The relevance of using various scoring schemes revealed by an impact assessment of feral mammals

Bianca L. Hagen¹, Sabrina Kumschick¹²

¹ Centre for Invasion Biology, Department of Botany & Zoology, Stellenbosch University, Private Bag X1, Matieland 7602, South Africa ² South African National Biodiversity Institute, Kirstenbosch National Botanical Gardens, Claremont 7735, South Africa

Corresponding author: Sabrina Kumschick (sabrina.kumschick@gmail.com)

Abstract
Impact scoring schemes are useful for identifying to what extent alien species cause damage. Quantifying the similarity and differences between impact scoring schemes can help determine how to optimally use these tools for policy decisions. Using feral mammals (including rats and mice) as a case study, environmental and socio-economic impacts were assessed using three schemes, namely the Generic Impact Scoring System (GISS), Environmental Impact Classification for Alien Taxa (EICAT) and Socio-Economic Impact Classification for Alien Taxa (SEICAT). The results show that socio-economic impacts scores differ between the respective schemes (GISS and SEICAT) possibly because they assess different aspects of social life and economy. This suggests that both scoring schemes should ideally be applied in concert to get a complete picture of socio-economic impacts. In contrast, environmental impact scores are correlated between GISS and EICAT assessments and this similarity is consistent over most mechanisms except for predation and ecosystems, suggesting that one scoring scheme is sufficient to capture all the environmental impacts. Furthermore, we present evidence for the island susceptibility hypothesis as impacts of feral mammals were found to be higher on islands compared to mainlands.

Keywords
Generic Impact Scoring System (GISS), Environmental Impact Classification for Alien Taxa (EICAT), Socio-economic Impact Classification for Alien Taxa (SEICAT), invasive species

Copyright Bianca L. Hagen, Sabrina Kumschick. This is an open access article distributed under the terms of the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.
Introduction

Alien species cause various and sometimes devastating changes to the environment where they are introduced and influence social and economic aspects of human life (e.g. Pyšek and Richardson 2010, Vilà et al. 2010, Kumschick et al. 2015, Bacher et al. 2017). To minimise the negative effect of alien species, the Convention on Biological Diversity in its Aichi target 9 has proposed steps to mitigate their impacts, including identifying harmful alien species and prioritising their management (www.cbd.int/sp/targets/). To reach these goals, standardised measures for impact assessment and species prioritisation are needed.

This need has recently been met by the development of impact scoring schemes (e.g. Hawkins et al. 2015, Nentwig et al. 2016, Bacher et al. 2017; see Leung et al. 2012 for a review on risk assessments more broadly). Such schemes are typically based on published evidence of impacts or expert opinion and are meant to be transparent, robust and easy to use (Vanderhoeven et al. 2017). However, they often differ in the parameters used for the assessment and the way published evidence is translated into impact magnitude (e.g. Kumschick et al. 2017, Turbé et al. 2017). Differences in the outcomes using these schemes can potentially influence policy decisions and, for this reason, there is a need to quantify whether impact assessment schemes are comparable.

Three scoring schemes are considered in this study. The Generic Impact Scoring System (GISS) was first developed to assess the environmental and economic impact of alien mammals in Europe (Nentwig et al. 2010) and is one of the most widely used scoring schemes to date (Nentwig et al. 2016). It has been applied to various taxa including vertebrates, plants and invertebrates (e.g. Kumschick and Nentwig 2010, Vaes-Petignat and Nentwig 2014, Measey et al. 2016, Rumlerová et al. 2016). By comparison, the Environmental Impact Classification for Alien Taxa (EICAT), developed by Blackburn et al. (2014), focuses only on the environmental impact of species. It was adopted by the IUCN (https://portals.iucn.org/congress/motion/014) to enable a classification of all alien species worldwide (Hawkins et al. 2015, Evans, Kumschick and Blackburn 2016). The third scoring scheme is the Socio-Economic Impact Classification of Alien Taxa (SEICAT), which exclusively assesses the socio-economic impact of alien species (Bacher et al. 2017).

As a case study to compare the impact scoring schemes, we use feral mammals (including mice and rats) alien to South Africa. Alien mammals are known to cause damage to many ecosystems worldwide (Howald et al. 2007, Witmer et al. 2007, Skead et al. 2011, Capellini et al. 2015) and they have been shown to have the highest impacts across various taxonomic groups in a European study (Kumschick et al. 2015). For example, feral dogs (*Canis familiaris*) have contributed to the decline of turtle and tortoise species in India, Costa Rica as well as the Galapagos Archipelago (e.g. MacFarland et al. 1974, Fowler 1979). In South Africa, they are known to transmit diseases to jackals and bat-eared foxes (Sabeta, Bingham and Nel 2003). Furthermore, the impacts of alien mammals have been reported as particularly severe on islands (Pimentel et al. 2001, Hays and Conant 2007, Reaser et al. 2007). Impacts of alien species in general
are thought to be more detrimental on island environments by causing higher numbers of extinctions due to higher endemism, simpler food webs and slow diversification rates of species compared to mainlands (Courchamp et al. 2003). This is known as the island susceptibility hypothesis (Elton 1958, Jeschke et al. 2012).

The aims of our study were threefold. Firstly, we compared the outcomes of the three scoring schemes by a) comparing environmental and socio-economic impacts of feral mammals (including mice and rats) between the respective schemes and b) disentangling differences in impact scores between impact mechanisms (such as competition and predation) for environmental impacts, expecting to find similar levels of impacts between the schemes. Secondly, a test of the island susceptibility hypothesis was conducted by looking at the differences between socio-economic and environmental impacts caused on islands and mainlands, hypothesising that impacts are higher on islands. Lastly, following the finding that some taxa receive more research attention than others (Pyšek et al. 2008), it was determined whether there is a publication bias in our study. However we do not expect a bias since mammals are generally well studied.

Methods
Species selection and literature search

Using data from various sources, including Spear and Chown (2009), Picker and Griffiths (2011), Spear et al. (2011), Skead et al. (2011), Department of Environmental Affairs (2016) and Invasive Species South Africa (www.invasives.org.za), a list of domestic mammals alien to and feral in South Africa was compiled. This includes eight species which were initially introduced for their use as pets and/or are of agricultural significance. Additionally, we included rats (Rattus rattus and R. norvegicus) and mice (Mus musculus) due to their global significance as invasive pests (Figure 1). These species all have established alien populations in South Africa, but also represent some of the most prevalent domestic mammals with feral populations globally and some of the most damaging alien mammals (Nentwig et al. 2010) and are referred to as “feral mammals” in this manuscript for simplicity. Even though the selection of species was based on aliens in South Africa, the literature search was based on these species’ global alien range and the classification therefore represents the entire alien range.

In order to assemble information on the global impacts of these species, a review of published literature was undertaken. A search string, developed by Evans et al. (2016), was adopted (see also Appendix 1 for further detail) and papers were selected based on manual filtering of titles and abstracts. Databases searched included Google Scholar, Scopus and Web of Science. Publications on the impact of domestic mammals or pets in captivity were excluded and only impacts of stray or feral populations were considered. The reference list of the papers selected was further analysed to search for additional records of impacts. The search was terminated when the same sources were repeatedly found. All impact references were assigned a score by the main assessor and
Figure 1. Total GISS environmental and socio-economic impacts of invasive mammal species alien to South Africa. Total scores represent summed scores of maximum impacts given in each subcategory for each species separately. Abbreviations represent impact scores using EICAT (black) and SEICAT (light grey) as minor (MN), moderate (MO), major (MR) and massive (MV).

checked by a second assessor. Discussions on scores only occurred when there were disagreements or uncertainties around the score. For each impact found, we noted if it occurred on an island or mainland.

Impact schemes, categories and levels

GISS includes both environmental and socio-economic impacts, with EICAT and SEICAT focusing on one impact type each (see Suppl. material 1: Table S1 for the differences in the descriptions of the impact categories of the three schemes). GISS measures impacts by assessing the damage each species causes using six environmental (impacts on plants or vegetation; predation; competition; transmission of diseases; hybridisation; impacts on ecosystems; labelled E_GISS hereafter) and six socio-economic (impacts on agricultural production; animal production; forestry production; human infrastructure and administration; human health; human social life; SE_GISS) impact categories with six subcategories each (based on impact mechanisms or socio-economic sectors) (Kumschick and Nentwig 2010, Nentwig et al. 2016). Impact magnitudes range from 0 to 5, zero meaning that no known or detectable impacts were recorded whereas scores of five were equal to the most severe impacts. For GISS, scores were aggregated in two ways: a) Maximum scores refer to highest scores a species achieved in any subcategory and b) sums of the maximum scores received in all subcategories of the environmental and socio-economic categories, respectively and these give an overall potential impact score, termed summed score and ranging from 0 to 30.
In addition, total scores per species referred to summed scores of the socio-economic and environmental scores combined, with a potential range from 0 to 60 (Nentwig et al. 2010).

EICAT focuses on environmental impacts consisting of 12 mechanisms and five impact magnitudes, namely minimal concern (MC), minor (MN), moderate (MO), major (MR) and massive (MV), where MC is equivalent to no detectable impact on native individuals and MV equates to most severe impacts equalling a community compositional change (Blackburn et al. 2014, Hawkins et al. 2015). According to the guidelines by Hawkins et al. (2015), only the maximum impacts across all mechanisms per species were considered for this scheme. Lastly, SEICAT (Bacher et al. 2017) investigates the socio-economic effects of species and is similar to EICAT in terms of impact levels. SEICAT is based on alien species’ influence on all constituents of human well-being by using changes in peoples’ activities to evaluate the impacts. As for EICAT, only maximum impacts were analysed. Impact scores for EICAT and SEICAT were transferred into numerical scores from 1 to 5 (where MC was translated to 1 and MV translated to 5) for statistical analyses.

Statistical analyses

Maximum and summed environmental scores per species were used to compare E_GISS to EICAT. The same process was followed for the socio-economic comparison of SE_GISS and SEICAT. Paired Wilcoxon’s signed rank tests were used to test the similarity of the maximum and summed scores obtained in GISS to maximum scores in EICAT and SEICAT respectively.

To examine the differences in magnitude between environmental and socio-economic impacts, EICAT scores were compared to SEICAT scores and E_GISS scores to SE_GISS scores using a non-paired Wilcoxon’s signed rank test. For the GISS comparisons, only maximum scores were used for this test.

In order to assess what drives the potential similarity and differences between E_GISS and EICAT scores, scores pertaining to specific mechanisms were contrasted. This was done by unifying similar mechanisms across the schemes (Table 1). A single mechanism in GISS, for example, is sometimes represented by more than one mechanism in EICAT. As we are interested in whether there are differences in how the two schemes treat each record of impact, each record was treated as one impact entry (as opposed to a maximum per species and mechanism). The scores relating to each of these were compared using paired Wilcoxon’s signed rank tests.

A non-paired Wilcoxon’s signed rank test was conducted to test the difference between impacts caused on islands and mainlands. Due to the small sample size when analysing impacts per species, each publication containing information on impact was used as a separate record instead of using maximum impacts per species.

A Kendall’s tau was used to examine the relationship between the aggregated scores per species and the number of publications. This was done separately for each scoring scheme to test for publication bias (Kumschick et al. 2017). All analyses were conducted in R studio (version 0.99.903) and R (version 3.3.1) (R Core Team 2016).
Table 1. Concatenation of the environmental impact mechanisms in GISS and EICAT that are similar following Nentwig et al. (2016) and Hawkins et al. (2015), as used to compare detailed outcomes of the two scoring schemes for each source or information. “Interaction with other alien species” in EICAT could not be attributed to specific mechanisms in GISS and was therefore not included here.

| GISS | EICAT |
|------|-------|
| Impacts on species through competition | Competition |
| Impacts on animals through predation, parasitism or intoxication | Predation |
| | Parasitism |
| | Poisoning/toxicity |
| Impacts on plants or vegetation | Grazing/herbivory/browsing |
| Impacts through hybridisation | Hybridisation |
| Impacts through transmission of diseases or parasites to native species | Transmission of disease |
| | Physical ecosystem |
| | Chemical ecosystem |
| | Structural ecosystem |
| | Bio-fouling |
| Impacts on ecosystems | |

Results

The total impact of the species using GISS ranged from 15 to 37 with the highest impact being from *Sus scrofa* and the lowest from *Felis catus* (Figure 1).

No difference between the scoring schemes could be found when comparing EICAT scores to maximum E_GISS scores (paired Wilcoxon’s signed rank test; V = 7.5, p = 0.424). Sixty four percent of the species had equivalent scores and, where differences occurred, it was only by a single magnitude. In contrast, when comparing EICAT scores to summed E_GISS scores, we found a significant difference (V = 66, p = 0.038). E_GISS summed scores ranged from 9 to 23 and all but three species (*Bos taurus*, *C. familiaris* and *Equus asinus* scored MR) had an impact magnitude of MV under EICAT.

However, SEICAT and maximum scores of SE_GISS were significantly different (paired Wilcoxon’s signed rank test; V = 50.5, p = 0.015). Only 9% of the species’ scores were equivalent, whereas more than 81% of the species scored higher in GISS than in SEICAT. This higher score was mostly by a single magnitude (e.g. 4 in GISS and MO in SEICAT), except for *S. scrofa* where the schemes differed by two magnitudes (5 versus MO). A difference remained when comparing SEICAT with summed SE_GISS scores (V = 54, p = 0.007). While summed SE_GISS scores in this case never exceeded 15, SEICAT scores ranged from MN to MR.

When testing how EICAT and GISS treat scores for various mechanisms mentioned in Table 1, competition (Figure 2a, paired Wilcoxon’s rank test, V = 372, p = 0.114), herbivory (Figure 2b, V = 289, p = 0.877), hybridisation (Figure 2c, V = 14.5, p = 1) and disease transmission (Figure 2d, V = 28, p = 0.096) showed no significant differences between scores. Where differences occurred, it was either by one impact magnitude or two. The only two mechanisms that yielded significantly different scores were those of predation and ecosystems (Figures 2e–f, V = 503 and 28, p = 0.009 and 0.096 respectively).
Impact assessment of feral mammals

Figure 2. Relationship between GISS environmental and EICAT scores given for comparable mechanisms, including: a) competition b) herbivory c) hybridisation d) disease e) predation and f) ecosystems. We used each publication as a separate impact record for this analysis. Significantly different scores for schemes are indicated using asterisks.

When comparing environmental and socio-economic impacts, EICAT scores were significantly higher than SEICAT scores (Wilcoxon's signed rank test, $W = 1.5$, $p < 0.0001$) and the same was true using GISS ($W = 105.5$, $p = 0.001$).

