P. M. and. Sale., J.S.P (1984). Experiments on the chemical control of Rhododendron ponticum L. *Aspects of Applied Biology* 5: 243-254.

Thomson A.G., Radford G.L., Norris D.A. and Good J.E.G. (1993). Factors affecting the distribution and spread of *Rhododendron* in North Wales. *Journal of Environmental management.* 39: 199-212.

Appendix 1: Characteristics of included studies

Study	Andrews, (1990)	
Methods	A site comparison based on sites treated with different interventions. There are % kill data, one for each site. There are two sites and results have been averaged. There is no true control, just a comparison of methods.	
Population	No detail on stand age, but it is located on lowland heathland.	
Intervention and Co interventions	Drilled holes filled with herbicide, compared with stumps painted with herbicide.	
Outcomes		% kill
	Painted stumps	30-40
	Drilled holes	95
Study design	Site comparison: 40	
Baseline Comparison	No information is provided regarding the actual site other than if it is lowland heathland. It is thus not possible to give a baseline comparison.: 0	
Intra treatment variation	There is no information describing the intra-treatment variation:0	
Measurement of intervention and Cointerventions	As the information regarding the sites is not given within the text there is insufficient knowledge to comment upon other management techniques within the area: 0	
Replication & parameter of abundance	There is no replication cited: 0	
Attrition bias	No information regarding the number of individuals lost within the study:0	
Sum of Data quality	40	
Notes	The study appears to comment on the use of techniques rather than providing the reader with scientific evidence, resulting in a low data quality score.	

Study	Becker, (1988)		
Methods	There is a single site comparison and 4 time series experiments.		
Population	All habitats are heterogeneous and the age of the stands are unknown		
Intervention and Co interventions	One experiment involves the application of herbicide; one involves winching (cutting and burning); and three involve cutting and then a secondary treatment of herbicide,		
Outcomes	Experiment/treatment	% regrowth	
	Experiment 1: Cutting	10	
	Experiment 2: Cutting and spray	40	
	Experiment 3: Cutting and spray	60	
	Experiment 4: Cutting and spray	10	
	Experiment 5: Winching	5	
Study design	A = Site comparison: 40; B, C, D, = Time series: 30		
Baseline Comparison	Size of experimental area prior to experiment is unknown, and thus assumed heterogeneous. The habitat type, altitude, age of stand at time of treatment and soil type are all unknown, for each study the geographical location is the same: 1		
Intra treatment variation	Only the geographical location is known. The habitats within each study are variable, and there is insufficient information about the other variants; they are thus assumed heterogeneous. The disposal method of cut material is either not relevant or described (when winched the material is burnt): 2		
Measurement of intervention and Cointerventions	There is no mention of co-intervention factors for any of the treatment, but as the experiments are carried out on managed site it is assumed that these factors exist: 0		
Replication & parameter of abundance	There is no data regarding the replication of experiments: 0		
Attrition bias	There is insufficient information regarding the number of individuals that were lost during the experiment: 0		
Sum of Data quality	Study	A	B, C, D,
	Data quality score	43	33
Notes	There is a qualitative narrative describing the techniques and there effectiveness but little data actually provided to back up the claims.		

