Literature review and meta-analysis of vegetation responses to goat and European rabbit eradications on islands

By Daniella Schweizer,* Holly P. Jones and Nick D. Holmes

Abstract
Introduced goats and European rabbits have caused devastating effects on island vegetation and many successful efforts to eradicate these introduced animals have taken place mainly since the 1950’s. Yet, a comprehensive review of vegetation response to goat and rabbit eradications is lacking. We conducted a literature search for articles on vegetation assessments before and after eradications. We conducted two kinds of reviews of species richness and cover response to eradication: a literature review for studies that provided qualitative or species-by-species responses to eradications and a meta-analysis on quantitative vegetation cover and species richness data. A key finding from our literature search was a significant information gap in the reporting of vegetation responses after eradication. Out of over 200 successful island eradications that have been conducted since the 1800’s, we found only 23 eradication studies that met our criteria for inclusion in the present analysis. Plant richness and vegetation cover increased more often than they decreased after eradication. Results varied according to region, herbivore type, habitat and vegetation type suggesting island specific circumstances influence responses. The effect of eradication on sub Antarctic tundra species richness and on tropical vegetation percent cover was higher than for other types of vegetation. Few cases differentiate responses of native versus exotic plant species, despite native biodiversity protection being one common goal of introduced herbivore eradication. We strongly recommend before and after eradication vegetation monitoring to understand how island ecosystems respond to eradication. Continuous monitoring would provide guidance on whether active restoration strategies need to be implemented to recover key native species and on the development of a general model of expected vegetation response, which is an integral first step to accelerate our predictive ability of vegetation responses.

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**Introduction**

Islands represent only 3.6% of the terrestrial surface, yet they harbor 9.5 times higher plant richness than continents (Kier et al. 2009). Habitat destruction, overexploitation and introduction of novel predators and competitors severely impact island biota (Sadler 1999, Blackburn et al. 2004). Two of the most widely introduced mammalian herbivores on islands are European rabbits (hereafter, rabbits; *Oryctolagus cuniculus*) and goats (*Capra hircus*), which have caused devastating effects on native insular vegetation (Gillham 1963, Rudge and Campbell 1977, Coblentz 1978, Armstrong 1982, Fernández and Sáiz 2007). Rabbits can adapt to many habitats, have high reproduction rates and a varied diet, which allows them to overgraze and reduce or eliminate island vegetation when they are introduced to islands (Courchamp et al. 2003). Goats also have a generalist diet, leading to widespread overgrazing on islands. For example, on Volcan Alcedo (Isabela Island, Galápagos), a rapid increase in introduced goat populations led to large scale deforestation, and conversion of forest and scrub to grasslands (Desender et al. 1999). Goats and rabbits have the potential of dispersing and increasing exotic plant species, thus significantly altering plant composition and diversity on islands (Parker et al. 2006). For example, rabbits increased the seed shadow of the introduced opium poppy, *Papaver somniferum*, via endozoochory on Robinson Crusoe Island (Fernández and Sáiz 2007). Other direct effects include destruction of nesting habitat by trampling, or competing for nesting burrows with seabirds (e.g. Young 1981, Cruz and Cruz 1987). Introduced goats and rabbits can also have indirect effects by providing food for other introduced animals and altering food webs via trophic cascades. On Macquarie Island, rabbits were an important food source to feral cats until they were eradicated (Bergstrom et al. 2009).

The negative effects of introduced goats and rabbits on island ecosystems have spurred concerted efforts to remove these species where feasible. Since the 1800’s there have been at least 90
successful rabbit eradactions and 147 successful goat eradactions on islands (Fig 1). An eradication campaign is deemed successful when all the individuals of the target species are removed from the island. Methodology and efficacy have been improving steadily through the years, leading to an almost continuous increase in the number of eradications of goats and rabbits through time (Myers et al. 2000, Campbell and Donlan 2005, Clout and Russell 2006, Carrion et al. 2011, DIISE 2014).