Environmental scores were higher on islands than mainlands (Figure 3, Wilcoxon's signed rank test, $W = 26338$, $p < 0.001$) whereas socio-economic scores were similar ($W = 490$, $p = 0.702$).

A total of 318 papers were used for impact scoring (see Appendix 2). An average of 32 publications per species was found for environmental impacts in comparison to 7.5 publications per species for socio-economic impacts. None of the environmental impact
Figure 3. EICAT scores recorded on islands (n= 235) vs. mainlands (n= 167); p < 0.001. Each study containing an impact record was used separately for this analysis, with n indicating the number of studies found per region over all species.

measures was correlated to the number of papers (Figure 4a, Kendall’s tau = 0.056, p = 0.838). In contrast, socio-economic impacts were positively correlated to the number of publications (Figure 4b, Kendall’s tau = 0.765, p = 0.004).

Discussion

Firstly, following the publication of EICAT (Hawkins et al. 2015) and SEICAT (Bacher et al. 2017), this is the first application of these schemes for mammals. Until now, EICAT has only been used to assess the impacts of amphibians and birds introduced globally (Evans et al. 2016, Kumschick et al. 2017) and gastropods alien to South Africa (Kesner and Kumschick in revision) and SEICAT exclusively for the latter two (Bacher et al. 2017; Kesner and Kumschick in revision). Our study provides a starting point to adding another taxonomic group to the list of alien species with evidence based impact classifications and shows that EICAT and SEICAT are applicable to mammals. Furthermore, this study provided support for the already commonly used scoring scheme GISS (Nentwig et al. 2016) and adds assessments of many mammal species which were excluded in previous studies (Nentwig et al. 2010 excluded domesticated mammals).

Besides proving the applicability of the schemes to further taxa, our analysis reveals which impact measures might be necessary and most useful for management decisions. The comparison of environmental and socio-economic impact magnitudes, for example, shows that it is not sufficient to study one aspect to get a full picture of impacts (see also Vilà et al. 2010, Kumschick et al. 2015). Previous studies, such as those by Nentwig et al. (2010) and Kumschick et al. (2015), found that, within schemes, environmental and
socio-economic impacts were comparable, with species with high environmental impacts generally showing high economic impacts as well. This study found that feral mammals generally have larger environmental than socio-economic impacts. Yet, the difference in environmental and socio-economic impacts does not mean that the socio-economic impacts are low (Kumschick et al. 2015) with some species, such as *C. familiaris*, still scoring MR. Furthermore, different societal sectors (which includes conservation, health, agriculture and social) also have different priorities and for that reason, will be interested in different aspects of impacts covered by different scoring schemes (Kumschick et al. 2015). The scoring schemes used here (Kumschick et al. 2012), as well as others previously developed (e.g. D’hondt et al. 2015) therefore allow for the explicit weighting of categories. However we do not consider this to be the task of scientists, but rather the decision-makers and therefore consider all sectors to be of equal weight for this study.

**Figure 4.** The relationship between the number of publications and a environmental impact scores using EICAT scores and b socio-economic impact scores for alien mammals using SEICAT, where each dot represents a species and the line represents the relationship between impacts and number of publications. Maximum GISS scores and the sum of GISS environmental and socio-economic scores showed the same pattern as Figure 4a and b, respectively (results not shown).
The difference in magnitude recorded for socio-economic impacts between the scoring schemes has various possible causes. While both schemes are based on the same literature and are able to score all socio-economic impacts found for the selected species, GISS and SEICAT are based on different endpoints and use different “currencies” to compare impacts, with GISS addressing the actual economic damage of species and SEICAT transcribing these changes into effects on human well-being and activities being affected by the damage (Nentwig et al. 2016, Bacher et al. 2017). SEICAT has thus moved away from a mainly economic and value-driven (monetary) approach and assesses how people react to the damage caused by the invasive species rather than the actual damage itself. As an example, the damage that feral donkeys (*E. asinus*) cause to agricultural production might seem high at first, as seen in the GISS impact scores of 4, but it has not stopped farmers from continuing to produce agricultural products in any way (leading to low SEICAT scores of MN) (Tisdell and Takahashi 1988). Hence, SEICAT assumes that if peoples’ behaviour does not change as a result of the impact caused, the impact is not bad enough; or conversely, an impact does not have to cause huge monetary costs to be perceived as bad by certain vulnerable communities which have limited possibilities to cope with the problem (Bacher et al. 2017). As both scoring schemes cover important aspects of socio-economic impacts, but in fundamentally different ways with GISS focusing on actual damage and monetary losses and SEICAT focusing on resulting changes to activities more generally and peoples’ well-being, we suggest that using a combination of GISS and SEICAT assessments could prove useful to obtain a more complete and distinct picture of socio-economic impacts of alien species. Although this might not be the most practical solution, both schemes rely on the same evidence base. Alternatively, one scheme could be chosen based on the specific needs and scope of the assessment, with the respective endpoints assessed by each in mind.

In contrast, environmental impact scores were comparable between EICAT and GISS in our study, especially when the maximum impact was considered, suggesting only one scheme is needed. This supports the decision by the IUCN to adopt one scheme, namely EICAT, for a global classification of all alien taxa according to their environmental impacts. However, a previous study comparing the two schemes using amphibians as a case study highlights important differences for certain mechanisms between the schemes which should be considered in future applications (Kumschick et al. 2017). These differences were mainly attributed to uncertainties in the scoring of disease impacts in general (for transmission of diseases) and the differences between the two schemes in assigning the highest impact levels for hybridisation, with GISS depending on the size of the hybrid population and EICAT only referring to the fertility of F1 offspring. The main difference, which was found between certain mechanisms in this study, could be attributed to the split in some mechanisms in GISS (namely “Impacts on ecosystems” and “Impacts on animals through predation, parasitism or intoxication”) into several mechanisms in EICAT and which allows for more detailed assessments. Furthermore, EICAT consistently focuses on the recipient native community, while GISS assesses changes in nutrient fluxes and other abiotic changes as well, without
a necessary link to the native biota. This can, in certain cases (mainly for plant impacts), be an advantage as studies sometimes lack a link from changes in nutrient availability to effects on the native community (e.g. Castro-Diez et al. 2009 for two exotic trees). On another note, EICAT also includes distinct categories of impact through bio-fouling and interactions with other alien species, which are not separated out in GISS (Blackburn et al. 2014; Nentwig et al. 2016). This allows for a more detailed assessment of impacts of a larger variety of taxonomic groups which is another advantage of EICAT.

In terms of the various ways to aggregate scores, EICAT and SEICAT suggest using the maximum across all categories as summary classification (Blackburn et al. 2014, Hawkins et al. 2015, Bacher et al. 2017) while GISS originally promoted the use of summed scores (Nentwig et al. 2010, but see Kumschick et al. 2016, Nentwig et al. 2016). Both have their strengths and shortcomings and can introduce different biases (as outlined in Nentwig et al. 2017 and Turbé et al. 2017). Consequently, for some taxa, we found marked differences when scores are aggregated in different ways. The cat (*F. catus*) for example had the lowest recorded sum score in GISS of all taxa here considered, even though it is widely recognised as one of the most damaging alien species globally (e.g. Lowe et al. 2004) and has contributed to many extinctions of birds especially on islands (e.g. Dickman 1996). This seeming discrepancy is due to the limited range of mechanisms through which feral cats cause harm to native communities, namely mainly through predation, which leads to relatively low summed scores in GISS. Therefore we would like to highlight the importance of documenting all the sources used for each assessment and the details on all scores obtained to make a more informed policy decision, regardless of which tool is used.

Even though impacts of alien mammals are generally well studied compared to other taxa (e.g. Kumschick et al. 2015), there is a potential publication bias which can influence the magnitude of impacts recorded – the less is known about a species the lower the likelihood a severe impact is found or *vice versa*. We expect this to be more of a problem for less conspicuous and generally understudied taxa like invertebrates. It needs to be further evaluated how such (potential) publication biases could be addressed and avoided (see e.g. Evans et al. 2018).

Given that the selected species all have alien populations in South Africa, the results shown here could be useful to provide information for local policy-making and prioritisation. Little evidence exists on impacts of these species in the country, but data from elsewhere show that all these mammals have caused severe impacts leading to the disappearance of at least one species locally and some even contributed to global extinctions (Figure 1). Even though impacts on island have generally been more severe, they are not restricted to these regions and we expect many of the changes caused elsewhere could also happen in South Africa or have already occurred but not been documented. As an example, knowing that feral dogs hybridise with wolves and coyotes in Europe and America (Gipson and Sealander 1976, Freeman and Shaw 1979, Randi and Lucchini 2002), it is possible that domestic dogs could hybridise with other native species such as the African wild dog and jackals. Evidence from other African countries in fact shows that hybridisation and disease transmission is occurring between these species (Kat et
al. 1995, Randall et al. 2006). As another example, feral pigs (*S. scrofa*) have the highest summed impact (Figure 1) showing that the range of mechanisms through which they have impacts is quite widespread. For example, impacts on ecosystems have shown to be massive due to uprooting damage leading to the elimination of a rare plant, *Navarretia plieantha* in the United States of America (Barrett et al. 1988). Other impacts include impacts through predation, herbivory and competition. These are very generalist impacts which are not dependent on specific conditions in the recipient environment. In South Africa, however, environmental impacts of feral pigs have only been recorded to be minor as the damage reported does not affect species composition yet (Spear and Chown 2009). This might be a function of the species’ limited distribution or a bias due to lacking research. It therefore seems timely to consider this vast amount of evidence and evaluate management options for these species in sensitive areas.

**Island susceptibility hypothesis**

Only few studies have tested the island susceptibility hypothesis explicitly (Jeschke et al. 2012 found only 9 studies, most on birds), even though islands are generally thought to be more susceptible to invasions. Furthermore, previous studies testing this hypothesis have looked at “invasion success” or establishment rather than impact, finding limited support (Sol 2000, Jeschke 2008). A recent study on birds also used EICAT to classify species according to impacts and, as in our study, it confirmed impacts to be more severe on islands compared to mainlands (Evans et al. 2016). This might suggest that establishment and invasion success (cf. Blackburn et al. 2011) are not increased on islands, but alien species are causing more harm to the native biota. For example, ground-nesting birds and giant tortoises are particularly vulnerable to predation and trampling by invasive rodents and other mammals (MacFarland et al. 1974, Brown 1997, Angelici et al. 2012). However, further studies would need to be undertaken to confirm this pattern more broadly.

**Conclusion**

This study highlights the similarity and differences amongst three impact scoring schemes when using feral mammals as a case study and which can be used to make recommendations as to how prioritisation for actions can be improved. While using more than one scoring scheme to assess the same impacts seems cumbersome and unnecessary, it can help us to get an improved understanding of the various dimensions of such impacts, especially on socio-economic systems. Although this can be time-consuming, the most labour-intensive part of the impact scoring process is collating the relevant literature. All the schemes used here are based on the same data to assess and score impacts (Kumschick et al. 2017) and, once data is accumulated for the GISS assessment, the same references can be used to complete the other assessments.
Acknowledgements

BLH would like to thank Susan Canavan and Staci Warrington for their guidance with the statistical programme R. SK acknowledges financial support from the South African National Department of Environment Affairs through its funding to the Invasive Species Programme of the South African National Biodiversity Institute. We also thank the DST-NRF Centre of Excellence for Invasion Biology for its support.

References

Angelici C, Marini F, Battisti C, Bertolino S, Capizzi D, Monaco A (2012) Cumulative impact of rats and coypu on nesting waterbirds: first evidences from a small Mediterranean wetland (Central Italy). Vie et milieu - Life and environment 62(3): 137–141.

Bacher S, Blackburn TM, Essl F, Genovesi P, Heikkinä J, Jeschke JM, Jones G, Keller R, Kenis M, Kueffer C, Martinou AF, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Roy HE, Saul W-C, Scalera R, Vilá M, Wilson JRU, Kumschick S (2017) Socio-economic impact classification of alien taxa (SEICAT). Methods in Ecology and Evolution: 1–10. https://doi.org/10.1111/2041-210X.12844

Barrett RH, Goatcher BL, Gogan PJ, Fitzhugh EL (1988) Removing feral pigs from Annadel State Park. Transactions of the Western Section of the Wildlife Society 24: 47–52.

Blackburn TM, Pyšek P, Bacher S, Carlton JT, Duncan RP, Jarošík V, Wilson JRU, Richardson DM (2011) A proposed unified framework for biological invasions. Trends in Ecology and Evolution 26(7): 333–339. https://doi.org/10.1016/j.tree.2011.03.023

Blackburn TM, Essl F, Evans T, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Marková Z, Mrugala A, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Ricciardi A, Richardson DM, Sendek A, Vilá M, Wilson JRU, Winter M, Genovesi P, Bacher S (2014) A unified classification of alien species based on the magnitude of their environmental impacts. PLoS Biology 12(5): e1001850. https://doi.org/10.1371/journal.pbio.1001850

Brown KP (1997) Predation at nests of two New Zealand endemic passerines; implications for bird community restoration. Pacific Conservation Biology 3: 91–98. https://doi.org/10.1071/PC970091

Capellini I, Baker J, Allen WL, Street SE, Venditti C (2015) The role of life history traits in mammalian invasion success. Ecology Letters 18: 1099–1107. https://doi.org/10.1111/ele.12493

Castro-Díez P, González-Muñoz N, Alonso A, Gallardo A, Poorter L (2009) Effects of exotic invasive trees on nitrogen cycling: a case study in Central Spain. Biological Invasions 11(8): 1973–1986. https://doi.org/10.1007/s10530-008-9374-3

Couchamp F, Chapuis J-L, Pascal M (2003) Mammal invaders on islands: impact, control and control impact. Biological Reviews 78: 347–383. https://doi.org/10.1017/S1464793102006061

D’hondt B, Vanderhoeven S, Roelantd S, Mayer F, Versteirt V, Adriaens T, Ducheyne E, San Martin G, Grégoire JC, Stiers I, Quoilin S (2015) Harmonia+ and Pandora+: risk screening
tools for potentially invasive plants, animals and their pathogens. Biological Invasions 17(6): 1869–1883. https://doi.org/10.1007/s10530-015-0843-1

Department of Environmental Affairs (2016) National environmental management: biodiversity act, 2004 (Act No. 10 of 2004) Alien and invasive species list. Government Gazette 40166(864): 31–104.