<table>
<tr><th>Study</th><th colspan="4">Clay et al, (1992)</th></tr>
<tr><td>Methods</td><td colspan="4">Randomised control trials, four experiments performed on pot-grown Rhododendron in a glasshouse. Different concentrations of herbicides were applied. The first and second experiments present data regarding the application of different herbicides to the shoots of Rhododendron. The third experiment compared the effect of herbicide application to young or old stands; and the fourth compared the effect of adding sodium monochloroacetate.</td></tr>
<tr><td>Population</td><td colspan="4">R. ponticum, grown from seeds in pots maintained in an unheated glasshouse. Seeds were sown in February 1990 on an acid-heath soil: peat mixture.</td></tr>
<tr><td>Intervention and Co interventions</td><td colspan="4">The herbicide Imazapyr is applied in all cases with a track sprayer. In the fourth experiment Imazapyr is applied along with sodium monochloroacetate.</td></tr>
<tr><td rowspan="21">Outcomes</td><td>Study</td><td>Shoot fresh weight (g)</td><td>Study</td><td>Shoot fresh weight (g)</td></tr>
<tr><td>A</td><td>80.2</td><td>R</td><td>103</td></tr>
<tr><td>B</td><td>83.2</td><td>S</td><td>133</td></tr>
<tr><td>C</td><td>46.0</td><td>T</td><td>131</td></tr>
<tr><td>D</td><td>39.5</td><td>U</td><td>71</td></tr>
<tr><td>E</td><td>27.0</td><td>V</td><td>144</td></tr>
<tr><td>F</td><td>8.0</td><td>W</td><td>133</td></tr>
<tr><td>Control</td><td>88.2</td><td>X</td><td>107</td></tr>
<tr><td>G</td><td>53.5</td><td>Y</td><td>66</td></tr>
<tr><td>H</td><td>32.5</td><td>Z</td><td>92</td></tr>
<tr><td>I</td><td>27.2</td><td>A1</td><td>124</td></tr>
<tr><td>J</td><td>18.0</td><td>B1</td><td>165</td></tr>
<tr><td>Control</td><td>95.0</td><td>C1</td><td>40</td></tr>
<tr><td>K</td><td>34.0</td><td>D1</td><td>87</td></tr>
<tr><td>L</td><td>41.0</td><td>E1</td><td>78</td></tr>
<tr><td>M</td><td>40.5</td><td>F1</td><td>48</td></tr>
<tr><td>N</td><td>37.0</td><td>G1</td><td>12</td></tr>
<tr><td>O</td><td>15.0</td><td>H1</td><td>44</td></tr>
<tr><td>P</td><td>22.5</td><td>I1</td><td>48</td></tr>
<tr><td>Control</td><td>73.0</td><td>J1</td><td>18</td></tr>
<tr><td>Q</td><td>146</td><td>Control</td><td>112</td></tr>
<tr><td>Study design</td><td colspan="4">All are randomised control trials : 80</td></tr>
<tr><td>Baseline Comparison</td><td colspan="4">Experimental areas are pots equal in size, habitat type, location, altitude, stand age at time of treatment and soil type are all homogenous: 6</td></tr>
<tr><td>Intra treatment variation</td><td colspan="4">The stand age at time of treatment, habitat type, location and altitude are all equal during the experiment: 5</td></tr>
<tr><td>Measurement of intervention and Cointerventions</td><td colspan="4">No information is provided on co-interventions: 0</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="4">All experiments include more than two replications:4</td></tr>
<tr><td>Attrition bias</td><td colspan="4">No information is provided: 0</td></tr>
<tr><td>Sum of Data quality</td><td colspan="4">95 (for all four experiments)</td></tr>
<tr><td>Notes</td><td colspan="4">There is data available for experiment 1 of the effect that the herbicide has on plant if applied to the roots instead of shoots; however, there is no control or standard deviations presented for this. A further experiment was carried out in the field comparing the effect of different herbicides, but no untreated control is presented and this data cannot therefore be synthesised.</td></tr>
<tr><td></td><td colspan="4"></td></tr>
</table>

<table>
<tr><th>Study</th><th colspan="2">De’ath (1988)</th></tr>
<tr><td>Methods</td><td colspan="2">A randomised control trial investigating the effects of the herbicide triclopyr on different forest weeds – including rhododendron. Triclopyr is applied at different dosages with different sprayers</td></tr>
<tr><td>Population</td><td colspan="2">No information is provided</td></tr>
<tr><td>Intervention and Co interventions</td><td colspan="2">There is no reference made to any other interventions occurring at the site</td></tr>
<tr><td rowspan="6">Outcomes</td><td>Study</td><td>% control after 9 weeks</td></tr>
<tr><td>A</td><td>56</td></tr>
<tr><td>B</td><td>57</td></tr>
<tr><td>C</td><td>56</td></tr>
<tr><td>D</td><td>62</td></tr>
<tr><td>Control</td><td>0</td></tr>
<tr><td>Study design</td><td colspan="2">A randomised control trial: 80</td></tr>
<tr><td>Baseline Comparison</td><td colspan="2">Only the size of the experimental area is homogeneous, no information is provided on the other factors therefore the worst case scenario is presumed: 1</td></tr>
<tr><td>Intra treatment variation</td><td colspan="2">There is no requirement for the disposal of cut material therefore one point is awarded, no other factors are taken into consideration: 1</td></tr>
<tr><td>Measurement of intervention and Cointerventions</td><td colspan="2">There is no information provided: 0</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="2">Three or four replicates: 4</td></tr>
<tr><td>Attrition bias</td><td colspan="2">No information: 0</td></tr>
<tr><td>Sum of Data quality</td><td colspan="2">86 (for all studies)</td></tr>
<tr><td>Notes</td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td></tr>
</table>