One of the aims of herbivore eradications is to restore native island vegetation (Campbell and Donlan 2005). However, a global synthesis of vegetation responses to herbivore eradications is currently lacking, therefore drawing general conclusions about the ability of herbivore eradication to restore island vegetation remains difficult. We performed a narrative review of articles providing qualitative measures of vegetation response to goat and rabbit eradication on islands and a meta-analysis on those publications that reported quantitative measures on vegetation cover and richness. In cases where a single study provided qualitative and quantitative information, we employed them for both the narrative review and the meta-analysis. We restricted the analysis to successful eradication of goats and rabbits because these two herbivores have been the most widely introduced and successfully eradicated worldwide (DIISE 2014).

In addition to herbivore type, we evaluated quantitative vegetation responses to eradication grouped by geographic region, habitat type, vegetation origin, time between eradication and assessment and time since herbivore introduction. We expected a weaker plant species response on islands in cold climates with tundra vegetation. Tundra vegetation do not recover well from herbivory (Chapuis et al. 2003, Anderson et al. 2006). We expected exotic plant species to be more resilient than native plant species to herbivore eradication. Many exotic plant species, such
as grasses, likely evolved under herbivory pressure on mainland environments, thus being able to sustain populations under and recover from grazing (e.g. Holgrem 2002). We hypothesized vegetation richness and cover would be positively related to time between eradication and assessment, as plants would have had more time to recover. However, we expected an increase in plant species richness and cover to be negatively related to time the island had been invaded, since plants would have been subjected to grazing pressure for longer and thus take longer to respond.

MATERIALS AND METHODS

We selected all islands on which successful, whole island, eradication events had been conducted using the Database of Island Invasive Species Eradications (DIISE 2014). This database records information on current and historical eradictions of introduced species on islands. At the time of the review, the information in the database was current up to April 2013.

We searched ISI Web of Science and Google Scholar using the following search terms: 1) goats, rabbits, AND 2) eradication, AND 3) islands, AND 4) vegetation, plants. We searched all the possible combinations of those terms, using one word from each group in the searches. We also searched for articles by the island names found in the DIISE in combination with the search terms above. We gathered relevant citations found in the articles as well and supplemented our web search by reviewing the Proceedings of the International Conference on Island Invasives hosted by the IUCN in 2002 and in 2011 (Veitch and M.N. 2002, Veitch et al. 2011). We looked for references on goat impacts on island vegetation in the publications listed on Appendix 1 of Campbell and Donlan (2005). In addition to the search of published data, we contacted experts from the main regions where eradications have been conducted, namely, Australia, New Zealand, the Galápagos, and the Pacific in an effort to gather unpublished literature. We selected all articles that provided before and after accounts of vegetation response. We focused on unassisted
vegetation responses and excluded islands where revegetation had been conducted after eradication. This excluded one study from Phillip Island, Australia (Coyne 2010).

**Literature review**

To conduct the literature review on vegetation responses to goat or rabbit eradication, we gathered information from those articles that provided either a qualitative account of vegetation response, by vegetation type (e.g. either herbaceous or woody) or listed the responses on a species-by-species basis. We extracted the information separately for each species for studies that listed specific species' responses. Therefore, we had many entries for a single study. We summarized the responses of vegetation cover and richness as either positive or negative and grouped them by vegetation type (e.g. herbaceous or woody), vegetation origin (native or exotic), type of herbivore (goats or rabbits), and presence of other mammalian herbivores.

**Meta-analysis**

We ran the meta-analysis on our two dependent variables - percent cover and richness - separately. The response of vegetation to eradication was analyzed using response ratios as a common measure of the effect (Chao et al. 2006). The response ratio was calculated as:

\[
lnR = ln \left( \frac{X_t}{X_c} \right)
\]

where \(X_t\) is the metric of vegetation richness or percent cover after the eradication and \(X_c\) is the same metric before the eradication. We estimated the cumulative mean effect size of eradication on vegetation richness and cover. The cumulative effect size of a sample of studies is a weighted average of the effect size of all studies combined. The weight of the \(i^{th}\) study is the reciprocal of its sampling variance (1/\(v_i\)) (Rosenberg et al. 2000).

\[
E = \frac{\sum_{i=1}^{n} W_i E_i}{\sum_{i=1}^{n} W_i}
\]
In our case, however, three out of seven studies that reported species richness were missing sample sizes, and only two reported sample size and standard deviation. Two reports on species percent cover out of seven were missing sample size and standard deviations. Therefore, we ran an unweighted model using sample size of 10 and standard deviation of 1 to maximize the data we could use for the analysis (Osenberg et al. 1999). The cumulative effect size varies between $-\infty$ and $\infty$, with 0 meaning no effect of eradication on the vegetation, positive values a positive effect of eradication on vegetation and negative values a negative effect (Rosenberg et al. 2000).