Dickman CR (1996) Overview of the impacts of feral cats on Australian native fauna. Canberra: Australian Nature Conservation Agency.

Elton CS (1958) The ecology of invasions by animals and plants. University of Chicago Press, 50–93. https://doi.org/10.1007/978-1-4899-7214-9

Evans T, Kumschick S, Blackburn TM (2016) Application of the Environmental Impact Classification for Alien Taxa (EICAT) to a global assessment of alien bird impacts. Diversity and Distributions 22: 919–931. https://doi.org/10.1111/ddi.12464

Evans T, Pigot A, Kumschick S, Sekercioglu CH, Blackburn TM (2018) Determinants of data deficiency in the impacts of alien bird species. Ecography. https://doi.org/10.1111/ecog.03232

Freeman CR, Shaw JH (1979) Hybridization in Canis (Canidae) in Oklahoma. The Southwestern Naturalist 24: 485–499. https://doi.org/10.2307/3671304

Fowler LE (1979) Hatching success and nest predation in the green sea turtle, Chelonia mydas, at Tortuguero, Costa Rica. Ecology 60(5): 946–955. https://doi.org/10.1007/1936863

Gipson PS, Sealander JA (1976) Changing food habits of wild Canis in Arkansas with emphasis on coyote hybrids and feral dogs. The American Midland Naturalist 95(1): 249–253. https://doi.org/10.2307/2424258

Hawkins CL, Bacher S, Essl F, Hulme PE, Jeschke JM, Kühn I, Kumschick S, Nentwig W, Pergl J, Pyšek P, Rabitsch W, Richardson DM, Vilá M, Wilson JRU, Genovesi P, Blackburn TM (2015) Framework and guidelines for implementing the proposed IUCN Environmental Impact Classification for Alien Taxa (EICAT). Diversity and Distributions 21: 1360–1363. https://doi.org/10.1111/ddi.12379

Hays WST, Conant S (2007) Biology and impacts of Pacific island invasive species. 1. A worldwide review of effects of the small Indian mongoose, Herpestes javanicus (Carnivora: Herpestidae). Pacific Science 61(1): 3–16. https://doi.org/10.1353/psc.2007.0006

Howald G, Donlan CJ, Galván JP, Russell JC, Parkes J, Samaniego A, Wang Y, Veitch D, Genovesi P, Pascal M, Saunders A, Tershy B (2007) Invasive rodent eradication on islands. Conservation Biology: 1–32. https://doi.org/10.1111/j.1523-1739.2007.00755.x

Jeschke JM (2008) Across islands and continents, mammals are more successful invaders than birds. Diversity and Distributions 14(6): 913–916. https://doi.org/10.1111/j.1472-4642.2008.00488.x

Jeschke JM, Aparicio LG, Haider S, Heger T, Lortie CJ, Pyšek P, Strayer DL (2012) Support for major hypotheses in invasion biology is uneven and declining. NeoBiota 14: 1–20. https://doi.org/10.3897/neobiota.14.3435

Kat PW, Alexander KA, Smith JS, Munson L (1995) Rabies and African wild dogs in Kenya. Biological Sciences 262: 229–233. https://doi.org/10.1098/rspb.1995.0200

Kumschick S, Nentwig W (2010) Some alien birds have as severe an impact as the most effectual alien mammals in Europe. Biological Conservation 143: 2757–2762. https://doi.org/10.1016/j.biocon.2010.07.023
Kumschick S, Bacher S, Dawson W, Heikkilä J, Sendek A, Pluess T, Robinson T, Kühn I (2012) A conceptual framework for prioritization of invasive alien species for management according to their impact. NeoBiota 14: 15-69. https://doi.org/10.3897/neobiota.15.3323

Kumschick S, Bacher S, Evans T, Marková Z, Pergl J, Pyšek P, Vaes-Petignat S, van der Veer G, Vilá M, Nentwig W (2015) Comparing impacts of alien plants and animals in Europe using a standard scoring system. Journal of Applied Ecology 52: 552–561. https://doi.org/10.1111/1365-2664.12427

Kumschick S, Blackburn TM, Richardson DM (2016) Managing alien bird species: time to move beyond “100 of the worst” lists? Bird Conservation International 26: 154–163. https://doi.org/10.1017/S0959270915000167

Kumschick S, Vimercati G, de Villiers FA, Mokhatla MM, Davies SJ, Thorp CJ, Rebelo AD, Measey GJ (2017) Impact assessment with different scoring tools: how well do alien amphibian assessments match? NeoBiota 33: 53–66. https://doi.org/10.3897/neobiota.33.10736

Leung B, Roura-Pascual N, Bacher S, Heikkilä J, Brotons L, Burgman MA, Dehnen-Schmutz K, Essl F, Hulme PE, Richardson DM, Sol D (2012) TEASIng apart alien species risk assessments: a framework for best practices. Ecology Letters 15(12): 1475–1493. https://doi.org/10.1111/ele.12003

Lowe S, Browne S, Boudjela SM, De Poorter SM (2004) 100 of the world’s worst invasive alien species. The Invasive Species Specialist Group (ISSG) of the World Conservation Union (IUCN), Auckland, New Zealand.

MacFarland CG, Villa J, Toro B (1974) The Galápagos giant tortoises (Geochelone elephantopus) Part I: Status of the surviving populations. Biological Conservation 6(2): 118–133.

Measey GJ, Vimercati G, de Villiers FA, Mokhatla M, Davies SJ, Thorp CJ, Rebelo AD, Kumschick S (2016) A global assessment of alien amphibian impacts in a formal framework. Diversity and Distributions 22: 970–981. https://doi.org/10.1111/ddi.12462

Nentwig W, Kühnel E, Bacher S (2010) Generic Impact-Scoring System applied to alien mammals in Europe. Conservation Biology 24(1): 302–311. https://doi.org/10.1111/j.1523-1739.2009.01289.x

Nentwig W, Bacher S, Pyšek P, Vilá M, Kumschick S (2016) The Generic Impact Scoring System (GISS): a standardized tool to quantify the impacts of alien species. Environmental Monitoring and Assessment 188: 315. https://doi.org/10.1007/s10661-016-5321-4

Nentwig W, Bacher S, Kumschick S, Pyšek P, Vilá M (2017) More than “100 worst” alien species in Europe. Biological Invasions. https://doi.org/10.1007/s10530-017-1651-6

Picker M, Griffiths C (2011) Alien & invasive animals: a South African perspective. Struik Nature, Random House Struik (Pty) Ltd.

Pimentel D, McNair S, Janecka J, Wightman J, Simmonds C, O’Connell C, Wong E, Russel L, Zern J, Aquino T, Tsmondo T (2001) Economic and environmental threats of alien plant, animal, and microbe invasions. Agriculture, Ecosystems and Environment 84: 1–20. https://doi.org/10.1016/S0167-8809(00)00178-X

Pyšek P, Richardson DM, Pergl J, Jarosík V, Sixtova Z, Weber E (2008) Geographical and taxonomic biases in invasion ecology. Trends in Ecology and Evolution 23: 237–244. https://doi.org/10.1016/j.tree.2008.02.002
Pyšek P, Richardson DM (2010) Invasive species, environmental change and management, and health. Annual Review of Environment and Resources 35: 25–55. https://doi.org/10.1146/annurev-environ-033009-095548

R Core Team (2016) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org.

Randall DA, Marino J, Haydon DT, Sillero-Zubiri C, Knobel DL, Tallents LA, Macdonald DW, Laurenson MK (2006) An integrated disease management strategy for the control of rabies in Ethiopian wolves. Biological Conservation 131: 151–162. https://doi.org/10.1016/j.biocon.2006.04.004

Randi E, Lucchini V (2002) Detecting rare introgression of domestic dog genes into wild wolf (Canis lupus) populations by Bayesian admixture analyses of microsatellite variation. Conservation Genetics 3: 31–45. https://doi.org/10.1023/A:1014229610646

Reaser JK, Meyerson LA, Cronk Q, De Poorter M, Eldrige LG, Green E, Kairo M, Latasi P, Mack RN, Mauremootoo J, O'Dowd D, Orapa W, Sastraputo S, Saunders A, Shine C, Thraissoon S, Vaiutu L (2007) Ecological and socioeconomic impacts of invasive alien species in island ecosystems. Environmental Conservation 34(2): 98–111. https://doi.org/10.1017/S0376892907003815

Rumlerová Z, Vilà M, Pergl J, Nentwig W, Pyšek P (2016) Scoring environmental and socioeconomic impacts of alien plants invasive in Europe. Biological invasions 18(12): 3697–3711. https://doi.org/10.1007/s10530-016-1259-2

Sabeta CT, Bingham J, Nel LH (2003) Molecular epidemiology of canid rabies in Zimbabwe and South Africa. Virus Research 91: 203–211. https://doi.org/10.1016/S0168-1702(02)00272-1

Skead CJ, Boshoff A, Kerley GIH, Lloyd P (2011) Historical incidence of the larger land mammals in the broader Western and Northern Cape. Centre for African Conservation Ecology, Nelson Mandela Metropolitan University, Port Elizabeth, South Africa.

Sol D (2000) Are islands more susceptible to be invaded than continents? Birds say no. Ecography 23(6): 687–692. https://doi.org/10.1111/j.1600-0587.2000.tb00312.x

Spear D, Chown SL (2009) The extent and impacts of ungulate translocations: South Africa in a global context. Biological Conservation 142(2): 353–363. https://doi.org/10.1016/j.biocon.2008.10.031

Spear D, McGech MA, Foxcroft LC, Bezuidenhout H (2011) Alien species in South Africa’s national parks. Koedoe 53(1): 1–4. https://doi.org/10.4102/koedoe.v53i1.1032

Tisdell C, Takahashi S (1988) Feral animals in Australia - economic and ecological impact. Geographical Sciences 43(1): 37–50.

Turbé A, Strubbe D, Mori E, Carrete M, Chiron F, Clergeau P, González-Moreno P, Le Louarn M, Luna A, Menchetti M, Nentwig W, Pàrâu LG, Postigo J-L, Rabitsch W, Senar JC, Tollington S, Vanderhoeven S, Weiserbs A, Shwartz A (2017) Assessing the assessments: evaluation of four impact assessment protocols for invasive alien species. Diversity and Distributions: 1–11. https://doi.org/10.1111/ddi.12528

Vaes-Petignat S, Nentwig W (2014) Environmental and economic impact of alien terrestrial arthropods in Europe. NeoBiota 22: 23–42. https://doi.org/10.3897/neobiota.22.6620

Vanderhoeven S, Branquart E, Casar J, D’hondt B, Hulme PE, Shwartz A, Strubbe D, Turbé A, Verreycken H, Adriaens T (2017) Beyond protocols: improving the reliability of ex-
pert-based risk analysis underpinning invasive species policies. Biological Invasions 19(9): 2507–2517. https://doi.org/10.1007/s10530-017-1434-0

Vilà M, Basnou C, Pysvek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE, DAISIE partners (2010) How well do we understand the impacts of alien species on ecosystem services? A pan-European, cross-taxa assessment. Frontiers in Ecology and the Environment 8(3): 135–144. https://doi.org/10.1890/080083

Witmer GW, Burke PW, Pitt WC, Avery ML (2007) Management of invasive vertebrates in the United States: an overview. Managing Vertebrate Invasive Species, paper 56.

Appendix 1

The search string used to assemble information on the global impacts of the mammals assessed in this study. Adopted from Evans et al. (2016).

Searches on the impacts of mammals were undertaken using the following search terms within a search string, in conjunction with the species scientific and common name: “introduced species”, “invasive species”, “invasive alien species”, “IAS”, “alien”, “non-native”, “non-indigenous”, “invasive bird”, “pest”, “feral” and “exotic”. Thus, the search string for the species feral pig was (“introduced species” OR “invasive species” OR “invasive alien species” OR “IAS” OR “alien” OR “non-native” OR “non-indigenous” OR “invasive bird” OR “pest” OR “feral” OR “exotic”) AND (“pig” OR “boar” OR “Sus scrofa”).

Appendix 2

List of references used for the scoring impacts using GISS, EICAT and SEICAT

Abdel-Moein KA, Hamza DA (2016) Norway rat (*Rattus norvegicus*) as a potential reservoir for *Echinococcus granulosus*: a public health implication. Acta Parasitologica 61(4): 815–819. https://doi.org/10.1515/ap-2016-0113

Abella SR (2008) A systematic review of wild burro grazing effects on Mojave Desert vegetation, USA. Environmental Management 41: 809–819. https://doi.org/10.1007/s00267-008-9105-7

Ahmad E, Hussain I, Brooks JE (1995) Losses of stored foods due to rats at grain markets in Pakistan. International Biodeterioration and Biodegradation 36(1-2): 125–133.

Aldezabal A, Garin I (2000) Browsing preference of feral goats (*Capra hircus* L.) in a Mediterranean mountain scrubland. Journal of Arid Environments 44: 133–142. https://doi.org/10.1006/jare.1999.0573

Alexander KA, Conrad PA, Gardner IA, Parish C, Appel M, Levy MG, Lerche N, Kat P (1993) Serologic survey for selected microbial pathogens in African wild dogs (*Lycaon pictus*) and sympatric domestic dogs (*Canis familiaris*) in Maasai Mara, Kenya. Journal of Zoo and Wildlife Medicine 24(2): 140–144. http://www.jstor.org/stable/20095255
Alexander KA, Appel MJG (1994) African wild dogs (*Lycaon pictus*) endangered by a canine distemper epizootic among domestic dogs near the Masai Mara National Reserve, Kenya. Journal of Wildlife Diseases 30(4): 481–485. https://doi.org/10.7589/0090-3558-30.4.481

Alexander KA, Kat PW, Munson LA, Kalake A, Appel MJG (1996) Canine distemper-related mortality among wild dogs (*Lycaon pictus*) in Chobe National Park, Botswana. Journal of Zoo and Wildlife Medicine 27(3): 426–427. http://www.jstor.org/stable/20095601

Ali R (2004) The effect of introduced herbivores on vegetation in the Andaman Islands. Current Science 86(8): 1103–1113.

Altesor A, Pineiro G, Lezama F, Jackson RB, Sarasola M, Paruelo JM (2006) Ecosystem changes associated with grazing in subhumid South American grasslands. Journal of Vegetation Science 17: 323–332.

Amarasekare P (1993) Potential impact of mammalian nest predators on endemic forest birds of western Mauna Kea, Hawai‘i. Conservation Biology 7(2): 316–326. http://www.jstor.org/stable/2386429.