<table>
<tr><th>Study</th><th colspan="2">Dixon & Clay (2002)</th></tr>
<tr><td>Methods</td><td colspan="2">A randomised controlled translocation experiment that also looks at the effect of herbicides. The study provides data on the final fresh shoot weight of the population 10 months after the initial treatment</td></tr>
<tr><td>Population</td><td colspan="2">The population are maintained within pots, in pairs, in a greenhouse. They are recorded as being 3 years old.</td></tr>
<tr><td>Intervention and Co interventions</td><td colspan="2">Imazapyr application</td></tr>
<tr><td rowspan="3">Outcomes</td><td></td><td>Shoot Weight (g plant $^{-1}$)</td></tr>
<tr><td>Treated</td><td>380</td></tr>
<tr><td>Control</td><td>188.5</td></tr>
<tr><td>Study design</td><td colspan="2">Randomised Control Trial : 80</td></tr>
<tr><td>Baseline Comparison</td><td colspan="2">Size of experimental area prior to experiment is unknown, and thus assumed heterogeneous. The habitat type, location/geographical area, altitude, age of stand at time of treatment and soil type are all homogenous as plants are grown in pots: 5</td></tr>
<tr><td>Intra treatment variation</td><td colspan="2">The stand age at time of treatment, the habitat type, location and altitude are all equal during the experiment. There is no disposal of cut material as the experiment involves spraying hence the maximum mark is awarded for this factor: 5</td></tr>
<tr><td>Measurement of intervention and Cointerventions</td><td colspan="2">The control and co-intervention are receiving different treatments as both plants are sprayed within the control pot, but only one receives the herbicide in the experimental group as part of the translocation experiment: 0</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="2">There are eight replication within each control and experimental group, resulting in a high accuracy level: 4</td></tr>
<tr><td>Attrition bias</td><td colspan="2">There is insufficient information regarding the number of individuals that were lost during the experiment: 0</td></tr>
<tr><td>Sum of Data quality</td><td colspan="2">94</td></tr>
<tr><td>Notes</td><td colspan="2">Further results were available relating to the health of the plants and was recorded on a scale of 0-7 (0 = dead, 4 = 50% reduction in health compared with the initial assessment, 7 = healthiest). This was assessed by eye and was thus considered subjective. Height of plants during the experiment were also recorded but is not an outcome related to this review. Synthesis of data will be performed on data relating to the shoot weight (g plant $^{-1}$).</td></tr>
<tr><td></td><td colspan="2"></td></tr>
</table>

Study	Edwards, and Mason (1999)	
Methods	There are two randomised control experiments. Experiment a looks at the effect of a follow-up treatment of herbicide application after an initial mechanical clearance of the experimental area. Experiment b looks at the effectiveness of foliar application of herbicides to regrowth after mechanical cutting.	
Population	A dense population of rhododendron situated in a woodland near Lochgilphead, Argyll. The rhododendron stand has been present for over 60 years.	
Intervention and Co interventions	In both experiments the stand was initially cut with a mechanical flail. Herbicides Imazapyr, Glyphosate, triclopyr and ammonium sulphamate were then applied at appropriate concentrations with a knapsack sprayer to appropriate parts of the plant.	
Outcomes	Herbicide treatment	% with regrowth
	Imazapyr (5% conc.)	0.0
	Imazapyr (1% conc.)	0.0
	Imazapyr (0.5% conc.)	3.3
	Glyphosate (7.2% conc.)	36.7
	Triclopyr (3.8% conc.)	46.7
	Control	90.0
	Herbicide treatment	Abundance (%)
	Imazapyr (300 g ha^{-1} a.e.)	5.0
	Imazapyr (150 g ha^{-1} a.e.)	19.0
	Imazapyr (50 g ha^{-1} a.e.)	30.0
	Imazapyr (25 g ha^{-1} a.e.)	45.0
	Imazapyr (12.5 g ha^{-1} a.e.)	56.0
	Glyphosate (32.8 kg ha^{-1} a.e.)	47.0
	Triclopyr (3.84 kg ha^{-1} a.e.)	36.0
	Ammonium sulphamate (40%)	7.0
	Control	60.0
Study design	A randomised controlled trial: 80	
Baseline Comparison	The size of the experimental area, habitat type, location, altitude and soil type are all homogenous, there is no information provided on the stand age: 5	
Intra treatment variation	There is no information provided on the age of the stand at treatment. There is no disposal method of cut material given, it is therefore assumed homogenous throughout. Habitat type, location, and altitude are all stated as being equal: 4	
Measurement of intervention and Cointerventions	There is no information on interventions or co-interventions: 0	
Replication & parameter of abundance	In both experiments there are 5 replications: 4	
Attrition bias	There is no information regarding attrition bias: 0	
Sum of Data quality	93 (for all studies)	
Notes	Experiment uses cut alone as the control, treatment is cut followed by herbicide, therefore this data will be used in a separate analysis that looks at the effectiveness of follow up treatments.	