We estimated 95% bias-corrected, bootstrapped confidence intervals around the cumulative effect sizes by drawing 5000 randomizations. Bootstrap confidence intervals are better estimates of the confidence intervals for small sample sizes that are not normally distributed, which is common in meta-analyses (Rosenberg et al. 2000). We estimated Rosenthal fail-safe tests to determine the number of studies that would be required to overturn the results. A Rosenthal value greater than 5n +10 is indicative of a reliable meta-analysis (Kotiaho and Tomkins 2002).

We calculated total heterogeneity ($Q_T$) to evaluate the variability in either richness or cover present across studies. Total heterogeneity evaluates differences in effect sizes in the sample data set by looking at how much the effect size of the $i^{th}$ study deviates from the cumulative effect size. Significance of $Q$ is estimated using a chi-square test with n-1 degrees of freedom, with n being the total number of studies (Rosenberg et al. 2000). The null hypothesis states that all effect sizes are equal and the significance of the heterogeneity value indicates that the variation is greater than expected by sampling error and that other variables may need to be explored to explain the variability.

In order to determine other explanatory variables that might account for the variation in effect size among studies, one can group studies according to categories that one would hypothesize to
have differential effects on the dependent variable (in our case, the response ratio of either vegetation richness or cover). We grouped studies by the following categorical variables: region (e.g. Pacific, Sub-Antarctic), habitat type (e.g. xeric, tundra (arctic vegetation), tropical (equatorial and subequatorial vegetation), vegetation type (herbaceous vs woody), vegetation origin (native or exotic) and type of herbivore (goats or rabbits). We did not include potentially important variables such as natural disturbances and history of human occupation due to the low number of studies with differences in those variables.

Other introduced animals, in addition to goats and rabbits, were reported on six of the islands (Great Island, San Benito West, Lehua Island, Sarigan, Selvagem Grande, San Clemente, Macauley Island, Motukaraka; See Appendices 2 and 3), primarily rats (*Rattus* spp.) and pigs (*Sus scrofa*). We acknowledge the confounding effect that the presence of rodents and other introduced herbivore brings to estimating vegetation responses to goat and rabbit eradications. However, we included those studies given data scarcity and grouped studies by presence or absence of rodents and other herbivores to assess differences in vegetation response. We analyzed the significance of the effect size using a categorical random model, that groups the vegetation response in the categories mentioned and analyzes the data considering a true random component of variation in the effect size among studies not solely attributed to sampling error (Rosenberg et al. 2000). In addition to total heterogeneity we estimated the between-group heterogeneity (*Q*) that looks at the variability in the mean effect among categories versus variability within categories (Rosenberg et al. 2000).

We evaluated percent cover and richness vegetation responses as a function of time the island had been invaded (hereafter, time invaded), and time between the end of the eradication and the vegetation assessment (hereafter, time since eradication). With continuous variables, the relationship between the effect size and the independent variable is estimated through a least
squares linear regression that employs effect size (E), weight (we employed a sample size of 10 for all studies) and the value of the independent time variable (Xi). Standard errors of the slope and the intercept are as:[1]

$$S_{b1} = \frac{1}{\sqrt{\sum_{i=1}^{n} W_iX_i^2 - \frac{(\sum_{i=1}^{n} X_iW_i)^2}{\sum_{i=1}^{n} W_i}}}$$

and the intercept as:[2]

$$S_{b0} = \frac{1}{\sqrt{\sum_{i=1}^{n} W_i - \frac{(\sum_{i=1}^{n} W_iX_i)^2}{\sum_{i=1}^{n} W_iX_i^2}}}$$

The statistical significance is calculated by dividing the slope and the intercept by their standard error, which gives a Z-score that is compared to the normal distribution. A significant response indicates that the independent, continuous variable explains a portion of the effect size (Rosenberg, 2000).