Angelici C, Marini F, Battisti C, Bertolino S, Capizzi D, Monaco A (2012) Cumulative impact of rats and coypu on nesting waterbirds: first evidences from a small Mediterranean wetland (Central Italy). Vie et milieu - Life and environment 62(3): 137–141.

Atickem A, Bekele A, Williams SD (2009) Competition between domestic dogs and Ethiopian wolf (*Canis simensis*) in the Bale Mountains National Park, Ethiopia. African Journal of Ecology 48: 401–407. https://doi.org/10.1111/j.1365-2028.2009.01126.x

Atkinson UAE (1973) Spread of the ship rat (*Rattus r. rattus*) L.) III New Zealand. Journal of the Royal Society of New Zealand 3(3): 457–472. https://doi.org/10.1080/03036758.1973.10421869

Avenant NL (1999) The ecology and ecophysiology of Marion Island mice, *Mus musculus* L. PHD Thesis. University of the Orange Free State (Bloemfontein).

Aviat F, Blanchard B, Michel V, Blanchet B, Branger C, Hars J, Mansotte F, Brasme L, De Champs C, Bolut P, Mondot P, Faliu J, Rochereau S, Kodjo A, Andre-Fontaine G (2009) Leptospira exposure in the human environment in France: A survey in feral rodents and in fresh water. Comparative Immunology, Microbiology and Infectious Diseases 32: 463–476. https://doi.org/10.1016/j.cimid.2008.05.004

Bakker ES, Olff H, Boekhoff M, Gleichman JM, Berendse F (2004) Impact of herbivores on nitrogen cycling: contrasting effects of small and large species. Oecologia 138: 91–101. https://doi.org/10.1007/s00442-003-1402-5

Bankovich B, Boughton E, Boughton R, Avery ML, Wisely SM (2016) Plant community shifts caused by feral swine rooting devalue Florida rangeland. Agriculture, Ecosystems and Environment 220: 45–54. http://dx.doi.org/10.1016/j.agee.2015.12.027

Barnett BD, Rudd RL (1983) Feral dogs of the Galapágos islands: impact and control. International Journal for the Study of Animal Problems 4(1): 44–58.

Baron J (1982) Effects of feral hogs (*Sus scrofa*) on the vegetation of Horn Island, Mississippi. American Midland Naturalist 107(1): 202–205. http://www.jstor.org/stable/2425204

Barrett RH (1978) The feral hog at Dye Creek Ranch, California. Hilgardia 46(9): 283–355. https://doi.org/10.3733/hilg.v46n09p283
Barrett RH, Goatcher BL, Gogan PJ, Fitzhugh EL (1988) Removing feral pigs from Annadel State Park. Transactions of the Western Section of the Wildlife Society 24: 47–52.

Baskaran N, Ramkumaran K, Karthikeyan G (2016) Spatial and dietary overlap between blackbuck (Antilope cervicapra) and feral horse (Equus caballus) at Point Calimere Wildlife Sanctuary, Southern India: competition between native versus introduced species. Mammalian Biology 81: 295–302. http://dx.doi.org/10.1016/j.mambio.2016.02.004

Beever EA, Brussard PF (2000) Examining ecological consequences of feral horse grazing using exclosures. Western North American Naturalist 60(3): 236–254.

Beever EA, Brussard PF (2004) Community- and landscape-level responses of reptiles and small mammals to feral-horse grazing in the Great Basin. Journal of Arid Environments 59: 271–297. https://doi.org/10.1016/j.jaridenv.2003.12.008

Beever EA, Herrick JE (2006) Effects of feral horses in Great Basin landscapes on soils and ants: Direct and indirect mechanisms. Journal of Arid Environments 66: 96–112. https://doi.org/10.1016/j.jaridenv.2005.11.006

Bell BD (2002) The eradication of alien mammals from five offshore islands, Mauritius, Indian Ocean. In: Veitch CR, Clout MN (Eds) Turning the tide: the eradication of invasive species. IUCN SSC invasive species specialist group. IUCN (United Kingdom): 40–45.

Belsky AJ, Matzke A, Uselman S (1999) Survey of livestock influences on stream and riparian systems in the Western United States. Journal of Soil and Water Conservation 54: 419–431.

Bergman D, Breck S, Bender S (2009) Dogs gone wild: feral dog damage in the United States. USDA National Wildlife Research Center - Staff Publications, 862.

Bergstrom DM, Lucieer A, Kiefer K, Wasley J, Belbin L, Pedersen TK, Chown SL (2009) Indirect effects of invasive species removal devastate World Heritage Island. Journal of Applied Ecology 46: 73–81. https://doi.org/10.1111/j.1365-2664.2008.01601.x

Bies L (n.d.) Feral cats: impacts of an invasive species. The Wildlife Society.

Bingham J (2005) Canine rabies ecology in Southern Africa. Emerging Infectious Diseases 11(9): 1337–1342. https://doi.org/10.3201/eid1109.050172

Bingham J, Foggin CM, Wandeler AI, Hill FWG (1999) The epidemiology of rabies in Zimbabwe. 2. Rabies in jackals (Canis adustus and Canis mesomelas). Onderstepoort Journal of Veterinary Research 66: 11–23.

Bizri AR, Azar A, Salam N, Mokhbat J (2000) Human rabies in Lebanon: lessons for control. Epidemiology and Infection 125: 175–179.

Blood BR, Clark MK (1998) Myotis vivesi. Mammalian Species 588: 1–5.

Boggess EK, Andrews RD, Bishop RA (1978) Domestic animal losses to coyotes and dogs in Iowa. Journal of Wildlife Management 42: 362–372. http://www.jstor.org/stable/3800272

Bolton M, Stanbury A, Baylis AMM, Cuthbert R (2014) Impact of introduced house mice (Mus musculus) on burrowing seabirds on Steeple Jason and Grand Jason Islands, Falklands, South Atlantic. Polar Biology 37: 1659–1668. https://doi.org/10.1007/s00300-014-1554-2

Bonnaud E, Bourgeois K, Vidal E, Kayser Y, Tranchant Y, Legrand J (2007) Feeding ecology of a feral cat population on a small Mediterranean Island. Journal of Mammalogy 88(4): 1074–1081. https://doi.org/10.1644/06-MAMM-A-031R2.1
Borchard P, Eldridge DJ (2012) Vegetation changes associated with cattle (Bos taurus) and wombat (Vombatus ursinus) activity in a riparian forest. Applied Vegetation Science 15: 62–70. https://doi.org/10.1111/j.1654-109X.2011.01157.x

Borgnia M, Vila BL, Cassini MH (2008) Interaction between wild camelids and livestock in an Andean semi-desert. Journal of Arid Environments 72: 2150–2158. https://doi.org/10.1016/j.jaridenv.2008.07.012

Bowers JE (1997) Demographic patterns of Ferocactus cylindraceus in relation to substrate age and grazing history. Plant Ecology 133: 37–48. http://www.jstor.org/stable/20050539

Bratton SP (1975) The Effect of the European wild boar, Sus scrofa, on Gray Beech Forest in the Great Smoky Mountains. Ecology 56(6): 1356–1366. http://www.jstor.org/stable/1934702

Brown KP (1997) Predation at nests of two New Zealand endemic passerines; implications for bird community restoration. Pacific Conservation Biology 3: 91–98.

Bueno C, Ruckstuhl KE, Arrigo N, Aivas AN, Neuhaus P (2012) Impacts of cattle grazing on small-rodent communities: an experimental case study. Canadian Journal of Zoology 90: 22–30. https://doi.org/10.1139/Z11-108

Bullock DJ, North SG, Dulloo ME, Thorsen M (2002) The impact of rabbit ad goat eradication on the ecology of Round Island, Mauritius. In: Veitch CR, Clout MN (Eds) Turning the tide: the eradication of invasive species. IUCN SSC invasive species specialist group. IUCN (United Kingdom), 53–63.

Butler JRA, du Toit JT (2002) Diet of free-ranging domestic dogs (Canis familiaris) in rural Zimbabwe: implications for wild scavengers on the periphery of wildlife reserves. Animal Conservation 5: 29–37. https://doi.org/10.1017/S136794300200104X

Buuveibaatar B, Young JK, Fine AE (2009) Mongolian saiga in Sharga Nature Reserve: Are domestic dogs a threat to saiga? Mongolian Journal of Biological Sciences 7(1-2): 37–43. http://dx.doi.org/10.22353/mjbs.2009.07.06

Calhoun JB (1948) Mortality and movement of brown rats (Rattus norvegicus) in artificially supersaturated populations. The Journal of Wildlife Management 12(2): 167–172. http://www.jstor.org/stable/3796412

Campbell K, Donlan CJ (2005) Feral goat eradications on islands. Conservation Biology 1362–1374. https://doi.org/10.1111/j.1523-1739.2005.00228.x

Campos CM, Ojeda RA (1997) Dispersal and germination of Prosopis flexuosa (Fabaceae) seeds by desert mammals in Argentina. Journal of Arid Environments 35: 707–714.

Campos CB, Estevés CF, Ferraz KMPMB, Crawshaw PG, Verdade LM (2007) Diet of free-ranging cats and dogs in a suburban and rural environment, south-eastern Brazil. Journal of Zoology 273: 14–20. https://doi.org/10.1111/j.1469-7998.2007.00291.x

Carrion V, Donlan CJ, Campbell K, Lavoie C, Cruz F (2007) Feral donkey (Equus asinus) eradications in the Galápagos. Biodiversity and Conservation 16: 437–445. https://doi.org/10.1007/s10531-005-5825-7

Carter AO, Frank JW (1986) Congenital toxoplasmosis: epidemiologic features and control. CMAJ 135: 618–623.

Causey MK, Cude CA (1980) Feral dog and white-tailed deer interactions in Alabama. The Journal of Wildlife Management 44(2): 481–484. http://www.jstor.org/stable/3807982
Impact assessment of feral mammals

Centers for Disease Control and Prevention (1997) Dog-bite-related fatalities—United States, 1995-1996. MMWR: morbidity and mortality weekly report 46(21): 463–467.

Challies CN (1975) Feral pigs (Sus scrofa) on Auckland Island: Status, and effects on vegetation and nesting sea birds. New Zealand Journal of Zoology 2(4): 479–490. http://dx.doi.org/10.1080/03014223.1975.9517889

Chapuis JL, Bousses P, Barnaud G (1994) Alien mammals, impact and management in the French sub-Antarctic islands. Biological Conservation 67: 97–104. https://doi.org/10.1016/0006-3207(94)90353-0

Cheeseman TF (1887) On the flora of the Kermadec islands: with notes on the fauna.

Chown SL, Smith VR (1993) Climate change and the short-term impact of feral house mice at the sub-Antarctic Prince Edward Islands. Oecologia 96(4): 508–516. http://www.jstor.org/stable/4220568

Chynoweth MW, Litton CM, Lepczyk CA, Hess SC, Cordell S (2013) Biology and impacts of Pacific island invasive species. 9. Capra hircus, the feral goat (Mammalia: Bovidae). Pacific Science 67(2): 141–156. https://doi.org/10.2984/67.2.1

Ciucci P, Boitani L (1998) Wolf and dog depredation on livestock in central Italy. Wildlife Society Bulletin 26(3): 504–514. http://www.jstor.org/stable/3783763

Clark DA (1981) Foraging patterns of black rats across a desert-montane forest gradient in the Galápagos Islands. Biotropica 13: 182–194.

Clark DA, Clark DB (1981) Effects of seed dispersal by animals on the regeneration of Bursena graveolens (Burseraceae) on Santa Fe Island, Galápagos. Oecologia 49: 73–75. https://doi.org/10.1007/BF00376900

Cleaveland S (1996) The epidemiology of rabies and canine distemper in the Serengeti, Tanzania. PhD Thesis. University of London. https://doi.org/10.17037/PUBS.00682291

Cleaveland S, Appel MGJ, Chalmers WSK, Chillingworth C, Kaare M, Dye C (2000) Serological and demographic evidence for domestic dogs as a source of canine distemper virus infection for Serengeti wildlife. Veterinary Microbiology 72: 217–227.

Coblentz BE (1978) The effects of feral goats (Capra hircus) on island ecosystems. Biodiversity Conservation 13: 279–286. https://doi.org/10.1016/0006-3207(78)90038-1

Coblentz BE (1990) Exotic organisms: a dilemma for conservation biology. Conservation Biology 4: 261–265. http://www.jstor.org/stable/2385783

Collares-Pereira M, Korver H, Terpstra WJ, Santos-Reis M, Ramalhinho MG, Mathias ML, Oom MM, Fons R, Libois R, Petrucci- Fonseca F (1997) First epidemiological data on pathogenic leptospires isolated on the Azorean islands. European Journal of Epidemiology 13: 435–441.

Coman BJ, Brunner H (1972) Food habits of the feral house cat in Victoria. The Journal of Wildlife Management 36(3): 848–853. http://www.jstor.org/stable/3799439

Cooper SM, Scott HM, de la Garza GR, Deck AL, Cathey JC (2010) Distribution and interspecies contact of feral swine and cattle on rangeland in South Texas: implications for disease transmission. Journal of Wildlife Diseases 46(1): 152–164. https://doi.org/10.7589/0090-3558-46.1.152

Copson G, Whinam J (1998) Response of vegetation on sub-Antarctic Macquarie Island to reduced rabbit grazing. Australian Journal of Botany 46: 15–24. https://doi.org/10.1071/ BT96123
Copson GR (1986) The diet of introduced rodents *Mus musculus* L. and *Rattus rattus* L. on sub-Antarctic Macquarie Island. Wildlife Research 13(3): 441–445. https://doi.org/10.1071/WR9860441

Cornell University College of Veterinary Medicine. Zoonotic disease: what can I catch from my cat?

Corrigan RM, Williams RE (1986) The house mouse in poultry operations: Pest significance and a novel baiting strategy for its control. Proceedings Twelfth Vertebrate Pest Conference 120–126.