Study	Edwards, (2004).	
Methods	A controlled trial looking at the effect that different herbicides have after an initial cut.	
Population	All experiments were located in Argyll on the west coast of Scotland. No further information on the Rhododendron stand is provided.	
Intervention and Co interventions	The combination technique used is to cut the stumps with a mechanical flail, and then to applied the herbicides (Imazapyr or glyphosate)	
Outcomes	Treatment	% cover
	Control	39.0
	Glyphosate	15.0
	Imazapyr	6.0
Study design	A controlled trial: 60	
Baseline Comparison	There is no information provided on the size of the experiment or the stand age, however, habitat type, location, altitude and soil type are all stated as being homogenous: 4	
Intra treatment variation	Stand age is not given and thus assumed to be heterogeneous. Disposal of cut material, habitat type, location and altitude are all equal: 4	
Measurement of intervention and Cointerventions	No information is provided regarding the other interventions that may be or have occurred previously: 0	
Replication & parameter of abundance	The number of replications is not stated in the experimental design, it is therefore assumed to be 0: 0	
Attrition bias	No information: 0	
Sum of Data quality	68	
Notes	Experiment uses cut alone as the control, treatment is cut followed by herbicide, therefore this data will be used in a separate analysis that looks at the effectiveness of follow up treatments.	

Study	Edwards (2005)		
Methods	A control trial to observe the effectiveness of glyphosate as a herbicide to control *R. ponticum*, comparisons are made with Imazapyr		
Population	Stands in Argyll, West Scotland		
Intervention and Co interventions	No further information was given.		
Outcomes	Study	Experimental population health score (1=healthy, 6=dead)	Control group health score (1=healthy, 6=dead)
	A	15.0	39.0
	B	6.0	39.0
	C	6	1
	D	6	1
	E	6	1
	F	6	1
	G	6	1
	H	6	1
	I	6	1
	J	6	1
	K	6	1
	L	6	1
	M	6	1
	N	6	1
	O	6	1
	P	6	1
	Q	6	1
	R	6	1
		Experimental population health score (1=healthy, 10=dead)	Control group health score (1=healthy, 10=dead)
	S	9.0	2.6
	T	8.1	2.6
	U	7.8	2.6
	V	8.3	2.6
	W	9.9	2.6
		Experimental population health score (1=healthy, 6=dead)	Control group health score (1=healthy, 6=dead)
	X	0.8	0.4
	Y	1.6	0.4
	Z	6	0.4
	A1	6	0.4
	B1	6	0.4
Study design	A randomised control trial: 80		
Baseline Comparison	No information: 0		
Intra treatment variation	No information: 0		
Measurement of intervention and Cointerventions	No information: 0		
Replication & parameter of abundance	No replication is made reference to. A health scale, scored by eye is used; 0		
Attrition bias	No information: 0		
Sum of Data quality	80 (for all studies)		
Notes			

<table>
<tr><th>Study</th><th colspan="2">Edwards & Morgan, (1996)</th></tr>
<tr><td>Methods</td><td colspan="2">The experiment is a randomised control trial that assesses the effects of the herbicides after an initial mechanical cut. The site is situated in Argyll.</td></tr>
<tr><td>Population</td><td colspan="2">The population is a dense Rhododendron stand in woodland which has been established for more than 60 years. Bushes range from 2 to 5m, with a maximum stem diameter of 17cm.</td></tr>
<tr><td>Intervention and Co interventions</td><td colspan="2">The primary treatment is mechanical cutting. The follow up treatment involves herbicide application – imazapyr at 3 different concentrations, glyphosate or triclopyr. Assessment of success is based on regrowth.</td></tr>
<tr><td rowspan="7">Outcomes</td><td>Herbicide Treatment</td><td>% stumps with regrowth</td></tr>
<tr><td>Imazapyr (5% conc.)</td><td>0</td></tr>
<tr><td>Imazapyr (1% conc.)</td><td>0</td></tr>
<tr><td>Imazapyr (0.5% conc.)</td><td>9.6</td></tr>
<tr><td>Triclopyr (3.8% conc.)</td><td>18.6</td></tr>
<tr><td>Glyphosate (7.2% conc.)</td><td>27.0</td></tr>
<tr><td>Control</td><td>80.4</td></tr>
<tr><td>Study design</td><td colspan="2">Randomised control trial: 80</td></tr>
<tr><td>Baseline Comparison</td><td colspan="2">Size of experimental area, habitat type, location, altitude and soil type are all stated as being equal. There is no information provided on the age of the stand : 5</td></tr>
<tr><td>Intra treatment variation</td><td colspan="2">There is no information provided regarding the disposal of the cut material, it is therefore presumed to be equal in all cases. Again, the habitat type, location and altitude are equal in all cases. There is no stand age given: 4</td></tr>
<tr><td>Measurement of intervention and Cointerventions</td><td colspan="2">No information is presented on any co-intervention factors that may be occurring: 0</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="2">There were 5 replications per treatment: 4</td></tr>
<tr><td>Attrition bias</td><td colspan="2">No information: 0</td></tr>
<tr><td>Sum of Data quality</td><td colspan="2">93</td></tr>
<tr><td>Notes</td><td colspan="2">Experiment uses cut alone as the control, treatment is cut followed by herbicide, therefore this data will be used in a separate analysis that looks at the effectiveness of follow up treatments.</td></tr>
<tr><td></td><td colspan="2"></td></tr>
</table>