RESULTS

Out of over 200 successful island eradications conducted since the 1800’s we found 23 eradication studies that met our criteria for inclusion in the present analysis. For the literature review we employed thirteen studies (Appendix 1). Ten studies reported a quantitative assessment of vegetation richness and/or percent cover in response to eradication and were used for the meta-analysis (Appendix 2). The articles represented a sample from widespread geographies: the Atlantic, the Indian Ocean, the North Pacific, Pacific Baja, Australia, Chile, the Galapagos, Hawaii, New Zealand, the Sub-Antarctic and the South Pacific.

*Literature review*
Eradication of rabbits increased vegetation cover in 80% of the plant species listed in the various articles, while eradication of goats had a positive response in 74% of the species. There were no records showing zero change in plant species vegetation cover after eradication. The literature reported that percent cover of 80% (n=36) of the native species and of 100% (n=24) of the exotic species listed increased after eradication. Herbaceous plant species showed a positive response in percent cover after the eradication in 83% of the species while 70% of the woody plant species increased. Species richness increased after eradication in all of the five studies that measured species richness.

Meta-analysis: Richness

Eradication of herbivores had a low but positive effect on species richness. We did not find significant variation in the effects of eradication on species richness either among the studies in the dataset (Q\textsubscript{T}=17.19, df=37, P =0.998) (Table 1) or when the data were grouped in categories (Q\textsubscript{b}=5.75, df=12, p =0.928).

The eradication of goats significantly increased species richness, but rabbit eradication did not show a significant effect (Fig. 2a). There were only two studies (Carnac and San Clemente Island) that distinguished the responses of native versus exotic vegetation and the effect was not significant for either case (Fig. 2b). There was a significant and positive effect of eradication on species richness for all regions and habitats (Fig. 2c and Fig. 2d). Vegetation richness showed a positive response after eradication of goats and rabbits despite the presence of rodents and other mammalian herbivores on some of the islands reviewed (Fig 2e).

The effect of eradication on vegetation richness increased with time invaded (regression coefficient= 0.0005, p<0.02), but not as a function of time since eradication. Some of the variables dropped from the analysis due to there being only one study in that category or to the
lack variation among the studies. We obtained a fail-safe number of 451 studies, which suggests the results were robust.

*Meta-analysis: Percent cover*

Eradication of goats and rabbits had a positive effect on vegetation percent cover. The total heterogeneity value was not significant indicating that studies were not different from each other ($Q_t=60.22$, df=61, $p = 0.504$; Table 1). Similarly, effect sizes between variables in the categorical analysis also did not differ significantly ($Q_b=3.43$, df=12, $p = 0.992$).

Similarly to species richness, rabbit eradication did not significantly affect vegetation percent cover, but goat eradication did (Fig. 3a). Native plant species showed a significant increase after eradication whereas exotic species did not (Fig. 3b). The presence of rodents and other mammalian herbivores on the island affected the vegetation cover change observed by the eradication of goats and rabbits, however, the effect was still positive despite the presence of rodents and other mammalian herbivores (Fig 3c). Only in tropical habitats was the effect of eradication on cover significant (Fig. 3d). Region was not included in the analysis due to low sample size (less than 2 cases). Time invaded was not a significant variable explaining the effect of eradication on vegetation cover ($p>0.05$), and time since eradication decreased the size of the effect of eradication on percent cover (regression coefficient= -0.0217, $p<0.00001$). A fail-safe number of 346 studies showed that the results were robust despite the low sample size.
DISCUSSION

Eradication of introduced vertebrates is regarded as a powerful tool to promote biodiversity conservation (Bellingham et al. 2010a). However, impacts to island vegetation post-eradication have not been consistently evaluated. From over 200 goat and rabbit eradications conducted since the 1800’s on islands worldwide, we found only 23 studies that met our criteria for inclusion either in the literature review or in the meta-analysis. We may have missed some literature due to inherent limitations of the search engine, or to papers that had not been published in indexed journals, but our search was extensive. The information gap that exists in vegetation monitoring before and after eradications on islands has been highlighted elsewhere (McEachern et al. 2009). Despite the low number of studies found, this study represents a first attempt to consolidate information on vegetation responses to eradication of goats and rabbits, which we hope will lead to further vegetation monitoring and thus more powerful analyses in the future.