Cory F, Wilson A, Priddel D, Carlile N, Klomp N (2011) Eradication of the house mouse (*Mus musculus*) from Montague Island, New South Wales, Australia. Ecological Management & Restoration 12(2): 102–109. https://doi.org/10.1111/j.1442-8903.2011.00583.x

Costin AB, Moore DM (1960) The effects of rabbit grazing on the grasslands of Macquarie Island. Journal of Ecology 48(3): 729–732. http://www.jstor.org/stable/2257346

Courchamp F, Langlais M, Sugihara G (2000) Rabbits killing birds: modeling the hyperpredation process. Journal of Animal Ecology 69(1): 154–164. http://www.jstor.org/stable/2647348

Courchamp F, Pascal M, Chapuis J-L (2003) Mammal invaders on islands, impact, control and control impact. Biological Reviews 78: 347–383. https://doi.org/10.1017/S1464793102006061

Crafford JE, Scholtz CH (1987) Quantitative differences between the insect faunas of sub-Antarctic Marion and Prince Edward Islands: A result of human intervention? Biological Conservation 40: 255–262. https://doi.org/10.1016/0006-3207(87)90119-4

Crafford JE (1990) The role of feral house mice in ecosystem functioning on Marion Island. In: Kerry KR, Hempel G (Eds) Antarctic Ecosystems. Springer-Verlag (Berlin): 359–364.

Crane KK, Smith MA, Reynolds D (1997) Habitat selection patterns of feral horses in south-central Wyoming. Journal of Range Management 50: 374–380. http://www.jstor.org/stable/4003303

Cuthbert R, Hilton G (2004) Introduced house mice *Mus musculus*: a significant predator of threatened and endemic birds on Gough Island, South Atlantic Ocean? Biological Conservation 117: 483–489. https://doi.org/10.1016/j.biocon.2003.08.007

Dabritz HA, Conrad PA (2010) Cats and toxoplasma: implications for public health. Zoonoses and Public Health 57: 34–52. https://doi.org/10.1111/j.1863-2378.2009.01273.x

Daltry JC, Bloxam Q, Cooper G, Day ML, Hartley J, Henry M, Lindsay K, Smith BE (2001) Five years of conserving the ‘world’s rarest snake’, the Antiguan racer *Alsophis antiguae*. Oryx 35(2): 119–127.

Daniel MJ, Williams GR (1984) A survey of the distribution, seasonal activity and roost sites of New Zealand bats. New Zealand Journal of Ecology 7: 9–25. http://www.jstor.org/stable/24052700

de Bruyn PJN, Bastos ADS, Eadie C, Tosh CA, Bester MN (2008) Mass mortality of adult male sub-Antarctic fur seals: are alien mice the culprits? PLoS ONE 3(11): 3757–3762. https://doi.org/10.1371/journal.pone.0003757

De Pietri DE (1992) The search for ecological indicators: is it possible to biomonitor forest system degradation caused by cattle ranching activities in Argentina? Vegetatio 101: 109–121.
de Villalobos AE, Zalba SM (2010) Continuous feral horse grazing and grazing exclusion in mountain pampean grasslands in Argentina. Acta Oecologica 36: 514–519. https://doi.org/10.1016/j.actao.2010.07.004

De Vos A, Petrides GA (1967) Biological effects caused by terrestrial vertebrates introduced into non-native environments. In Proceedings and Papers of the 10th Technical Meeting (Switzerland), June 1966. International Union for Conservation of Nature and Natural Resources Publication (Lucerne) 9: 113–119.

Deem SL, Merkel J, Ballweber L, Vargas F.H, Cruz, MB, Parker PG (2010) Exposure to Toxoplasma gondii in Galápagos penguins (Spheniscus mendiculus) and flightless cormorants (Phalacrocorax harrisi) in the Galápagos Islands, Ecuador. Journal of Wildlife Diseases 46: 1005–1011. https://doi.org/10.7589/0090-3558-46.3.1005

Demma LJ, Traeger MS, Nicholson WL, Paddock CD, Blau DM, Eremeeva ME, Dasch GA, Levin ML, Singleton J, Zaki SR, Cheek JE, Swerdlow DL, McQuiston JH (2005) Rocky Mountain spotted fever from an unexpected tick vector in Arizona. The New England Journal of Medicine 353(6): 587–594. https://doi.org/10.1056/NEJMoa050043

Desender K, Baert L, Maelfait J-P, Verdyck P (1999) Conservation on Volcan Alcedo (Galápagos): terrestrial invertebrates and the impact of introduced feral goats. Biological Conservation 87: 303–310. https://doi.org/10.1016/S0006-3207(98)00078-0

Dowding JE, Murphy EC (2001) The impact of predation by introduced mammals on endemic shorebirds in New Zealand: a conservation perspective. Biological Conservation 99: 47–64.

Dowler RC, Carroll DS, Edwards CW (2000) Rediscovery of rodents (Genus Nesoryzomyz) considered extinct in the Galápagos Islands. Oryx 34(2): 109–117.

Dunn EH, Tessaglia DL (1994) Predation of birds at feeders in winter (Depredación de aves en comederos durante el invierno). Journal of Field Ornithology 65(1): 8–16. http://www.jstor.org/stable/4513887

Eidson M, Bingman AK (2010) Terrestrial rabies and human postexposure prophylaxis, New York, USA. Emergin Infectious Diseases 16(3): 127–129. https://doi.org/10.3201/eid1603.090298

Eriksson B, Eldridge DJ (2014) Surface destabilisation by the invasive burrowing engineer Mus musculus on a sub-Antarctic island. Geomorphology 223: 61–66. http://dx.doi.org/10.1016/j.geomorph.2014.06.026

Fensham RJ, Skull SD (1999) Before cattle: a comprehensive floristic study of Eucalyptus Savanna grazed by macropods and cattle in North Queensland, Australia. Biotropica 31(1): 37–47.

Ferreira GA, Nakano-Oliveira E, Genaro G (2014) Domestic cat predation on neotropical species in an insular Atlantic forest remnant in southeastern Brazil. Wildlife Biology 20: 167–175. https://doi.org/10.2981/wlb.13131

Fitter RSR (1967) Animal introductions and their ecological effects in Europe. In Proceedings and Papers of the 10th Technical Meeting (Switzerland), June 1966. International Union for Conservation of Nature and Natural Resources Publication (Lucerne) 9: 177–180.

Fitzgerald AM, Karl BJ (1979) Foods of feral house cats (Felis catus L.) in forest of the Orongorongo Valley, Wellington. New Zealand Journal of Zoology 6(1): 107–126. https://doi.org/10.1080/03014223.1979.10428353
Fitzgerald BM, Veitch CR (1985) The cats of Herekopare Island, New Zealand: their history, ecology and effects on birdlife. New Zealand Journal of Zoology 12: 319–330. https://doi.org/10.1080/03014223.1985.10428285

Fitzgerald BM (1990) Diet of domestic cats and their impact on prey populations. In: Turner DC, Bateson P (Eds) The Domestic Cat: the biology of its behavior. Cambridge University Press, Cambridge, 123–150.

Flanigan T, Schwan T, Armstrong C, Van Voris L, Salata R (1991) Relapsing fever in the US Virgin Islands: a previously unrecognized focus of infection. Journal of Infectious Diseases 163: 1391–1392. https://doi.org/10.1093/infdis/163.6.1391

Fordham DA, Georges A, Brook BW (2007) Demographic response of snake-necked turtles correlates with indigenous harvest and feral pig predation in tropical northern Australia. Journal of Animal Ecology 76(6): 1231–1243. http://www.jstor.org/stable/4539235

Fortwangler C (2009) A place for the donkey: Natives and aliens in the US Virgin Islands. Landscape Research 34(2): 205–222. https://doi.org/10.1080/01426390802390665

Fowler de Neira LE, Roe JH (1984) Emergence success of tortoise nests and the effect of feral burros on nest success on Volcan Alcedo, Galápagos. Copeia 3: 702–707. http://www.jstor.org/stable/1445152

Fowler de Neira LE, Johnson MK (1985) Diets of giant tortoises and feral burros on Volcan Alcedo, Galápagos. Journal of Wildlife Management 49(1): 165–169. http://www.jstor.org/stable/3801865

Fowler LE (1979) Hatching success and nest predation in the green sea turtle, *Chelonia mydas*, at Tortuguero, Costa Rica. Ecology 60(5): 946–955. http://www.jstor.org/stable/1936863

Franklin AB, Clark DA, Clark DB (1979) Ecology and behaviour of the Galápagos rail. Wilson Bulletin 91(2): 202–221.

Freeland WJ, Choquenot D (1990) Determinants of herbivore carrying capacity: plants, nutrients, and *Equus asinus* in northern Australia. Ecology 71: 589–597. http://www.jstor.org/stable/1940312

Freeman CR, Shaw JH (1979) Hybridization in *Canis* (*Canidae*) in Oklahoma. The Southwestern Naturalist 24: 485–499. http://www.jstor.org/stable/3671304

Fuentes ED, Jaksic FM, Simonetti JA (1983) European rabbits versus native rodents in Central Chile: effects on shrub seedlings. Oecologia 58(3): 411–414. http://www.jstor.org/stable/4217052

Fuentes-Allende N, Vielma A, Paulsen K, Arredondo C, Corti P, Estades CF, Gonzalez BA (2016) Is human disturbance causing differential preference of agricultural landscapes by taruca and feral donkeys in high Andean deserts during the dry season? Journal of Arid Environments 135: 115–119. http://dx.doi.org/10.1016/j.jaridenv.2016.08.018

Gabay O, Perevolotsky A, Bar Massada A, Carmel Y, Shachak M (2011) Differential effects of goat browsing on herbaceous plant community in a two-phase mosaic. Plant Ecology 212(10): 1643–1653. https://doi.org/10.1007/s11258-011-9937-8

Garzón-Machado V, González-Mancebo JM, Palomares-Martínez A, Acevedo-Rodríguez A, Fernández-Palacios JM, Del-Arco-Aguilar M, Pérez-de-Paz PL (2010) Strong negative effect of alien herbivores on endemic legumes of the Canary pine forest. Biological Conservation 143: 2685–2694. https://doi.org/10.1016/j.biocon.2010.07.012
Gascoyne SC, King AA, Laurenson MK, Borner M, Schildger B, Barrat J (1993) Aspects of rabies infection and control in the conservation of the African wild dog (Lycaon pictus) in the Serengeti region, Tanzania. Onderstepoort Journal of Veterinary Research 60: 415–420.

Gillham ME (1963) Some interactions of plants, rabbits and seabirds on South African islands. Journal of Ecology 51: 275–294. http://www.jstor.org/stable/2257684

Gingold G, Yom-Tov Y, Kronfeld-Schor N, Geffen E (2009) Effect of guard dogs on the behavior and reproduction of gazelles in cattle enclosures on the Golan Heights. Animal Conservation 12: 155–162. https://doi.org/10.1111/j.1469-1795.2009.00235.x

Gipson PS, Sealander JA (1976) Changing food habits of wild Canis in Arkansas with emphasis on coyote hybrids and feral dogs. The American Midland Naturalist 95(1): 249–253. http://www.jstor.org/stable/2424258

Girard TL, Bork EW, Neilsen SE, Alexander MJ (2013) Landscape-scale factors affecting feral horse habitat use during summer within the Rocky Mountain foothills. Environmental Management 51: 435–447. https://doi.org/10.1007/s00267-012-9987-2

Gottelli D, Sillero-Zubiri C, Applebaum GD, Roy MS, Girman DJ, Garcia-Moreno J, Ostrender EA, Wayne RK (1994) Molecular genetics of the most endangered canid: the Ethiopian wolf, Canis simensis. Molecular Ecology 3: 301–312. https://doi.org/10.1111/j.1365-294X.1994.tb00070.x

Gottschalk JS (1967) The introduction of exotic animals into the United States. In Proceedings and Papers of the 10th Technical Meeting (Switzerland), June 1966. International Union for Conservation of Nature and Natural Resources Publication (Lucerne) 9: 124–140.

Gowtage-Sequeira S, Banyard AC, Barrett T, Buczkowski H, Funk SM, Cleaveland S (2009) Epidemiology, pathology, and genetic analysis of a canine epidemic in Namibia. Journal of Wildlife Diseases 45(4): 1008–1020. https://doi.org/10.7589/0090-3558-45.4.1008

Goyal SM, Mech LD, Rademacher RA, Khan MA, Seal SU (1986) Antibodies against canine parvovirus in wolves of Minnesota: a serological study from 1975 through 1985. Journal of the American Veterinary Medicine Association 189(9): 1092–1094.

Green JS, Gipson PS (1994) Feral dogs. The handbook: prevention and control of wildlife damage: 35.

Grinder MI, Krausman PR, Hoffmann RS (2006) Equus asinus. Mammalian Species 794: 1–9. https://doi.org/10.1644/794.1

Hall SJG, Moore GF (1986) Feral cattle of Swona, Orkney Islands. Mammal Review 16(2): 89–96. https://doi.org/10.1111/j.1365-2907.1986.tb00026.x

Hamman O (1975) Vegetational changes in the Galápagos Islands during the period 1966–1973. Biological Conservation 7: 37–59. https://doi.org/10.1016/0006-3207(75)90029-4

Hamrick RG, Piryandioglu T, Gunduz S, Carroll JP (2005) Feral donkey Equus asinus populations on the Karpaz peninsula, Cyprus. European Journal of Wildlife Research 51: 108–116. https://doi.org/10.1007/s10344-005-0085-0

Hanley TA, Brady WW (1977) Feral burro impact on a Sonoran desert range. Journal of Range Management 30(5): 374–377.