Study	Edwards, *et al*. (1993)	
Methods	An experiment investigating the effects that the timing of the spraying of imazapyr in relation to month has on the effectiveness of the herbicide. Only the effectiveness of the latest spray will be used.	
Population	No information is provided.	
Intervention and Co interventions	Imazapyr is sprayed at a single concentration using a knapsack sprayer	
Outcomes	Study	Damage score (0-10, where 10=dead)
	A	10.0
	B	10.0
	C	10.0
	D	10.0
	E	10.0
	F	10.0
	G	10.0
	H	9.7
	I	9.7
	J	9.4
	Control	0.5
Study design	A controlled trial: 60	
Baseline Comparison	Habitat type, location and altitude are all homogenous, there is no information given on the size of the experimental area, stand age or soil type, they are thus assumed heterogeneous: 3	
Intra treatment variation	No information is given on the stand age, however habitat, location and altitude are all homogenous: 4	
Measurement of intervention and Cointerventions	No information is provided: 0	
Replication & parameter of abundance	No replicates are mentioned in the methods: 0	
Attrition bias	No information is provided: 0	
Sum of Data quality	67	
Notes	Further data is available on spot treatment using different herbicides, however, it is presented in graph form and no actual figures are given.	

Study	Edwards, C. et al 2000	
Methods	4 randomised control trials; 3 in the field at three different locations (Quantock, Llanrwst and Loch Awe) and the fourth a pot-grown experiment. For the field trials *R. ponticum* populations were separated into blocks for treatments. The control used in all the 4 trials was a untreated block/pot.	
Population	Quantock: *R. ponticum* growing among mature larch and beech trees Llanrwst: Moderately sheltered Oak wood Loch Awe: Young broadleaved plantation. Pots	
Intervention and Co interventions	Application of one of three herbicides: imazapyr, tricolpyr or glyphosate. Quantock results are scored on a scale of 0 (dead) to 7 (healthy). Llanrwst results are scored on a scale of 1 (healthy) to 5 (dead) Loch Awe results are scored on a scale of 1 (healthy) to 10 (dead) Quantock results are scored on a scale of 0 (dead) to 7 (healthy).	
Outcomes	Location/Experiment	Health
	Quantock	4
	Quantock	2.3
	Quantock	2.2
	Quantock	0
	Quantock	0
	Quantock (Control)	6.2
	Llanrwst	5
	Llanrwst	5
	Llanrwst	5
	Llanrwst	5
	Llanrwst	3.2
	Llanrwst (Control)	1.9
	Loch Awe	8.4
	Loch Awe	9.6
	Loch Awe	8.5
	Loch Awe	9.5
	Loch Awe	7.5
	Loch Awe (Control)	2.8
	Pot-grown	0.8
	Pot-grown	0.3
	Pot-grown	3.2
	Pot-grown	0.8
	Pot-grown	1.2
	Pot-grown	1
	Pot-grown (Control)	6
Study design	Randomised Control Trial : 80	
Baseline Comparison	For all the studies the size of the experimental area is homogenous. The habitat type, geographical location is also constant. The altitude is not stated but assumed to be the same as the locations are all equal. The stand age is not known for the studies, but referred to as young for the M, N, O, P and Q. There is insufficient data on the soil type and stand age: 4	
Intra treatment variation	The stand age at time of treatment is not known and hence can not be described as homogenous, the habitat type, location and altitude are all equal during the experiment. There is no disposal of cut material as the experiment involves spraying: 4	
Measurement of intervention and Cointerventions	There are no reported co – intervention factors occurring. It is thus considered that there is a lack of information: 0	
Replication & parameter of abundance	There are four to six replications (depending on the experiment) within each control and experimental group, resulting in a high accuracy level: 4	
Attrition bias	There is insufficient information regarding the number of individuals that	

	were lost during the experiment: 0
Sum of Data quality	92
Notes	For the results of the effectiveness of interventions only mean quantities are provided. This means that at this stage it is not possible to gain a variance from the results. Each trial will not be considered independently because for the trials carried out at each site the results are compared to the same control, each result will thus have to be entered into the meta-analysis singularly.