In both the literature review and the meta-analysis, we found plant richness and percent cover increased after goat and rabbit eradication more often than they decreased. The literature review showed more species increasing in percent cover than decreasing after both goat and rabbit eradication (74% and 80% of the cases, respectively). This contrasts with results obtained in the meta-analysis, which suggested no effect of vegetation cover after rabbit removal, a result we suggest as idiosyncratic to the small sample size. The rabbit is a significant pest where introduced, with many examples of the negative effects of rabbits on island vegetation, and on positive effects of rabbit eradication or control (e.g., Bried et al. 2009, Olivera et al. 2010, Shaw et al. 2011, Scott and Kirkpatrick 2013).

Determining the response of native versus exotic vegetation is of management relevance because it can help assess if the goal of native species protection was met and identify any subsequent
management action required (e.g. revegetation, or exotic species control). Though we predicted that exotic plant species might respond more positively than native plants to eradication, the literature review showed that the percent cover of over 80% of both native and exotic plant species listed in the different articles increased after eradication, suggesting similar responses. Within our meta-analysis we had too small a sample size (n=2) to robustly distinguish whether the effect of eradication was stronger on native versus exotic species, leaving us unable to quantify any potential differences between native and exotic responses. However, several narrative accounts identify exotic plant species increase after goat and rabbit eradication, with various effects on the ecosystem such as outcompeting natives (Kessler 2002, Courchamp et al. 2003, Russell et al. 2005, Hata et al. 2010, Weller et al. 2011). The literature reviewed highlighted that plant species subject to more intense introduced goat or rabbit grazing tend to have a stronger positive response following eradication (Donlan et al. 2002, Bellingham et al. 2010b, Eijzenga 2011). If these species are exotics they can experience a population explosion after eradication.

There is evidence of preferred grazing, and therefore spread of exotic species by introduced herbivores, such as bison on Santa Catalina Island, California (Constible et al. 2005). Three years following rabbit eradication on Lehua Island, Hawaii, a 112% increase in exotic vegetation was recorded versus a 34% decrease in native vegetation (Eijzenga 2011). The removal of goats from the Sarigan Islands led to the explosion of the vine, *Operculina ventricosa*, which now covers part of the island as an uninterrupted carpet (Kessler 2002). On the other hand, goat eradication has led to dramatic endemic species recoveries in some cases. For example, the endemic Guadalupe cypress (*Callitropsis guadalupensis*) rapidly increased seedling recruitment following goat eradication (Garcillan et al. 2009). These case studies suggest that responses of native and exotic vegetation may be variable. Seed bank surveys and introduced herbivore feeding
preference studies would allow predictions about whether herbivore removal could lead to an increase in exotic population sizes that would need additional control.

Effect sizes grouped by geographic region and habitats showed variable results. Species richness showed a positive response after eradication in all regions and vegetation types, contrary to our prediction that there would be weaker responses in species richness in colder climates. Percent cover only increased following herbivore eradication in tropical habitats, but mainly of exotic grass and shrub species (North et al. 1994, Martin et al. 2008, Eijzenga 2011). Tropical islands are vulnerable to plant invasion mainly due to two interacting processes: high net resource availability and poor competitive ability of native species (Denslow 2003). Thus it appears that the removal of the introduced herbivore in tropical islands releases exotic species from grazing pressure with their consequent increase in percent cover at least during the time span of the revised studies.