Harper GA (2010) Diet of feral cats on subantarctic Auckland Island. New Zealand Journal of Ecology 34(2): 259–261.
Harris DB, MacDonald DW (2007) Interference competition between introduced black rats and endemic Galápagos rice rats. Ecology 88(9): 2330–2344. https://doi.org/10.1890/06-1701.1
Harris DB (2009) Review of negative effects of introduced rodents on small mammals on islands. Biological Invasions 11: 1611–1630. https://doi.org/10.1007/s10530-008-9393-0.
Harris MP (1967) Sea bird research in Galápagos 1965-67. Noticias de Galápagos. 9/10: 11–14.
Hart RH, Hepworth KW, Smith MA, Waggoner JW (1991) Cattle grazing behavior on a foothill elk winter range in southeastern Wyoming. Journal of Range Management 44(3): 262–266.
Haydon DT, Laurenson MK, Sillero-Zubiri C (2002) Integrating epidemiology into population viability analysis: managing the risk posed by rabies and canine distemper to the Ethiopian wolf. Conservation Biology 16: 1372–1383. https://doi.org/10.1046/j.1523-1739.2002.00559.x
Herrero J, Fernandez De Luco D (2003) Wild boars (Sus scrofa L.) in Uruguay: Scavengers or predators? Mammalia 67(4): 485–491. https://doi.org/10.1515/mamm-2003-0402.
Hervías S, Oppel S, Medina FM, Pipa T, Díez A, Ramos JA, Ruiz de Ybáñez R, Nogales M (2014) Assessing the impact of introduced cats on island biodiversity by combining dietary and movement analysis. Journal of Zoology 292: 39–47. https://doi.org/10.1111/jzo.12082
Hess SC, Hansen H, Nelson D, Swift R, Banko PC (2007) Diet of feral cats in Hawai’i Volcanoes National Park. Pacific Conservation Biology 13(4): 244–249.
Hicks DJ, Mauchamp A (1995) Size dependent predation by feral mammals on Galápagos Opuntia. Noticias de Galápagos 55: 15–17.
Holdgate MW (1967) The influence of introduced species on the ecosystems of temperate oceanic islands. In Proceedings and Papers of the 10th Technical Meeting (Switzerland), June 1966. International Union for Conservation of Nature and Natural Resources Publication (Lucerne) 9: 151–176.
Holmgren M (2002) Exotic herbivores as drivers of plant invasion and switch to ecosystem alternative states. Biological Invasions 4: 25–33.
Howard WE (1967) Ecological changes in New Zealand due to introduced mammals. In Proceedings and Papers of the 10th Technical Meeting (Switzerland), June 1966. International Union for Conservation of Nature and Natural Resources Publication (Lucerne) 9: 219–240.
Huyser O, Ryan PG, Cooper J (2000) Changes in population size, habitat use and breeding biology of lesser sheathbills (Chionis minor) at Marion Island: impacts of cats, mice and climate change? Biological Conservation 92: 299–310. https://doi.org/10.1016/S0006-3207(99)00096-8
Imber MJ, Bell BD, Bell EA (2005) Antipodes Islands birds in autumn 2001. Notornis 52: 125–132.
Innes J, Brown K, Jansen P, Shorten R, Williams D (1996) Kokako population studies at Rotoehu Forest and on Little Barrier Island. Science for Conservation 30: 1–34.
Innes J, Hay R, Flux I, Bradfield P, Speed H, Jansen P (1999) Successful recovery of North Island kokako Callaeas cinerea wilsoni populations, by adaptive management. Biological Conservation 87: 201–214. https://doi.org/10.1016/S0006-3207(98)00053-6
Iverson JB (1978) The impact of feral cats and dogs on populations of the West Indian rock iguana, Cyclura carinata. Biodiversity Conservation 14: 63–74. https://doi.org/10.1016/0006-3207(78)90006-X

Jaksic FM, Fuentes ER (1980) Why are native herbs in the Chilean Maroral more abundant beneath bushes: microclimate or grazing? Journal of Ecology 68(2): 665–669. http://www.jstor.org/stable/2259427

Jaksic FM (1998) Vertebrate invaders and their ecological impacts in Chile. Biodiversity and Conservation 7: 1427–1445.

Jaksic FM, Iriarte JA, Jiménez JE, Martínez DR (2002) Invaders without frontiers: cross-border invasions of exotic mammals. Biological Invasions 4: 157–173.

Jhala YV, Giles RH (1991) The status and conservation of the wolf in Gujarat and Rajasthan, India. Conservation Biology 5(4): 476–483. http://www.jstor.org/stable/2386069

Jones AG, Chown SL, Gaston KJ (2002) Terrestrial invertebrates of Gough Island: An assemblage under threat? African Entomology 10(1): 83–91.

Jones AG, Chown SL, Gaston KJ (2003) Introduced house mice as a conservation concern on Gough Island. Biodiversity and Conservation 12: 2107–2119.

Jones JL, Lopez A, Wilson M, Schulkin J, Gibbs R (2001) Congenital toxoplasmosis: a review. CME Review Article 56(5): 296–305.

Judge S, Lippert JS, Misajon K, Hu D, Hess SC (2012) Videographic evidence of endangered species depredation by feral cat. Pacific Conservation Biology 18: 293–296.

Karl BJ, Best HA (1982) Feral cats on Stewart Island; their foods, and their effects on kakapo. New Zealand journal of zoology 9(2): 287–293. https://doi.org/10.1080/03014223.1982.10423857

Kat PW, Alexander KA, Smith JS, Munson L (1995) Rabies and African wild dogs in Kenya. Biological Sciences 262: 229–233. http://www.jstor.org/stable/50221

Katahira LK, Finnegan P, Stone CP (1993) Eradicating feral pigs in montane mesic habitat at Hawaii Volcanoes National Park. Wildlife Society Bulletin 21(3): 269–274. http://www.jstor.org/stable/3782865

Kaufman DW, Kaufman DM, Kaufman GA (2011) Abundance and spatiotemporal distribution of the non-native house mouse in native tallgrass prairie. Transactions of the Kansas Academy of Science 114(3/4): 217–230. http://www.jstor.org/stable/23264094

Keitt BS, Wilcox C, Tershy BR, Croll DA, Donlan CJ (2002) The effect of feral cats on the population viability of black-vented shearwaters (Puffinus opisthomelas) on Natividad Island, Mexico. Animal Conservation 5: 217–223. https://doi.org/10.1017/S1367943002002263

Key G, Munoz Heredia E (1994) Distribution and current status of rodents in the Galápagos. Noticias de Galápagos 53: 21–25.

Kitts-Morgan SE, Caires KC, Bohannon LA, Parsons EI, Hilburn KA (2015) Free-ranging farm cats: Home range size and predation on a livestock unit in Northwest Georgia. PloS ONE 10(4): p.e0120513. https://doi.org/10.5061/dryad.v3n85

Kotanen PM (1995) Responses of vegetation to a changing regime of disturbance: effects of feral pigs in a Californian coastal prairie. Ecography 18: 190–199. https://doi.org/10.1111/j.1600-0587.1995.tb00340.x
Kramer P (1974) Galápagos conservation: present position and future outlook. Noticias de Galápagos 22: 19–21.
Kramer A, Reich P, Lake PS (2007) Preliminary insights into the status of ground-dwelling terrestrial arthropods at sites representing three riparian conditions. Ecological Management and Restoration 8: 147–150. https://doi.org/10.1111/j.1442-8903.2007.00354.x
Kruuk H, Snell H (1981) Prey selection by feral dogs from a population of marine iguanas (Amblyrhynchus cristatus). Journal of Applied Ecology 18: 197–204. http://www.jstor.org/stable/2402489.

Kurdila J (1998) The introduction of exotic species into the United States: there goes the neighborhood! Boston College Environmental Affairs Law Review 16(1): 95–119.

Kurle CM, Coll DA, Tershy BR (2007) Introduced rats indirectly change marine intertidal communities from algae- to invertebrate-dominated. PNAS 105(10): 3800–3804.

Lacerda ACR, Tomas WM, Marinho-Filho J (2009) Domestic dogs as an edge effect in the Brasilia National Park, Brazil: Interactions with native mammals. Animal Conservation 12: 477–487. https://doi.org/10.1111/j.1469-1795.2009.00277.x

Latorre L, Larrinaga AR, Santamaría L. (2013) Combined impact of multiple exotic herbivores on different life stages of an endangered plant endemism, Medicago citrina. Journal of Ecology 101: 107–117. https://doi.org/10.1111/j.1365-2745.12005

Laurenson K, Sillero-Zubiri C, Thompson H, Shiferaw F, Thirgood S, Malcolm J (1998) Disease as a threat to endangered species: Ethiopian wolves, domestic dogs and canine pathogens. Animal Conservation 1: 273–280. https://doi.org/10.1111/j.1469-1795.1998.tb00038.x

Le Roux V, Chapuis J-L, Frenot Y, Vernon P (2002) Diet of the house mouse (Mus musculus) on Guillou Island, Kerguelen archipelago, Subantarctic. Polar Biology 25: 49–57. https://doi.org/10.1007/s003000100310

Leathwick JR, Hay JR, Fitzgerald AE (1983) The influence of browsing by introduced mammals on the decline of North Island kokako. New Zealand Journal of Ecology 6: 55–70.

Lembo T, Hamson K, Haydon DT, Craft M, Dobson A, Dushoff J, Ernest E, Hoare R, Kaare M, Mengeya T, Mentzel C, Cleaveland S (2008) Exploring reservoir dynamics: A case study of rabies in the Serengeti ecosystem. Journal of Applied Ecology 45(4): 1246–1257. https://doi.org/10.1111/j.1365-2664.2008.01468.x

León-de la Luz JL, Domínguez-Cadena R (2006) Herbivory of feral goats on Espiritu Santo Island, Gulf of California, Mexico. Contributions to Botany 22(2): 1135–1143. http://www.jstor.org/stable/41969088

Levin PS, Ellis J, Petrik R, Hay ME (2002) Indirect effects of feral horses on estuarine communities. Conservation Biology 16: 1364–1371. https://doi.org/10.1046/j.1523-1739.2002.01167.x

Liberg O (1984) Food habits and prey impact by feral and house-based domestic cats in a rural area in southern Sweden. Journal of Mammalogy 65(3): 424–432. http://www.jstor.org/stable/1381089

Linkie M, Dinata Y, Nofrianto A, Leader-Williams N (2007) Patterns and perceptions of wildlife crop raiding in and around Kerinci Seblat National Park, Sumatra. Animal Conservation 10: 127–135. https://doi.org/10.1111/j.1469-1795.2006.00083.x
Lipscomb DJ (1989) Impacts of feral hogs on longleaf pine regeneration. Southern Journal of Applied Forestry 13(4): 177–181.

Lowry DA, McArthur KL (1978) Domestic dogs as predators on deer. Wildlife Society Bulletin 6(1): 38-39. http://www.jstor.org/stable/3781064

MacFarland CG, Villa J Toro B (1974a) The Galápagos giant tortoises (Geochelone elephantopus) Part I: status of the surviving populations. Biological Conservation 6(2): 118–133. https://doi.org/10.1016/0006-3207(74)90024-X

MacFarland CG, Villa J, Toro B (1974b) The Galápagos giant tortoises (Geochelone elephantopus) Part II: conservation methods. Biological Conservation 6(3): 198–212. https://doi.org/10.1016/0006-3207(74)90068-8

Mack MC, D’Antonio CM (1998) Impacts of biological invasions on disturbance regimes. Tree 13(5): 195–198. https://doi.org/10.1016/S0169-5347(97)01286-X.

Malo JE, Acebes P, Giannoni SM, Traba J (2011) Feral livestock threatens landscapes dominated by columnar cacti. Acta Oecologica 37: 249–255. https://doi.org/10.1016/j.actao.2011.02.008

Malo JE, Gonzalez BA, Mata C, Villa A, Donoso DS, Fuentes N, Estades CF (2016) Low habitat overlap at landscape scale between wild camelids and feral donkeys in the Chilean desert. Acta Oecologica 70: 1–9. http://dx.doi.org/10.1016/j.actao.2015.11.002

Mamaev LV, Denikina NN, Belikov SI, Volchkov VE, Visser IKG, Fleming M, Kai C, Harder TC, Liess B, Osterhaus ADME, Barrett T (1995) Characterisation of morbilliviruses isolated from Lake Baikal seals (Phoca sibirica). Veterinary Microbiology 44: 251–259. https://doi.org/10.1016/0378-1135(95)00018-6

Manor R, Saltz D (2004) The impact of free-roaming dogs on gazelle kid/female ratio in a fragmented area. Biological Conservation 119: 231–236. https://doi.org/10.1016/j.biocon.2003.11.005

Marks CA, Moore SJ (1998) Nursery practices influence comparative damage to juvenile blue gum by wallabies (Wallabia bicolor) and European rabbits (Oryctolagus cuniculus). Forest Ecology and Management 112: 1–8. https://doi.org/10.1016/S0378-1127(98)00301-6

Marris JWM (2000) The beetle (Coleoptera) fauna of the Antipodes Islands, with comments on the impact of mice; and annotated checklist of the insect and arachnid fauna. Journal of the Royal Society of New Zealand 30(2): 169–195. https://doi.org/10.1080/03014223.2000.9517616

Marshal JP, Bleich VC, Andrew NG (2008) Evidence for interspecific competition between feral ass Equus asinus and mountain sheep Ovis canadensis in a desert environment. Wildlife Biology 14(2):228–236. https://doi.org/10.2981/0909-6396(2008)14[228:EFICBF]2.0.CO;2

Marshal JP, Bleich VC, Krausman PR, Reed M, Neibergs A (2012) Overlap in diet and habitat between the mule deer (Odocoileus hemionus) and feral ass (Equus asinus) in the Sororan Desert. The Southwestern Naturalist 57(1): 16–25. https://doi.org/10.1894/0038-4909-57.1.16

Martin J, Thibault J, Bretagnolle V (2000) Black rats, island characteristics, and colonial nesting birds in the Mediterranean: consequences of an ancient introduction. Conservation Biology 14(5): 1452–1466. https://doi.org/10.1046/j.1523-1739.2000.99190.x
McKenzie ME, Davidson WR (1989) Helminth parasites of intermingling axis deer, wild swine and domestic cattle from the island of Molokai, Hawaii. Journal of Wildlife Diseases 25(2): 252–257. https://doi.org/10.7589/0090-3558-25.2.252

McKnight TL (1958) The feral burro in the United States: distribution and problems. The Journal of Wildlife Management 22(2): 163–179. http://www.jstor.org/stable/3797325.

Means DB, Travis J (2007) Declines in ravine-inhabiting dusky salamanders of the southeastern US Coastal Plain. Naturalist 6(1): 83–96. http://www.jstor.org/stable/4540981

Micol T, Jouventin P (1995) Restoration of Amsterdam Island, South Indian Ocean, following control of feral cattle. Biological Conservation 73: 199–206. https://doi.org/10.1016/0006-3207(94)00109-4

Miller R (1983) Habitat use of feral horses and cattle in Wyoming’s red desert. Journal of Range Management 36(2): 195–199. http://www.jstor.org/stable/3898161

Mitchell BD, Banks PB (2005) Do wild dogs exclude foxes? Evidence for competition from dietary and spatial overlaps. Austral Ecology 30: 581–591. https://doi.org/10.1111/j.1442-9993.2005.01473.x

Moro D (2001) Evaluation and cost-benefits of controlling house mice (Mus domesticus) on islands: an example from Thévenard Island, Western Australia. Biological Conservation 99: 355–364. https://doi.org/10.1016/S0006-3207(00)00231-7

Morris KD (2002) The eradication of the black rat (Rattus rattus) on Barrow and adjacent islands off the north-west coast of Western Australia. In: Veitch CR, Clout MN (Eds) Turning the tide: the eradication of invasive species. IUCN SSC invasive species specialist group (United Kingdom), 219–225.