<table>
<tr><th>Study</th><th colspan="5">Esen & Zedaker (2003)</th></tr>
<tr><td>Methods</td><td colspan="5">A randomised block design with 5 replications, each plot was further divided into treatment bands. The control was an untreated band. Results were recorded as % basal area reduced.</td></tr>
<tr><td>Population</td><td colspan="5">R. ponticum in beech stands, with continuous Rhododendron under storey.</td></tr>
<tr><td>Intervention and Co interventions</td><td colspan="5">Foliar herbicide spray, cut and herbicide spray, hand cutting and hand grubbing.</td></tr>
<tr><td rowspan="3">Outcomes</td><td></td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>Treatment</td><td>86.8</td><td>85.9</td><td>45.6</td><td>17.4</td></tr>
<tr><td>Control</td><td>-15.8</td><td>-15.8</td><td>-15.8</td><td>-15.8</td></tr>
<tr><td>Study design</td><td colspan="5">Randomised control trial: 80</td></tr>
<tr><td>Baseline Comparison</td><td colspan="5">The size of the experimental area is equal in all trials, and is situated in the same habitat. All experiments take place in the same location in Turkey. There is no altitude given, but latitude and longitude is stated and thus altitude is expected is to be equal: 4</td></tr>
<tr><td>Intra treatment variation</td><td colspan="5">There is no information describing the stand age at the time of treatment, or the method used to dispose of cut material. Again, habitat, geographical location and altitude are all equal: 3</td></tr>
<tr><td>Measurement of intervention and Cointerventions</td><td colspan="5">There is insufficient knowledge to comment on any co-interventions that may be occurring within the habitat: 0</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="5">There are three replicates of each intervention: 4</td></tr>
<tr><td>Attrition bias</td><td colspan="5">No information regarding the number of individuals lost within the study:0</td></tr>
<tr><td rowspan="2">Sum of Data quality</td><td>Study</td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>Data quality assessment</td><td>91</td><td>91</td><td>91</td><td>91</td></tr>
<tr><td>Notes</td><td colspan="5">For each study only a mean % basal reduction is cited, therefore the measure of variance can not be carried out. There is also additional information comparing the effectiveness of different herbicides; however, there is not a control for this experiment and the information can not be included.</td></tr>
</table>

Study	Gritten, (1981)	
Methods	A site comparison. Information regarding the control of Rhododendron was collected via a national questionnaire distributed to experts and practitioners who deal with *R. ponticum* on a regular basis.	
Population	*R. ponticum* throughout Britain, in different habitats	
Intervention and Co interventions	Interventions were cut, cut and spray with herbicide (type not specified), and spray.	
Outcomes	Treatment	% kill
	Cut	40
	Cut and Herbicide	63
	Cut and Spray	55
Study design	Site comparison: 40 (comparison of different interventions on different sites	
Baseline Comparison	Size of experimental area prior to experiment is unknown, and thus assumed heterogeneous. The habitat type, location/geographical area, altitude, age of stand at time of treatment and soil type are all unknown as data was collected as a questionnaire and attained from many sources: 0	
Intra treatment variation	There is no information provided regarding the intra-treatment variation. If it were collected though it would be likely that it would be heterogeneous as it came from many sources:0	
Measurement of intervention and Cointerventions	Insufficient knowledge to comment: 0	
Replication & parameter of abundance	It is unknown how many replications, if any, took place: 0	
Attrition bias	There is insufficient information regarding the number of individuals that were lost during the experiment: 0	
Sum of Data quality	Studies A, B, and C: 40	
Notes	The study is a collection of information from questionnaires that has been analysed. Hence there is little information provided regarding the study characteristics. There is also further information assessing the effectiveness of different herbicides.	

Study	**Lawrie *et al*, (1993)**
Methods	A randomised control trial on the effect that mixtures of herbicides and herbicides with surfactants have on the success of *R. ponticum* stands. Five pot-grown plant experiments were carried out; two outside and three in the glasshouse.
Population	Seedlings were collected from the Quantock forest and then grown-up in in the glasshouse, and potted for the experiment. Each pot contained a single bush in acid heath soil and moss peat.
Intervention and Co interventions	As the plants were grown from seed no other intervention had occurred previously or during the experiment.