Vegetation on islands where rodents or other introduced mammalian herbivores/omnivores were present along with goats or rabbits showed a positive response from the removal of grazing pressure. Rats as omnivores can affect vegetation through herbivory or granivory, and are capable of dietary shifts if their main resource becomes temporarily unavailable (Campbell and Atkinson 2002, Caut et al. 2008). We acknowledge that the presence of other mammalian herbivores, along with goats and rabbits, is a confounding variable. However, for most islands were other herbivores were present we could attribute the vegetation responses to the eradication of the herbivores of interest, goats or rabbits, due either to their higher number or that authors directly linked the vegetation responses to the removal of goats or rabbits (Donlan et al. 2002, Donlan et al. 2003, Chapuis et al. 2004, Martin et al. 2008, Wylie 2012). More studies on the interactions between introduced herbivores and on any potential herbivore release that removing
one but not all introduced species on an island might lead to are needed to better predict the consequences of single species eradication on islands with multiple introduced species.

Long-term monitoring of vegetation would help to evaluate whether the patterns after eradication seen in our analysis continue over the long term. Our meta-analysis suggests that time since the island had been invaded and time between eradication and assessment were significant covariables in the effect of eradication on species richness or percent cover, respectively. However, the effect of time was contrary to our expectations. We expected time the island had been invaded to reduce the response of vegetation, however it increased the effect of eradication on species richness and was not a significant covariable for variations in percent cover. We thought time between eradication and vegetation assessment would lead to an increase in the effect size of the vegetation response, but it was not significant for richness and decreased the effect observed on vegetation cover. These results highlight the importance of continuous monitoring of vegetation as species composition and percent cover can be very dynamic and assessments at different times after eradication may lead to different, unexpected, results. Nevertheless, practitioners should recognize and plan for the possibility that island vegetation exposed to relatively recent invasions may respond differently than vegetation that has endured introduced herbivores for longer periods of time.

Eradication of introduced mammals from islands is best contextualized as a baseline conservation activity towards achieving broader restoration goals. As an example, eradication of introduced goats and rabbits from islands reduces grazing pressure on plant species. However, other restoration techniques may be required in order to fully realize biodiversity protection goals, such as endangered species protection, revegetation or habitat creation (e.g. Letman 2008). Concurrent eradication of all introduced plants and animals may be required in places were other introduced species besides goats and rabbits exist to avoid unintended consequences of single...
species eradications such as the population release of other introduced species (e.g. Lehua Island, Eijzenga 2011). Planning for, and understanding responses to herbivore eradication should be viewed in a whole ecosystem context (Zavaleta et al. 2001), with the monitoring of native and exotic species response informing subsequent adaptive management.

A general model of expected vegetation response to eradications should be paired with species-specific approaches for important native or endemic species that managers seek to restore, and should account for potential trophic interactions with both native and exotic species post-eradication (Veitch and Bell 1990, Zavaleta et al. 2001, Courchamp et al. 2003, Tetsuto et al. 2011). Our findings in both the literature review and meta-analysis will be strengthened and further clarified with future extensive monitoring efforts. Several locations have been the focus of extensive vegetation monitoring assessments, including the California Channel Islands and the Galápagos Islands. Two long-term studies of vegetation response before and after herbivore eradication, Donlan et al. (2002) and Donlan (2003), represent study approaches that should be repeated elsewhere.

ACKNOWLEDGEMENTS

We acknowledge and thank Island Conservation for providing the baseline data regarding eradications of goats and European rabbits on islands worldwide (DIISE database). We would also like to thank Dr. David Towns, Dr. Ole Hamann, Dr. Donald Croll, Dr. Bernie Tershy for providing their expertise regarding the topic and guiding us to any unpublished sources of information.
Table 1

Effect sizes and heterogeneity values for plant species richness and percent cover after goat and rabbit eradication on islands. Results are based on an n of six studies for species richness and on an n of eight studies for percent cover. The studies used are marked with * for richness and with a † for cover on appendix 2. A CI bounding zero means the effect size is not significant. The p-value corresponds to the significance of the total heterogeneity value.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Effect size</th>
<th>CI</th>
<th>$Q_t$</th>
<th>df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Richness</td>
<td>0.3922</td>
<td>0.2561-0.5283</td>
<td>17.19</td>
<td>37</td>
<td>0.998</td>
</tr>
<tr>
<td>Percent Cover</td>
<td>0.2413</td>
<td>0.1461-0.3286</td>
<td>60.22</td>
<td>61</td>
<td>0.504</td>
</tr>
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</table>
Figure 1. Cumulative number of goat and rabbit eradications on islands by decade (Source: Database of Island Invasive Species Eradications)
Figure 2. Effect sizes (filled circles) and bootstrapped confidence intervals (error bars) looking at the effect of herbivore eradication on vegetation richness, comparing various grouping variables. Effect sizes are significant if the confidence interval does not bound zero. A positive effect size means that eradication increased species richness, and vice versa if the value is negative. The numbers above the error bars represent the sample sizes.
Figure 3. Effect sizes (filled circles) and bootstrapped confidence intervals (error bars) looking at the effect of herbivore eradication on vegetation cover, comparing various grouping variables. Effect sizes are significant if the confidence interval does not bound zero. A positive effect size means that eradication increased species cover, and vice versa if the value is negative. The numbers above the error bars represent the sample sizes.
LITERATURE CITED