Mutze G, Cooke B, Jennings S (2016) Density-dependent grazing impacts of introduced European rabbits and sympatric kangaroos on Australian native pastures. Biological Invasions 18: 2365–2376. DOI 10.1007/s10530-016-1168-4

Natoli E (1994) Urban feral cats (Felis catus L.): perspectives for a demographic control regarding the psycho-biological welfare of the species. Annali dell’Istituto superiore di sanita 30(2): 223–227.

North SG, Bullock D (1986) Changes in the vegetation and populations of introduced mammals of Round Island and Gunner’s Quoin, Mauritius. Biological Conservation 37: 99–117. https://doi.org/10.1016/0006-3207(86)90086-8

North SG, Bullock DJ, Dulloo ME (1994) Changes in the vegetation and reptile populations on Round Island, Mauritius, following eradication of rabbits. Biological Conservation 67: 21–28. https://doi.org/10.1016/0006-3207(94)90004-3

Novillo A, Ojeda RA (2007) The exotic mammals of Argentina. Biological Invasions 10(8): 1333. https://doi.org/10.1007/s10530-007-9208-8

O’Neil ME, Mack KA, Gilchrist J (2007) Epidemiology of non-canine bite and sting injuries treated in U.S. emergency departments, 2001–2004. Public Health Reports 122: 764–775. http://www.jstor.org.ez.sun.ac.za/stable/20057209

Ojeda RA, Novillo A, Cuevas F (2010) Exotic mammals of Argentina. In Settele J, Penev L, Georgiev T (Eds) Atlas of Biodiversity Risk. Pensoft Publishers, Sofia-Moscow, 154–155.

Olivera P, Menezes D, Trout R, Buckle A, Geraldes P, Jesus J (2010) Successful eradication of the European rabbit (Oryctolagus cuniculus) and house mouse (Mus musculus) from the is-
Impact assessment of feral mammals

land of Selvagem Grande (Macaronesian Archipelago), in the Eastern Atlantic. Integrative Zoology 1: 70–83. https://doi.org/10.1111/j.1749-4877.2010.00186.x

Ovejero RJA, Acebes P, Malo JE, Traba J, Torres MEM, Borghi CE (2011) Lack of feral livestock interference with native guanaco during the dry season in a South American desert. European Journal of Wildlife Research 57: 1007–1015. https://doi.org/10.1007/s10344-011-0511-4

Palmer M, Pons GX (1996) Diversity in western Mediterranean islets: effects of rat presence on a beetle guild. Acta Oecologica 17: 297–305.

Palmer M, Pons GX (2001) Predicting rat presence on small islands. Ecography 24: 121–126.

Parkes JP (1984) Feral goats on Raoul Island, II. Diet and notes on the flora. New Zealand Journal of Ecology 7: 95–101.

Parkes JP (1990) Feral goat control in New Zealand. Biological Conservation 54: 335–348. https://doi.org/10.1016/0006-3207(90)90145-F

Parkes J, Henzell R, Pickles G (1996) Managing vertebrate pests: feral goats. Australian Government Publishing Service, Canberra.

Pascal M, Siorat F, Lorvelec O, Yesou P, Simberloff D (2005) A pleasing consequence of Norway rat eradication: two shrew species recover. Diversity and Distributions 11: 193–198. https://doi.org/10.1111/j.1366-9516.2005.00137.x

Pascal M, Lorvelec O, Bretagnolle V, Culioli J (2008) Improving the breeding success of a colonial seabird: a cost-benefit comparison of the eradication and control of its rat predator. Endangered Species Research 4: 267–276. https://doi.org/10.3354/esr00080

Patrick B (1994) Antipodes Island Lepidoptera. Journal of the Royal Society of New Zealand 24(1): 91–116. https://doi.org/10.1080/03014223.1994.9517457

Peck DR, Faulquier L, Pinet P, Jaquemet S, Le Corre M (2008) Feral cat diet and impact on sooty terns at Juan de Nova Island, Mozambique Channel. Animal Conservation 11: 65–74. https://doi.org/10.1111/j.1469-1795.2007.00153.x

Penloup A, Martin J, Gory G, Brunstein D, Bretagnolle V (1997) Distribution and breeding success of pallid swifts, Apus pallidus, on Mediterranean islands: nest predation by the roof rat, Rattus rattus, and nest site quality. Oikos 80: 78–88. https://doi.org/10.2307/3546518.

Pickard J (1982) Catastrophic disturbance and vegetation on Little slope, Lord Howe Island. Australian Journal of Ecology 7: 161–170. https://doi.org/10.1111/j.1442-9993.1982.tb01589.x

Pierce RJ (1989) Differences in susceptibility to predation during nesting between pied and black stilts (Himantopus spp.). The Auk 103: 273–280.

Pimentel D, Lach L, Zuniga R, Morrison D (2000) Environmental and economic costs associated with non-indigenous species in the United States. BioScience 50(1): 53–65. https://doi.org/10.1641/0006-3568(2000)050[0053:EAECON]2.3.CO;2

Pimentel D, McNair S, Janecka J, Wightman J, Simmonds C, O’Connell C, Wong E, Russel L, Zern J, Aquino T, Tsomondo T (2001) Economic and environmental threats of alien plant, animal, and microbe invasions. Agriculture, Ecosystems and Environment 84: 1–20.

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. Ecological Economics 52(3): 273–288. https://doi.org/10.1016/j.ecolecon.2004.10.002
Pozio E (1998) Trichinellosis in the European Union: epidemiology, ecology and economic impact. Parasitology Today 14: 35–38. https://doi.org/10.1016/S0169-4758(97)01165-4

Prakash V, Pain DJ, Cunningham AA, Donald PF, Prakash N, Verma A, Gargi R, Sivakumar S, Rahmani AR (2003) Catastrophic collapse of Indian white-backed Gyps bengalensis and long-billed Gyps indicus vulture populations. Biological Conservation 109: 381–390. https://doi.org/10.1016/S0006-3207(02)00164-7

Prakash V, Pain DJ, Cunningham AA, Donald PF, Prakash N, Verma A, Gargi R, Sivakumar S, Rahmani AR (2003) Catastrophic collapse of Indian white-backed Gyps bengalensis and long-billed Gyps indicus vulture populations. Biological Conservation 109: 381–390. https://doi.org/10.1016/S0006-3207(02)00164-7

Prakash V, Pain DJ, Cunningham AA, Donald PF, Prakash N, Verma A, Gargi R, Sivakumar S, Rahmani AR (2003) Catastrophic collapse of Indian white-backed Gyps bengalensis and long-billed Gyps indicus vulture populations. Biological Conservation 109: 381–390. https://doi.org/10.1016/S0006-3207(02)00164-7

Prakash V, Pain DJ, Cunningham AA, Donald PF, Prakash N, Verma A, Gargi R, Sivakumar S, Rahmani AR (2003) Catastrophic collapse of Indian white-backed Gyps bengalensis and long-billed Gyps indicus vulture populations. Biological Conservation 109: 381–390. https://doi.org/10.1016/S0006-3207(02)00164-7

Randall DA, Williams SD, Kuzmin IV, Rupprecht CE, Tallents LA, Tefera Z, Argaw K, Shiferaw F, Knobel DL, Sillero-Zubiri C, Laurensen MK (2004) Rabies in endangered Ethiopian wolves. Emerging Infectious Diseases 10: 2214–2217. https://doi.org/10.3201/eid1012.040080

Randall DA, Williams SD, Kuzmin IV, Rupprecht CE, Tallents LA, Tefera Z, Argaw K, Shiferaw F, Knobel DL, Sillero-Zubiri C, Laurensen MK (2004) Rabies in endangered Ethiopian wolves. Emerging Infectious Diseases 10: 2214–2217. https://doi.org/10.3201/eid1012.040080

Randall DA, Williams SD, Kuzmin IV, Rupprecht CE, Tallents LA, Tefera Z, Argaw K, Shiferaw F, Knobel DL, Sillero-Zubiri C, Laurensen MK (2004) Rabies in endangered Ethiopian wolves. Emerging Infectious Diseases 10: 2214–2217. https://doi.org/10.3201/eid1012.040080

Randall DA, Marino J, Haydon DT, Sillero-Zubiri C, Knobel DL, Tallents LA, Macdonald DW, Laurensen MK (2006) An integrated disease management strategy for the control of rabies in Ethiopian wolves. Biological Conservation 131: 151–162. https://doi.org/10.1016/j.biocon.2006.04.004

Randi E, Tosi G, Toso S, Lorenzini R, Fusco G (1990) Genetic variability and conservation problems in Alpine ibex, domestic and feral goat populations (genus Capra). Saugetierkunde 55: 413–420.

Randi E, Lucchini V (2002) Detecting rare introgression of domestic dog genes into wild wolf (Canis lupus) populations by Bayesian admixture analyses of microsatellite variation. Conservation Genetics 3: 31–45.

Reus ML, Cappa FM, Andino N, Campos VE, de los Rios C, Campos CM (2014) Trophic interactions between the native guanaco (Lama guanicoe) and the exotic donkey (Equus asinus) in the hyper-arid Monte desert (Ischigualasto Park, Argentina). Studies on Neotropical Fauna and Environment 49(3): 159–168. https://doi.org/10.1080/01650521.2014.948772

Roelke-Parker ME, Munson L, Packer C, Kock R, Cleaveland S, Carpenter M, O’Brien SJ, Pospischil A, Hofmann-Lehmann R, Lutz H, Mwandengele LM, Mgas MN, Machange GA, Summers BA, Appel MJG (1996) A canine distemper virus epidemic in Serengeti lions (Panthera leo). Nature 379(6564): 441–444.

Rosenberg DK (1990) The impact of introduced herbivores on the Galapagos rail (Laterallus spilonotus). Monographs in Systematic Botany from the Missouri Botanical Garden 32: 169–179.

Rossell CR, Clarke HD, Schultz M, Schwartzman E, Patch SC (2016) Description of rich montane seeps and effects of wild pigs on the plant and salamander assemblages. The American Midland Naturalist 175: 139–154. https://doi.org/10.1674/0003-0031-175.2.139
Rowe-Rowe DT, Green B, Crafford JE (1989) Estimated Impact of feral house mice on sub-Antarctic invertebrates at Marion Island. Polar Biology 9(7): 457–460.

Rudman R (1990) The behavior and ecology of feral burros on St. John, U.S. Virgin Islands. PHD thesis. Cornell University, New York.

Russell-Smith J, Bowman DJMS (1992) Conservation of monsoon rainforest isolates in the Northern Territory, Australia. Biological Conservation 59: 51–63. https://doi.org/10.1016/0006-3207(92)90713-W

Sabeta CT, Bingham J, Nel LH (2003) Molecular epidemiology of canid rabies in Zimbabwe and South Africa. Virus Research 91: 203–211. https://doi.org/10.1016/S0168-1702(02)00272-1

Sacks JJ, Sattin RW, Bonzo SE (1989). Dog bite-related fatalities from 1979 through 1988. Journal of American Medical Association 262(11): 1489–1492. https://doi.org/10.1001/jama.1989.03430110079032

Sacks JJ, Kresnow M, Houston B (1996) Dog bites: how big a problem? Injury Prevention 2: 52–54.

Salb AL, Barkema HW, Elkin BT, Thompson RCA, Whiteside DP, Black SR, Dubey JP, Kurtz SJ (2008) Dogs as sources and sentinels of parasites in humans and wildlife, Northern Canada. Emerging Infectious Diseases 14(1): 60–63. https://doi.org/10.3201/eid1401.071113

Salter RE, Hudson RJ (1980) Range relationships of feral horses with wild ungulates and cattle in western Alberta. Journal of Range Management 33(4): 266–271.

Scanlan JC, Berman DM, Grant WE (2006) Population dynamics of the European rabbit (Oryctolagus cuniculus) in north eastern Australia: simulated responses to control. Ecological Modelling 196: 221–236. https://doi.org/10.1016/j.ecolmodel.2006.02.008

Schulz TT, Leininger WC (1990) Differences in riparian vegetation structure between grazed areas and exclosures. Journal of Range Management 43: 295–299.

Scientific American: Cat disease threatens endangered monk seals. https://www.scientificamerican.com/article/cat-disease-threatens-endangered-monk-seals/

Scott P (1967) Cause and effect in the introduction of exotic species. In Proceedings and Papers of the 10th Technical Meeting (Switzerland), June 1966. International Union for Conservation of Nature and Natural Resources Publication (Lucerne) 9: 120–123.

Scowcroft PG, Hobdy R (1978) Recovery of goat-damaged vegetation in an insular tropical montane forest. Biotropica 19(3): 208–215. http://www.jstor.org/stable/2388338

Scowcroft PG, Sakai HF (1983) Impact of feral herbivores on maname forests of Mauna Kea, Hawaii: bark stripping and diameter class structure. Journal of Range Management 36(4): 495-498. http://www.jstor.org/stable/3897951

Seegmiller RF, Ohmart RD (1981) Ecological relationships of feral burros and desert bighorn sheep. Wildlife Monographs 78: 1–58. http://www.jstor.org/stable/3830689

Shiels AB, Flores CA, Khamsing A, Krushelnycky PD, Mosher SM, Drake DR (2013) Dietary niche differentiation among three species of invasive rodents (Rattus rattus, R. exulans, Mus musculus). Biological Invasions 5: 1037–1048.

Sidorov GN, Putin AV (2010) The house mouse (Mus musculus L.) in Omsk Educational Institutions: seasonal migration, abundance, reproduction, distribution, foraging, and associated damage. Contemporary Problems of Ecology 3(5): 601–605. https://doi.org/10.1134/S1995425510050164.
Siemann E, Carrillo JA, Gabler CA, Zipp R, Rogers WE (2009) Experimental test of the impacts of feral hogs on forest dynamics and processes in the southeastern US. Forest Ecology and Management 258: 546–553. https://doi.org/10.1016/j.foreco.2009.03.056

Sierra C (2001) Cimarron pig (Sus scrofa, Suidae) on Cocos Island, Costa Rica: felling, soil alteration and erosion. Journal of Tropical Biology 49(3-4): 1159.

Sillero-Zubiri C, King AA, Macdonald DW (1996) Rabies and mortality in Ethiopian wolves (Canis simensis). Journal of Wildlife Diseases 32(1): 80–86. https://doi.org/10.7589/0090-3558-32.1.80

Silva-Rodriguez EA, Ortega-Solís GR, Jimenez JE (2010) Conservation and ecological implications of the use of space by chilla foxes and free-ranging dogs in a human-dominated landscape in southern Chile. Austral Ecology 35: 765–777. https://doi.org/10.1111/j.1442-9993.2009.02083.x

Singer FJ, Swank WT, Clebsch EEC (1984) Effects of wild pig rooting in a deciduous forest. The Journal of Wildlife Management 48(2): 464–473. http://www.jstor.org/stable/3801179

Smith C, Valdez R, Holechek JL, Zwank PJ, Cardenas M (1998) Diets of native and non-native ungulates in Southcentral New Mexico. The Southwestern Naturalist 43(2): 163–169. http://www.jstor.org/stable/3005532

Smith DG, Polhemus JT, Van der Werf EA (2002) Comparison of managed and unmanaged wedge-tailed shearwater colonies in O‘ahu: effects of predation. Pacific Science 56(4): 451–457. https://doi.org/10.1353/psc.2002.0044

Smith R (1984) Producers need not pay startling rodent tax losses. Feedstuffs 56 (22): 13–14.

Smith VR, Avenant NL, Chown SL (2002) The diet and impact of house mice on a sub-Antarctic island. Polar Biology 25: 703–715. https://doi.org/10.1007/s00300-002-0405-8

Snell HL, Snell HM, Tracy CR (1984) Variation among populations of Galapagos land iguanas Conolophus: contrasts of phylogeny and ecology. Biological Journal of the Linnean Society 21: 185–207. https://doi.org/10.1111/j.1095-8312.1984.tb02061.x

Spatz G, Mueller-Dombois D (1973) The influence of feral goats on koa tree reproduction in Hawaii Volcanoes National Park. Ecology 54(4): 870–876. http://www.jstor.org/stable/1935682

Spear D, Chown SL (2009a) Non-indigenous ungulates as a threat to biodiversity. Journal of Zoology 279: 1–17. https://doi.org/10.1111/j.1469-7998.2009.00604.x

Spear D, Chown SL (2009b) The extent and impacts of ungulate translocations: South Africa in a global context. Biological Conservation 142(2): 353–363. https://doi.org/10.1016/j.biocon.2008.10.031

Stagno S, Dykes AC, Amos CS, Head RA, Juranek DD, Walls K (1980) An outbreak of toxoplasmosis linked to cats. Pediatrics 65: 706–712.

Steadman DW, Stafford TW, Donahue DJ, Jull AJT (1991) Chronology of holocene vertebrate extinction in the Galápagos Islands. Quaternary Research 36: 126–133. https://doi.org/10.1016/0033-5894(91)90021-V

Steadman DW (1995) Prehistoric extinctions of Pacific Island birds biodiversity meets zooarchaeology. Science 267: 1123–1131. http://www.jstor.org/stable/2886080

Steffens M, Kölbl A, Totsche KU, Kögel-Knabner I (2008) Grazing effects on soil chemical and physical properties in a semiarid steppe of Inner Mongolia (P.R. China). Geoderma 143: 63–72. https://doi.org/10.1016/j.geoderma.2007.09.004
Sykes WR (1969) The effect of goats on vegetation of the Kermadec Islands. Proceedings of the New Zealand Ecological Society 16: 13–16. http://www.jstor.org/stable/24061357
Taborsky M (1988) Kiwis and dog predation: observations in Waitangi State Forest. Notornis Journal of the Ornithological Society of New Zealand 35(3): 197–202.
Taylor RH (1979) How the Macquarie Island parakeet became extinct. New Zealand Journal of Ecology 2: 42–46. http://www.jstor.org/stable/24052640
Taylor RB, Hellgren EC (1997) Diet of feral hogs in the Western South Texas Plains. The Southwestern Association of Naturalists 42(1): 33–39. http://www.jstor.org/stable/30054058
Taylor RH, Kaiser GW, Drever MC (2000) Eradication of Norway rats for recovery of seabird habitat on Langara Island, British Columbia. Restoration Ecology 8(2): 151–160.
Teutsch SM, Juranek DD, Sulzer A, Dubey JP, Sikes RK (1979) Epidemic toxoplasmosis associated with infected cats. New England Journal of Medicine 300: 695–699. https://doi.org/10.1056/NEJM197903293001302
Thibault J (1995) Effect of predation by the black rat Rattus rattus on the breeding success of Cory’s shearwater Calonectris diomedea in Corsica. Marine Ornithology 23(1): 1–10.
Thompson J, Riethmuller J, Kelly D, Miller E, Scanlan JC (2002) Feral goats in south-western Queensland: a permanent component of the grazing lands. Rangeland Journal 24: 268–287. https://doi.org/10.1071/RJ02015
Thorne RF (1967) A flora of Santa Catalina Island, California. Aliso: A Journal of Systematic and Evolutionary Botany 6(3/2): 1–77.
Tolleson DR, Pinchak WE, Rollins D, Hunt LJ (1995) Feral hogs in the rolling plains of Texas: perspectives, problems and potential. In: Masters RE, Huggins JG (Eds) Twelfth Great Plains Wildlife Noble Foundation, Ardmore, Oklahoma, 124–128.
Tollner EW, Calvert GV, Langdale G (1990) Animal trampling effects on soil physical properties of two Southeastern U.S. ultisols. Agriculture, Ecosystems and Environments 33: 75–87. https://doi.org/10.1016/0167-8809(90)90145-4
Turbott EG (1948) Effects of goats on Great Island, Three Kings, with description of vegetation quadrats. Records of the Auckland Institute Museum 3: 253–272. http://www.jstor.org/stable/42906015
Turner MG (1988) Simulation and management implications of feral horse grazing on Cumberland Island, Georgia. Journal of Range Management 41(5): 441–446. http://www.jstor.org/stable/3899586
Tye A, Jäger H (2000) Galvezia leucantha subsp. porphyrantha (Scrophulariaceae), a new shrub snapdragon endemic to Santiago Island, Galápagos, Ecuador. Novon 10: 164–168. https://doi.org/10.2307/3393021
van Aarde RJ (1980) The diet and feeding behaviour of the feral cat, Felis catus, at Marion Island. South African Journal of Wildlife Research 10: 123–128.
van Bommel L (2013) Guardian dogs for livestock and protection in Australia. MSC Thesis. University of Tasmania (Hobart).
vander Werff H (1983) Effects of feral pigs and donkeys on the distribution of selected food plants. Noticias de Galápagos 36: 17–18.
Vanak AT, Gompper ME (2009) Dogs Canis familiaris as carnivores: their role and function in intraguild competition. Mammal Review 39(4): 265–283. https://doi.org/10.1111/j.1365-2907.2009.00148.x
Vanak AT, Thaker M, Gompper ME (2009) Experimental examination of behavioural interactions between free-ranging wild and domestic canids. Behavioural Ecology and Sociobiology 64: 279–287. https://doi.org/10.1007/s00265-009-0845-z

Vazquez DP (2002a) Interactions among introduced ungulates, plants, and pollinators: A field study in the temperate forest of the Southern Andes. PHD Thesis. University of Tennessee. Vazquez DP (2002b) Multiple effects of introduced mammalian herbivores in a temperate forest. Biological Invasions 4: 175–191.

Veblen TT, Mermoz M, Martin C, Kitzberger T (1992) Ecological impacts of introduced animals in Nahuel Huapi National Park, Argentina. Conservation Biology 6(1): 71–83. http://www.jstor.org/stable/2385852

Vigne J, Valladas H (1996) Small mammal fossil assemblages as indicators of environmental change in Northern Corsica during the last 2500 years. Journal of Archaeological Science 23: 199–215. https://doi.org/10.1006/jasc.1996.0018

Vila C, Wayne RK (1999) Hybridization between wolves and dogs. Conservation Biology 13(1): 195–198. https://doi.org/10.1046/j.1523-1739.1999.97425.x

Vtorov IP (1993) Feral pig removal: Effects in soil microarthropods in a Hawaiian rain forest. The Journal of Wildlife Management 54(4): 875–880. http://www.jstor.org/stable/3809092

Wanless RM, Cunningham J, Hockey PAR, Wanless J, White RW, Wiseman R (2002) The success of a soft-release reintroduction of the flightless Aldabra rail (Dryolimnas [cuvieri] aldabranus) on Aldabra Atoll, Seychelles. Biological Conservation 107: 203–210. https://doi.org/10.1016/S0006-3207(02)00067-8

Wanless RM, Angel A, Cuthbert GM, Ryan PG (2007) Can predation by invasive mice drive seabird extinctions? Biology Letters 3: 241–244. https://doi.org/10.1098/rsbl.2007.0120

Ward TJ, Bielawski JP, Davis SK, Templeton JW, Derr JN (1999) Identification of domestic cattle hybrids in wild cattle and bison species: a general approach using mtDNA markers and the parametric bootstrap. Animal Conservation 2: 51–57.

Wardle DA, Barker GM, Yeates GW, Bonner KI, Ghani A (2001) Introduced browsing mammals in New Zealand natural forests: aboveground and belowground consequences. Ecological Monographs 71(4): 587–614. https://doi.org/10.1890/0012-9615(2001)071[0587:IBMINZ]2.0.CO%3B2

Warner RE (1963) Recent history and ecology of the Laysan duck. The Condor 65: 1–23. http://www.jstor.org/stable/1365134

Weaver RA (1974) Feral burros and wildlife. Proceedings of the 6th Vertebrate Pest Conference 49.

Whitby JE, Johnstone P, Sillero-Zubiri C (1997) Rabies virus in the decomposed brain of an Ethiopian wolf detected by nested reverse transcription-polymerase chain reaction. Journal of Wildlife Diseases, 33(4): 912–915. https://doi.org/10.7589/0090-3558-33.4.912

Wilcox JT, Van Vuren DH (2009) Wild pigs as predators in oak woodlands of California. Journal of Mammalogy 90(1): 114–118. https://doi.org/10.1644/08-MAMM-A-017.1

Winter L, Wallace GE (2006) Impacts of feral and free-ranging cats on bird species of conservation concern. A report from the American Bird Conservancy.

Witmer G, Martins H, Flor L (2004) Leptospirosis in the Azores: the rodent connection. Proceedings of the Vertebrate Pest Conference 21: 217–220. http://digitalcommons.unl.edu/icwdm_usdanwrc/401
Impact assessment of feral mammals

Witmer GW, Campbell EW, Boyd F (1998) Rat management for endangered species protection in the U.S. Virgin Islands. Proceedings of the Eighteenth Vertebrate Pest 22: 281–286.

Witmer GW, Boyd F, Hillis-Starr Z (2007) The successful eradication of introduced roof rats (*Rattus rattus*) from Buck Island using diphtacinone, followed by an irruption of house mice (*Mus musculus*). Wildlife Research 34: 108–115. http://digitalcommons.unl.edu/nwrcinvasive/56

Wood GW, Mengak MT, Murphy M (1987) Ecological importance of feral ungulates at Shackleford Banks, North Carolina. American Midland Naturalist 118(2): 236–244. http://www.jstor.org/stable/2425780

Wood GW, Roark DN (1980) Food habits of feral hogs in coastal South Carolina. Journal of Wildlife Management 44(2): 506–511. http://www.jstor.org/stable/2407990

Woodall PF (1983) Distribution and population dynamics of dingoes (*Canis familiaris*) and feral pigs (*Sus scrofa*) in Queensland, 1945-1976. The Journal of Applied Ecology 20(1): 85–95.

Woodward SL, Ohmart RD (1976) Habitat use and fecal analysis of feral burros (*Equus asinus*), Chemehuevi Mountains, California. Journal of Range Management 29(6): 482–485. http://www.jstor.org/stable/3897256

Work TM, Massey JG, Rideout BA, Gardiner CH, Ledig DB, Kwok OCH, Dubey JP (2000) Fatal toxoplasmosis in free-ranging endangered ‘alala from Hawaii. Journal of Wildlife Diseases 36(2): 205–212. https://doi.org/10.7589/0090-3558-36.2.205

Young JK, Olson KA, Reading RP, Amgalanbaatar S, Berger J (2011) Wildlife going to the dogs? Impacts of feral and free-roaming dogs on wildlife populations. BioScience 61: 125–132. https://doi.org/10.1525/bio.2011.61.2.7

Zalba SM, Cozzani NC (2004) The impact of feral horses on grassland bird communities in Argentina. Animal Conservation 7: 35–44. https://doi.org/10.1017/S1367943003001094

Zavaleta ES, Hobbs RJ, Mooney HA (2001) Viewing invasive species removal in a whole-ecosystem context. Trends in Ecology & Evolution 16(8): 454–459. https://doi.org/10.1016/S0169-5347(01)02194-2

---

**Supplementary material I**

**Differences between scoring schemes (Table S1)**

Authors: Bianca L. Hagen, Sabrina Kumschick

Data type: List of impact scores and associated references.

Explanation note: Scoring differences for GISS, EICAT and SEICAT. This table was adapted from Kumschick et al. (2016) and Bacher et al. (2017). The numbers in the top column refer to the GISS scoring classifications, whereas the terms ‘massive’ to ‘minimal concern’ refer to EICAT and SEICAT scoring classifications.

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/neobiota.38.23509.suppl1
Supplementary material 2

Detailed GISS assessments (Table S2)
Authors: Bianca L. Hagen, Sabrina Kumschick
Data type: Impact scores and references.
Explanation note: Details of the environmental and socio-economic impact assessment using the Generic Impact Scoring System (GISS). Full reference details are given in Appendix 2. Region indicates whether the impact was found on islands or the mainland.
Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.
Link: https://doi.org/10.3897/neobiota.38.23509.suppl2

Supplementary material 3

Detailed EICAT assessments (Table S3)
Authors: Bianca L. Hagen, Sabrina Kumschick
Data type: Impact scores and references.
Explanation note: A summary of the impact assessment using the Environmental Impact Classification for Alien Taxa (EICAT). Impact scores, from highest to lowest are Massive (MV), Major (MR), Moderate (MO), Minor (MN) and Minimal Concern (MC). Full reference details are given in Appendix 2. Region indicates whether the impact was found on islands or the mainland.
Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.
Link: https://doi.org/10.3897/neobiota.38.23509.suppl3
Supplementary material 4

Detailed SEICAT assessments (Table S4)
Authors: Bianca L. Hagen, Sabrina Kumschick
Data type: Impact scores and references.
Explanation note: A summary of the impact assessment using the Socio-Economic Impact Classification for Alien Taxa (SEICAT). Impact scores, from highest to lowest are Massive (MV), Major (MR), Moderate (MO), Minor (MN) and Minimal Concern (MC). Full reference details are given in Appendix 2. Region indicates whether the impact was found on islands or the mainland.
Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.
Link: https://doi.org/10.3897/neobiota.38.23509.suppl4