Outcomes	Study	Shoot fresh weight (g^{-1})	Study	Shoot fresh weight (g^{-1})
	A	84.5	Q3	7.9
	B	91.6	R3	7.9
	C	4.8	S3	2.9
	D	0	T3	0
	E	30.4	Control	124.1
	F	20.9	U3	55
	G	23.3	V3	76
	H	19.4	W3	128
	I	29.0	X3	51
	J	70.9	Y3	48
	K	93.2	Z3	42
	L	88.1	A4	16
	M	165.4	B4	12
	N	77.9	C4	130
	O	100.5	D4	94
	P	109.2	E4	31
	Control	35.92	F4	42
	Q	4.3	G4	89
	R	5.0	H4	3
	S	4.5	I4	18
	T	4.9	J4	0
	U	4.1	K4	63
	V	4.6	L4	28
	W	3.6	M4	7
	X	5.1	N4	20
	Y	4.6	O4	114
	Z	4.7	P4	86
	A1	1.9	Q4	13
	B1	4.4	R4	39
	C1	4.0	S4	32
	D1	2.3	T4	39
	E1	2.7	U4	10
	F1	4.6	V4	0
	G1	4.3	W4	58
	H1	2.2	X4	24
	I1	3.7	Y4	0
	J1	3.8	Z4	8
	K1	3.9	A5	28
	L1	0.2	B5	20
	M1	0.3	C5	9
	N1	3.9	D5	10
	Control	3.8	E5	77
	O1	75.9	F5	39
	P1	62.4	G5	1
	Q1	64.7	H5	15
	R1	92.8	Control	86
	S1	82.9	I5	97
	T1	21.9	J5	90
	U1	23.9	K5	12
	V1	33.2	L5	73
	W1	49.5	M5	43

	X1	52.9	N5	22
	Y1	3.5	O5	32
	Z1	0	P5	0
	A2	4.6	Q5	0
	B2	14.7	R5	61
	C2	1.0	S5	24
	D2	40.7	T5	2
	E2	9.0	U5	85
	F2	10.7	V5	56
	G2	13.8	W5	5
	H2	38.0	X5	33
	I2	33.1	Y5	23
	J2	0	Z5	7
	K2	0	A6	46
	L2	16.4	B6	2
	M2	13.9	C6	2
	N2	0	D6	54
	O2	2.4	E6	22
	P2	14.5	F6	1
	Q2	0	G6	54
	R2	131.7	H6	11
	S2	27.5	I6	0.3
	T2	60.0	Control	79
	U2	41.4	J6	29
	V2	57.0	K6	19
	W2	3.0	L6	11
	X2	0.3	M6	107
	Y2	29.7	N6	26
	Z2	5.1	O6	1
	A3	21.5	P6	84
	B3	0	Q6	62
	C3	0	R6	2
	D3	16.0	S6	18
	E3	0	T6	18
	F3	36.8	U6	1
	G3	23.6	V6	82
	H3	15.3	W6	12
	i3	14.4	X6	6
	J3	24.1	Y6	72
	K3	22.9	Z6	59
	L3	3.0	A7	0.3
	M3	5.7	B7	97
	N3	12.1	C7	21
	O3	14.2	D7	14
	P3	4.2	Control	47
Study design	RCT: 80			
Baseline Comparison	As the experiment was performed under artificial conditions control and experimental arms are equal: 6			
Intra treatment variation	As the experiment was performed under artificial conditions control and experimental arms are equal :5			
Measurement of intervention and Cointerventions	As the experiment is carried out on pot-grown plants there is no other interventions e.g. grazing, occurring on them: 3			
Replication & parameter of abundance	There are either three or four replicates of each experiment: 4			
Attrition bias	There is no information on the loss of any plants due to factors other than the intervention: 0			
Sum of Data quality	98 (for all studies)			
Notes				

Study	Pysek *et al* (1995)
Methods	A controlled trial comparing the use of a flail mower with handpulling Rhododendrons.
Population	Other than the fact that the technique involves the control of *R. ponticum* there is no other information on the population.
Intervention and Co interventions	The technique is mechanical cutting
Outcomes	Qualitative information describing the flail mower as more successful than conventional handpulling,
Study design	Controlled Trial: 60
Baseline Comparison	The geographical location is homogenous for the experiments. The other factors (size of experimental area, habitat type, altitude, stand age at time of treatment and soil type), are unknown though and are thus considered to be heterogeneous: 1
Intra treatment variation	Due to the lack of information regarding the study design and area only the geographical location and disposal of cut material (left at the site) can be described as heterogeneous: 2
Measurement of intervention and Cointerventions	There are no reported co – intervention factors occurring. It is thus considered that there is a lack of information: 0
Replication & parameter of abundance	There is no information regarding the number of replications that are occurring: 0
Attrition bias	There is insufficient information regarding the number of individuals that were lost during the experiment: 0
Sum of Data quality	63
Notes	The report is a discussion regarding the current rhododendron control initiatives in the Snowdonia National Park area, therefore quantitative data is not present. Without this it is not possible to carry out data analysis.