Appendix 1. Literature employed in the systematic review. NA: not applicable.

<table>
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<tr>
<th>Authors</th>
<th>Year</th>
<th>Title</th>
<th>Island group</th>
<th>Island name</th>
<th>Island (size)</th>
<th>Type herbivore removed</th>
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<td>Alves et al.</td>
<td>2011</td>
<td>Return of endemic plant populations on Trindade Island, Brazil, with comments on the fauna</td>
<td>Trindade Archipelago</td>
<td>Trindade Archipelago</td>
<td>(1040 ha)</td>
<td>Goats</td>
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<td>Barkla et al.</td>
<td>2008</td>
<td>Homalanthus polyandrus (Euphorbiaceae) on Macauley Island, southern Kermadec Islands, with notes on that island's vascular flora</td>
<td>Kermadec Islands</td>
<td>Macauley</td>
<td>(306 ha)</td>
<td>Goats</td>
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<td>Garcillan et al.</td>
<td>2009</td>
<td>Recruitment response of Guadalupe Cypress (Callitropsis guadalupensis) three years after goat eradication on Guadalupe Island</td>
<td>NA</td>
<td>Guadalupe Island</td>
<td>(2439 ha)</td>
<td>Goats</td>
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<td>Hamann.</td>
<td>2004</td>
<td>Vegetation changes over three decades on Santa Fe Island, Galapagos, Ecuador</td>
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<td>(2413 ha)</td>
<td>Goats</td>
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<td>Title</td>
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<td>Island name (size)</td>
<td>Type herbivore removed</td>
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<td>Hamann,</td>
<td>1993</td>
<td>On vegetation recovery, goats, and giant tortoises on Pinta island, Galápagos, Ecuador</td>
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<td>Pinta Island (5900 ha)</td>
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<td>Hata et al.,</td>
<td>2007</td>
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<td>Henderson and Dawson.</td>
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<td>Alien invasions from space observations: detecting feral goat impacts on Isla Isabela, Galapagos Islands with the AVHRR</td>
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<td>2002</td>
<td>Eradication of feral goats and pigs and consequences for other biota on Sarigan Island, Commonwealth of the Northern Mariana Islands</td>
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<td>Successful eradication of the European rabbit (Oryctolagus cuniculus) and house mouse (Mus musculus) from the island of Selvagem Grande (Macaronesian archipelago), in the Eastern Atlantic</td>
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<td>2010</td>
<td>Atoll restoration in the Phoenix Islands, Kiribati: Survey results in November-December 2009</td>
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<td>Rawaki island (65 ha)</td>
<td>Rabbits</td>
<td></td>
</tr>
<tr>
<td>Robin <em>et al.</em>,</td>
<td>2011</td>
<td>Remote sensing of vegetation cover change in islands of the Kerguelen archipelago</td>
<td>Kerguelen Islands</td>
<td></td>
<td>Rabbits</td>
<td></td>
</tr>
<tr>
<td>Russell <em>et al.</em>,</td>
<td>2005</td>
<td>Ecological Survey of Motukaraka (Flat Island), Beachlands, Auckland</td>
<td>NA</td>
<td>Motukaraka (Flat) Island (5.6 ha)</td>
<td>Rabbits</td>
<td></td>
</tr>
<tr>
<td>Sykes and West.,</td>
<td>1996</td>
<td>New records and other information on the vascular flora of the Kermadec islands</td>
<td>Kermadec Islands</td>
<td>Raoul (2938 ha) and Macauley (306 ha)</td>
<td>Goats</td>
<td></td>
</tr>
</tbody>
</table>
References