<table>
<tr><th>Study</th><th colspan="3">Stables and Nelson (1991)</th></tr>
<tr><td>Methods</td><td colspan="3">A control trial to observe the effectiveness of glyphosate as a herbicide to control R. ponticum.</td></tr>
<tr><td>Population</td><td colspan="3">No information is provided on the populations treated</td></tr>
<tr><td>Intervention and Co interventions</td><td colspan="3">The glyphosate was applied to cut stumps. No further information was given.</td></tr>
<tr><td rowspan="25">Outcomes</td><td>Study</td><td>% live cover (experimental plot)</td><td>% live cover (control plot)</td></tr>
<tr><td>A</td><td>0</td><td>94</td></tr>
<tr><td>B</td><td>0</td><td>94</td></tr>
<tr><td>C</td><td>0</td><td>94</td></tr>
<tr><td>D</td><td>0</td><td>94</td></tr>
<tr><td>E</td><td>0</td><td>100</td></tr>
<tr><td>F</td><td>0</td><td>100</td></tr>
<tr><td>G</td><td>0</td><td>100</td></tr>
<tr><td>H</td><td>0</td><td>100</td></tr>
<tr><td>I</td><td>26</td><td>100</td></tr>
<tr><td>J</td><td>6</td><td>100</td></tr>
<tr><td>K</td><td>0</td><td>100</td></tr>
<tr><td>L</td><td>0</td><td>100</td></tr>
<tr><td>M</td><td>0</td><td>100</td></tr>
<tr><td>N</td><td>0</td><td>100</td></tr>
<tr><td>O</td><td>0</td><td>100</td></tr>
<tr><td>P</td><td>0</td><td>100</td></tr>
<tr><td>Q</td><td>0</td><td>66</td></tr>
<tr><td>R</td><td>0</td><td>66</td></tr>
<tr><td>S</td><td>0</td><td>66</td></tr>
<tr><td>T</td><td>0</td><td>66</td></tr>
<tr><td>U</td><td>46</td><td>74</td></tr>
<tr><td>V</td><td>20</td><td>74</td></tr>
<tr><td>W</td><td>0</td><td>74</td></tr>
<tr><td>X</td><td>26</td><td>74</td></tr>
<tr><td>Study design</td><td colspan="3">A control trial: 60</td></tr>
<tr><td>Baseline Comparison</td><td colspan="3">No information: 0</td></tr>
<tr><td>Intra treatment variation</td><td colspan="3">No information: 0</td></tr>
<tr><td>Measurement of intervention and Cointerventions</td><td colspan="3">No information: 0</td></tr>
<tr><td>Replication & parameter of abundance</td><td colspan="3">No replication is made reference to. Percentage cover is the measure used to estimate the effectiveness – no information is provided on how this is obtained: 0</td></tr>
<tr><td>Attrition bias</td><td colspan="3">No information: 0</td></tr>
<tr><td>Sum of Data quality</td><td colspan="3">60 (for all studies)</td></tr>
<tr><td>Notes</td><td colspan="3"></td></tr>
<tr><td></td><td colspan="3"></td></tr>
</table>

Study	**Tabbush *et al*, (1984)**	
Methods	A randomised control trial on the effectiveness of different chemicals in the control of rhododendron.	
Population	The sites for the experiments are situated the west of Scotland.	
Intervention and Co interventions	No information is provided on interventions other than the experimental controls	
Outcomes	Study	% kill
	A	30
	B	35
	C	50
	D	10
	E	3
	F	78
	G	68
	H	73
	I	98
	J	5
	K	-
	L	5
	M	5
	N	-
	O	10
	P	0
	Q	0
	R	0
	S	10
	T	3
	U	13
	Control	0
Study design	A randomised control trial: 80	
Baseline Comparison	Habitat, location and altitude are all equal in all arms of experiment: 3	
Intra treatment variation	There is no need to dispose of cut material: 1	
Measurement of intervention and Cointerventions	No information: 0	
Replication & parameter of abundance	Three replications: 4	
Attrition bias	No information: 0	
Sum of Data quality	88 (for all studies)	
Notes		