Appendix 2. Literature employed in the meta-analysis. The main criteria for selection of the articles was reporting quantitative vegetation percent cover or richness, before and after eradication of goats or rabbits.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Title</th>
<th>Island group</th>
<th>Island name (size)</th>
<th>Type herbivore removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abbott et al., *</td>
<td>2000</td>
<td>Long term change in the floristic composition and vegetation structure of Carnac Island, Western Australia</td>
<td>NA</td>
<td>Carnac Island (19 ha)</td>
<td>Rabbits</td>
</tr>
<tr>
<td>Bellingham et al., *</td>
<td>2010</td>
<td>Disperser communities and legacies of goat grazing determine forest succession on the remote Three Kings Islands in New Zealand</td>
<td>Three Kings Islands</td>
<td>Great Island (407 ha)</td>
<td>Goats</td>
</tr>
<tr>
<td>Chapuis et al., *+</td>
<td>2004</td>
<td>Recovery of native plant communities after eradication of rabbits from the subantarctic Kerguelen Islands, and influence of climate change</td>
<td>Kerguelen Archipelago</td>
<td>Ille Verte (148 ha) and Ille Guillou (145 ha)</td>
<td>Rabbits</td>
</tr>
<tr>
<td>Donlan et al., +</td>
<td>2003</td>
<td>Islands, exotic herbivores, and invasive plants: their roles in coastal California restoration</td>
<td>Todos Los Santos</td>
<td>Todos Los Santos South (100 ha)</td>
<td>Rabbits</td>
</tr>
</tbody>
</table>
## Meta analysis

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Title</th>
<th>Island group</th>
<th>Island name (size)</th>
<th>Type herbivore removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Donlan et al., +</td>
<td>2002</td>
<td>Islands and introduced herbivores: conservation action as ecosystem experimentation</td>
<td>San Benito Islands</td>
<td>San Benito West (350 ha)</td>
<td>Rabbits</td>
</tr>
<tr>
<td>Eijzenga, +</td>
<td>2011</td>
<td>Vegetation change following rabbit eradication on Lehua Island, Hawaiian Islands</td>
<td>NA</td>
<td>Lehua Island (112 ha)</td>
<td>Rabbits</td>
</tr>
<tr>
<td>Martin et al., *+</td>
<td>2008</td>
<td>Wildlife and vegetation surveys of Sarigan Island. 2008 Technical Report # 14. CNMI Division of Fish and Wildlife</td>
<td>Mariana Islands</td>
<td>Sarigan (500 ha)</td>
<td>Goats</td>
</tr>
<tr>
<td>North et al., +</td>
<td>1994</td>
<td>Changes in the vegetation and reptile populations on Round Island, Mauritius, following eradication of rabbits</td>
<td>NA</td>
<td>Round Island (169 ha)</td>
<td>Rabbits</td>
</tr>
</tbody>
</table>
## Meta analysis

<table>
<thead>
<tr>
<th>Authors</th>
<th>Year</th>
<th>Title</th>
<th>Island group</th>
<th>Island name (size)</th>
<th>Type herbivore removed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Olivera et al. *+</td>
<td>2010</td>
<td>Successful eradication of the European rabbit (Oryctolagus cuniculus) and house mouse (Mus musculus) from the island of Selvagem Grande (Macaronesian archipelago), in the Eastern Atlantic</td>
<td>Macronesia Archipelago</td>
<td>Selvagem Grande (340 ha)</td>
<td>Rabbits</td>
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<tr>
<td>Wylie ++</td>
<td>2012</td>
<td>Vegetation change on San Clemente Island following the removal of feral herbivores</td>
<td>Channel Islands</td>
<td>San Clemente Island (14713 ha)</td>
<td>Goats</td>
</tr>
</tbody>
</table>

* Denotes studies employed in the meta analysis of plant vegetation richness response to eradication
+ Denotes studies employed in the meta analysis of plant vegetation percent cover response to eradication

References:


