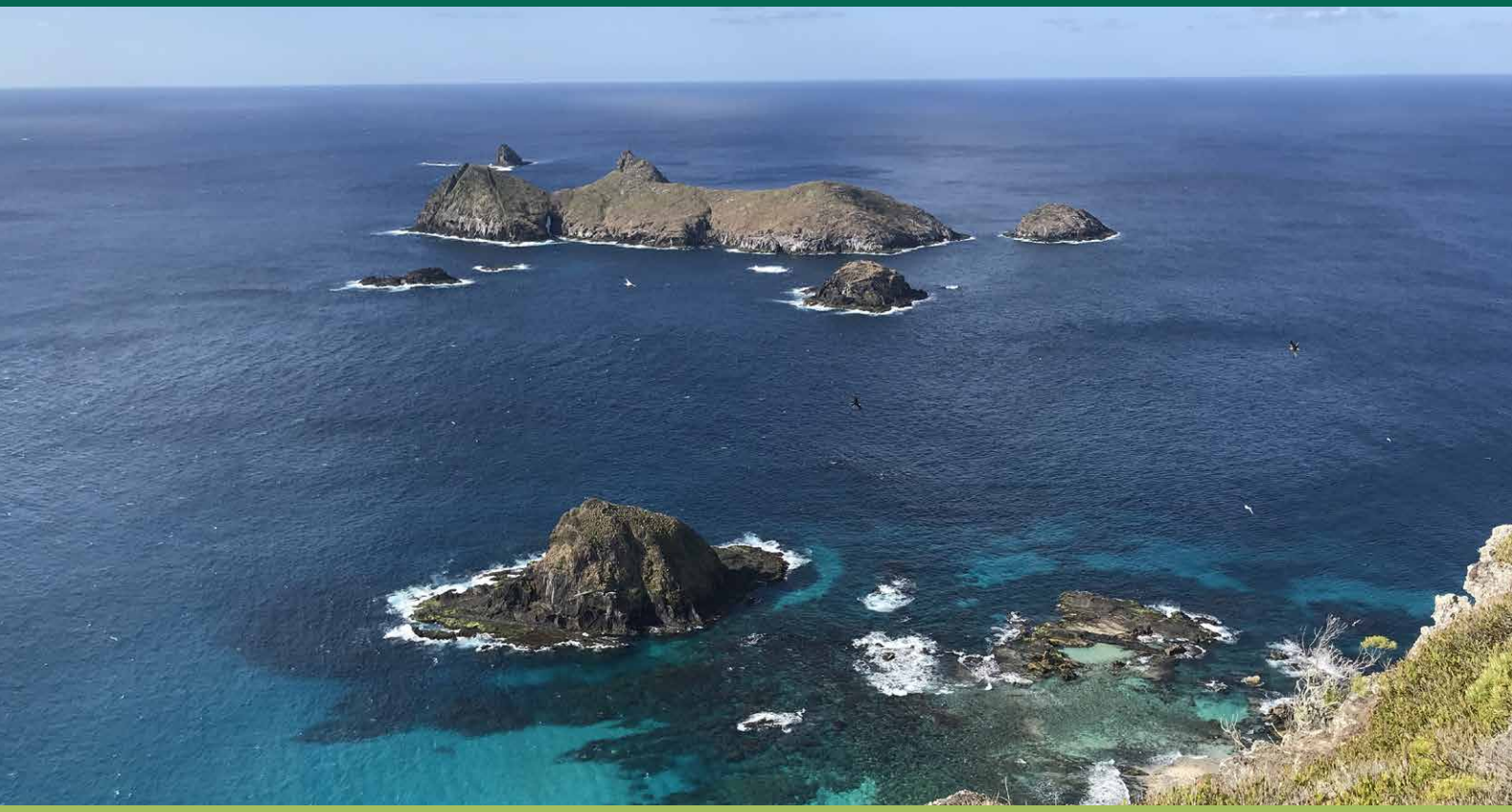
Threatened Species Recovery Hub

National Environmental Science Programme



Informing island eradications: Lessons learned

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Cover image: View offshore from Lord Howe Island. Image: Justine Shaw

Contents

Summary

- Australia is a world leader in invasive species eradications on islands
- Over 220 eradications of invasive vertebrates have been undertaken on Australian islands
- At least 170 Australian islands have had invasive vertebrates successfully eradicated
- To date, most island eradications have focused on ungulates and rodents
- The number of rodent and ungulate eradications have increased in recent years
- 96 islands have had two or more invasive vertebrate species successfully eradicated
- Bigger, more complex and multi-species island eradications are more likely to occur in the future as many of the small, single species island eradications have been undertaken
- Very few eradication plans (or supporting documents) have clear, defined objectives beyond removal of the targeted invasive species. The identification of intended outcomes is essential for informing future management
- Monitoring the ecosystem response to eradication is becoming more important for large, and more complex islands
- Monitoring should be considered and funded as part of an eradication
- Several island eradications in Australia present novel opportunities for informing the likelihood of trophic cascades
- Biosecurity planning would benefit from being integrated within eradication plans
- Updating and maintaining databases of invasive species on Australian islands should be a priority

Background

Australia has over 8000 islands. They are home to a huge proportion of Australia's biodiversity and many threatened species. Islands provide refuge from threatening processes such as predation by invasive species including feral cats, foxes and invasive rodents. However, many of Australia's island species are threatened on Australia's islands due to their naturally restricted distributions, i.e. being island species. One of the most successful conservation strategies for threatened species and island biodiversity is invasive species eradication. In our work at the Threatened Species Recovery Hub we have been investigating the role eradications play in protecting Australia's island biodiversity, and documenting success stories.

Island conservation and management

Islands have high conservation value. They are unique ecosystems and support many threatened and endemic species (Myers et al., 2000; Kier et al 2009; Tershy et al 2015). Island species are often relatively distinct phylogenetically, and low dispersal means considerable opportunities for rapid and diverse allopatric speciation (Savolainen et al., 2006; Papadopulos et al., 2011). Unfortunately, the same unique factors that lead to high biodiversity – small size and isolation – have meant that a higher proportion of extinctions have occurred on islands, primarily due to the arrival of humans, through a combination of overharvesting and assisted migration of invasive vertebrates (Simberloff, 1995; Courchamp et al., 2003b; Sax & Gaines, 2008; Jones, 2010). Australia's some 8000 islands are home to hundreds of threatened plant and animal species. Management and protection of these species are critical for ensuring the future of Australia's biodiversity.

There are many management actions that can be implemented to maintain or promote island biodiversity. They include formal area protection, invasive species control and eradication, and species translocation or reintroduction. To date this has been tackled using a case by case, or more accurately, an island by island (or archipelago by archipelago) approach. Given the increasing threats to Australia's biodiversity, particularly to threatened species, and the widely acknowledged benefits of island conservation (Jones et al. 2016), there is increasing interest to explore island conservation opportunities.

Invasive species on islands

To date there have been few systematic reviews that have focused on the impacts of invasive species to Australia's island biodiversity. This is a critical omission considering invasive species are recognised as one of the most pervasive threats to global biodiversity, especially on islands (Doherty et al. 2016). Invasive predators and herbivores often occur at extremely high densities on islands (Terborgh et al. 2001; Legge et al., 2017). They are responsible for numerous extinctions and continue to threaten many island species via predation, competition and habitat destruction (Kier et al., 2009; Medina et al., 2011; Courchamp et al 2014; Spatz et al., 2014).

Many vertebrate species have been introduced to Australia's islands intentionally (e.g. cats, goats, sheep, rabbits etc) and unintentionally (e.g. rats, mice, cane toads, foxes). The Ferals on Offshore Islands database (DoE 2016), managed by the Australian Government has more than 2,000 records for 154 vertebrate species on 523 islands. Many of these species are native to other parts of Australia, but their occurrence on some islands is non-native, due to human facilitated introduction.

Legge et al. (2018) compiled the most comprehensive, contemporary assessment of invasive vertebrate species on Australian islands, including information on foxes, cats and native mammals. Fox and cat occurrence was known for 752 of Australia's 5442 islands (14%; Legge et al 2018). Foxes and cats were present on 162 islands (22%). The authors highlighted that information on the distribution of introduced predators was imperfect. They called for greater island monitoring effort and better collation of data. It should also be noted that very few assessments or reviews have been undertaken on invasive invertebrates and plants on islands.

Eradication as a management action

The eradication of invasive species from islands offers substantial benefits to conservation (Towns and Broome 2003; Jones et al 2016; Brook et al. 2018). The removal of entire invasive species populations is an increasingly attractive management goal. To date, over 1200 eradication events have been implemented across 806 islands globally (DIISE 2018), targeting numerous invasive plants and animals (Keitt et al., 2011). Eradication has been successful in terrestrial projects at small scales (Hayward & Kerley, 2009; Pridell et al 2011; Dickman, 2012; Helmstedt et al., 2014). Insular invasive species populations on islands have provided unique conservation opportunities: eradication needs only be achieved once provided there is not a high risk of reinvasion (Courchamp et al., 2003), and if eradication is truly successful, little ongoing management is required. This is attractive particularly for isolated islands that are difficult or expensive to reach.

Aims

To inform current threatened species and invasive species management on islands, we explored invasive vertebrate species eradication previously implemented on Australia's islands. We aimed to:

- Quantify the number of successful invasive vertebrate eradications that have been undertaken on Australia's islands
- Determine which invasive vertebrate species have been targeted by Australian island eradications
- Identify how common multi-species eradications are
- Determine if threatened species protection is a major objective for invasive vertebrate eradications from islands
- Understand how we can better anticipate ecological outcomes that may arise from invasive species eradications
- Determine how ecosystem monitoring undertaken as part of previous island eradications in Australia can inform future island eradications

Methodology

Documenting eradications/Knowledge exchange on eradications

The Database of Island Invasive Species Eradications (DIISE) was used to identify invasive species eradications on Australian islands and to guide literature searches and data collation. We coupled this data with information contained within the Australian government's feral animals on offshore islands database (http://www.environment.gov.au/biodiversity/invasive-species/feral-animals-australia/offshore-islands). We note that the DIISE has incorporated much of the information contained within the feral animals database. Several other resources were explored including the global invasive species database (http://www.iucngisd.org/gisd/ISSG), the threatened island biodiversity database (http://tib.islandconservation.org/), and the Atlas of Living Australia (https://www.ala.org.au/).

The DIISE provides the most up to date compilation of planned, active and completed eradications on a global scale. The DIISE attempts to compile all historical and current invasive vertebrate eradication projects on islands (both successful and failed). The vast majority of the dataset is focused on invasive mammals. The DIISE stores data on island location and characteristics, target species, dates, duration, methods and outcome for each eradication, provides contact names and details of the organisations involved, and links to supporting documents. As of December 2019, the database contains over 2,000 global eradication events, including over 500 eradications added during the updates. The number of completed mammalian eradications from islands (classified as whole island events, where data quality is good or satisfactory, and excluding domestic populations and reinvasion events), includes 1,233 events, with an 88% success rate on 806 islands. More than 60 countries and territories have attempted eradications. Holmes et al. (2019) provides a review of how the database was collated, and recommendations for how to use the data.

Where possible, we reviewed supporting documents for each island eradication. To access these documents, we searched those identified as reference material in the DIISE and then undertook web searches and searched scientific publication databases using the island name and 'eradication' as keywords. We also consulted with key experts. A qualitative assessment of the available reports and plans was then undertaken whereby each document was assessed in reference to a set of key questions (see Table 1).

Table 1. *Questions posed in a qualitative assessment of management documents and implementation plans associated with eradications*

Questions
Were eradication objectives clearly identified?
Which threatened or native species were the targeted beneficiaries of the eradication?
Which additional species were perceived to benefit from the eradication?
Was monitoring proposed or undertaken?
If so, what was the monitoring objective?
Was pre- and /or post eradication monitoring proposed or undertaken?
What was the duration of monitoring?
Who funded the eradication operation? What were the estimated costs versus expenditure?
Was a detailed budget available?
What project components were funded? i.e. monitoring, eradication operations and/ or biosecurity?
Were any species of concern identified that may have been negatively affected by the eradication? e.g. non-target species impacts including native predators or scavengers
If single invasive species eradications occurred within multi-invaded ecosystems were there any concerns about the responses of remaining non-native species?
Were remaining non-native species responses to the eradication monitored?

Eradications on Australian Islands: Our findings

To date there have been over 220 island eradications undertaken on Australian islands targeting invasive vertebrates. These management initiatives span over ~70 years. Two hundred and twenty three successful eradications have been undertaken on 169 islands. Over this time, eradications have scaled- up to target more and more species (see Figure 1).

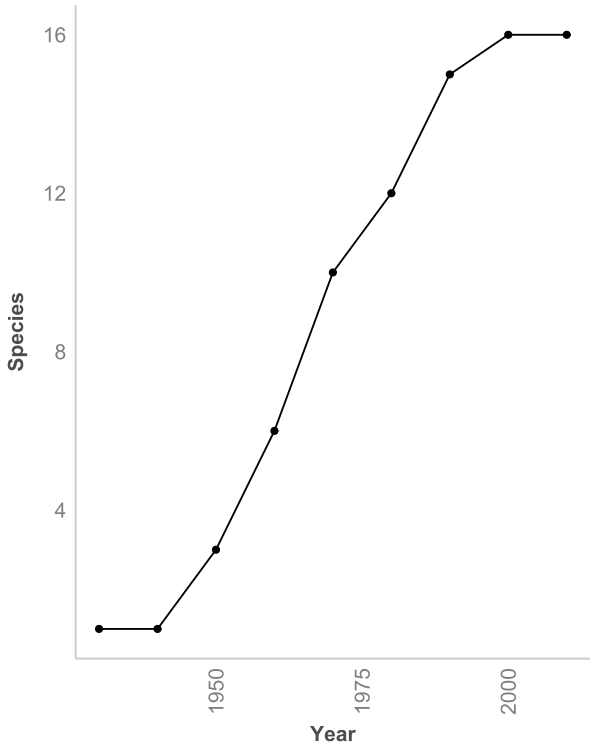

Figure 1: *The number of invasive vertebrate species successfully eradicated over time on Australian islands.*

The majority of eradications on Australian islands targeted ungulates (goats and cattle) and rodents (rats and mice; see Figure 2). Over recent decades there has been an increase in the number of rodent and ungulate eradications undertaken (Figure 3).

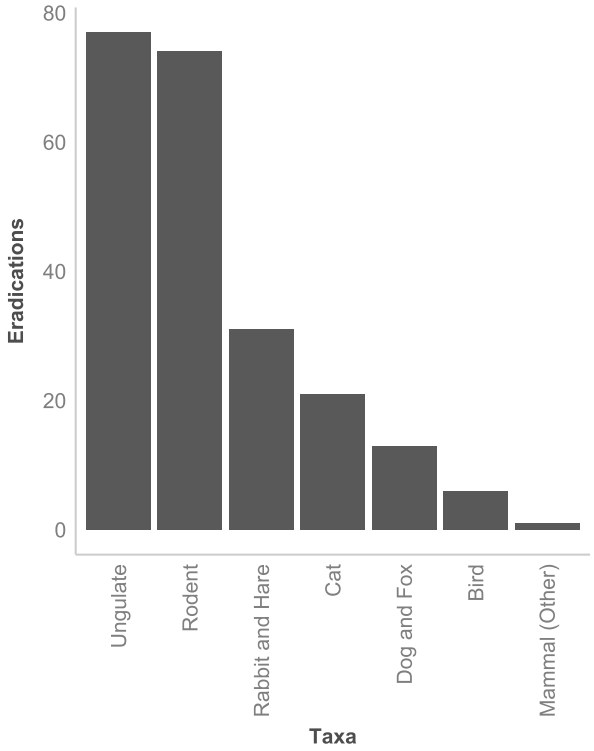

Figure 2. *The number of eradication events on an island for the major invasive vertebrates on Australia's islands. In some instances species have been grouped. 'Ungulate' represents goats and cattle, 'Rodent' represents rats and mice, 'Birds' represents chickens, wekas and Eurasian tree sparrow.*

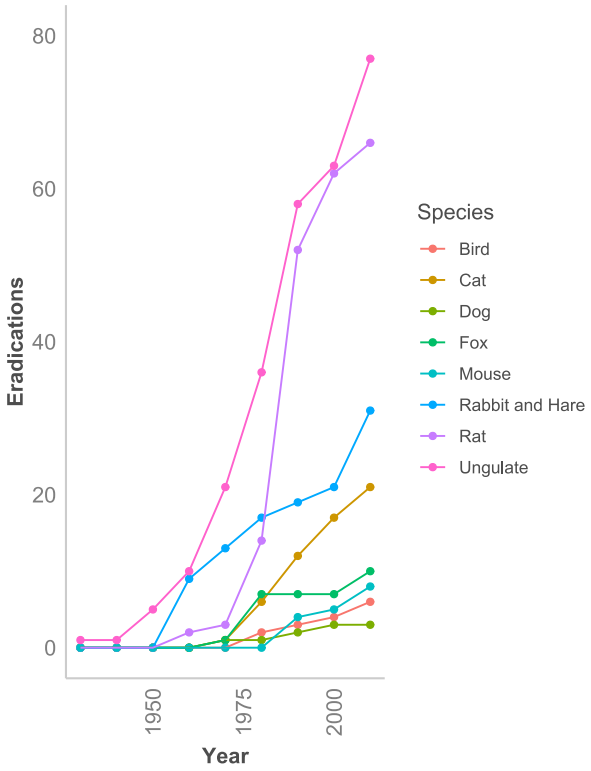

Figure 3. *The number of successful eradication events implemented for key groups of invasive vertebrates.*

For the majority of island eradications, only one species was targeted (Figure 4). There were 96 Australian islands for which 2 or more eradications were completed. Multiple invasive species were rarely eradicated simultaneously.

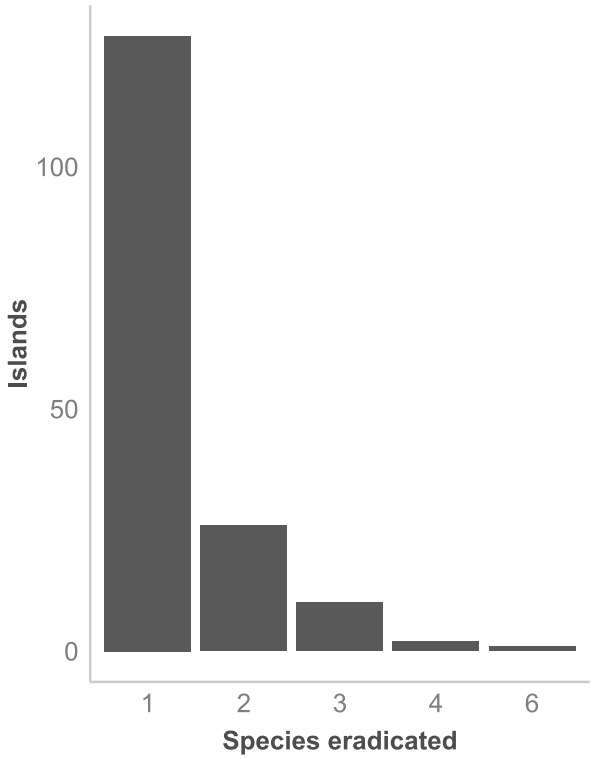

Figure 4. *The number of species that have been successfully eradicated from Australia's islands. Most islands have only had one species eradicated.*

In most cases where more than one eradication occurred on an island, the eradications were separated in time. That is, species were eradicated in succession, rather than simultaneously. There were 12 islands where multiple eradications were undertaken simultaneously (Table 2). The most recent program undertaken was Macquarie Island, where rabbits, rats and mice were all targeted in 2011 across the island's 12, 900 ha. At the time this was the largest multi-species eradication ever undertaken, it still remains the largest rabbit eradication ever undertaken globally.

Table 2. *Eradication of multiple species through one management campaign*

Island	Invasive species eradicated	Timeframe**
Angel	*Vulpes Vulpes, Felis catus*	1980 - 1985
Brampton	*Capra hircus, Sus scrofa*	x - 1985
Broughton	*Oryctolagus cuniculus, Rattus rattus*	2009 – 2011
Dirk Hartog	*Capra hircus, Ovis aries*	2005 – 2017
Dolphin	*Felis catus, Vulpes vulpes*	1980 – 1985
Legendre	*Vulpes vulpes, Felis catus*	1980 – 1985
Macquarie	*Rattus rattus, Mus musculus, Oryctolagus cuniculus*	2011 -2014
Montague	*Mus musculus, Oryctolagus cuniculus*	2007
Mutton Bird (North Coff's)	*Vulpes vulpes, Canis familiaris*	x - 1971
Orpheus	*Oryctolagus cuniculus, Capra hircus*	x - 1991
Rat	*Felis catus, Rattus rattus*	1991 – 2000
Thistle	*Capra hircus, Sus scrofa*	x – 1972

** in many instances this time period may also reflect the time until eradication was declared, e.g. all target invasives were eradicated from Macquarie Island in 2011, but it was not deemed successful until 2 years later.

On 17 islands, cats were eradicated and rodents were left (Table 3). Active management of invasive rats occurred during cat eradications for Hermite and Rat islands.

Table 3. *Islands where cats were eradicated and invasive rodents remained on the island*

Island	Region	State	Cat eradication end date	Rats remained until
Lord Howe	Pacific Ocean - South West	NSW	1980	2019[1]
Gabo	Pacific Ocean - South West	VIC	1991	Current, but eradication scheduled (2018)
Macquarie	Pacific Ocean - South West	TAS	2000	2011
North West	Pacific Ocean - South West		1985	Current (mouse) but will be focus of future erad (2014)
Hermite	Indian Ocean - East	WA	1999	2001 (controlled prior and simultaneous to Cats)
Great Dog (Big Dog)	Pacific Ocean - South West	TAS	1992	Current (rat and mouse)
Reevesby	Indian Ocean - East	WA	1990	Current (mouse)
Rottnest	Indian Ocean - East	WA	2002	Current (Rat and mouse)
Faure	Indian Ocean - East	WA	2001	Current (mouse)
Gidley	Indian Ocean - East	WA	1990	Current (rats)
Rat	Indian Ocean - East	WA	2000	1996 (Simultaneous)
Sunday	Pacific Ocean - South West	VIC	na	Current (rats, mouse, rabbits)
Churchill	Pacific Ocean - South West	VIC	na	Current (rats, mouse)
Boston	Indian Ocean - East	WA	1970	Current (mouse)
Althorpes	Indian Ocean - East	WA	2002	Current (mouse)
Muttonbird	Pacific Ocean - South West		na	Current
Dirk Hartog	Indian Ocean - East	WA	2012	Current (native rodents and mouse)[3]

[1] Eradication program commenced and was finalised in 2019; declaration of success was due in 2021

[2] Ferals on offshore islands DB reference cats being eradicated but no information is available within the DIISE (only dog and fox)

[3] Three species of native rodents present and house mouse, rats were surveyed following cat removal but no sign of presence

Poison baiting was the most often used method to control invasive species. Its use has been increasing over time, and it has been increasingly used on larger islands over time. The majority of eradications that were undertaken with poison baiting as the control method used bait stations as the baiting method. Hunting was the second most important control method (Figure 5).

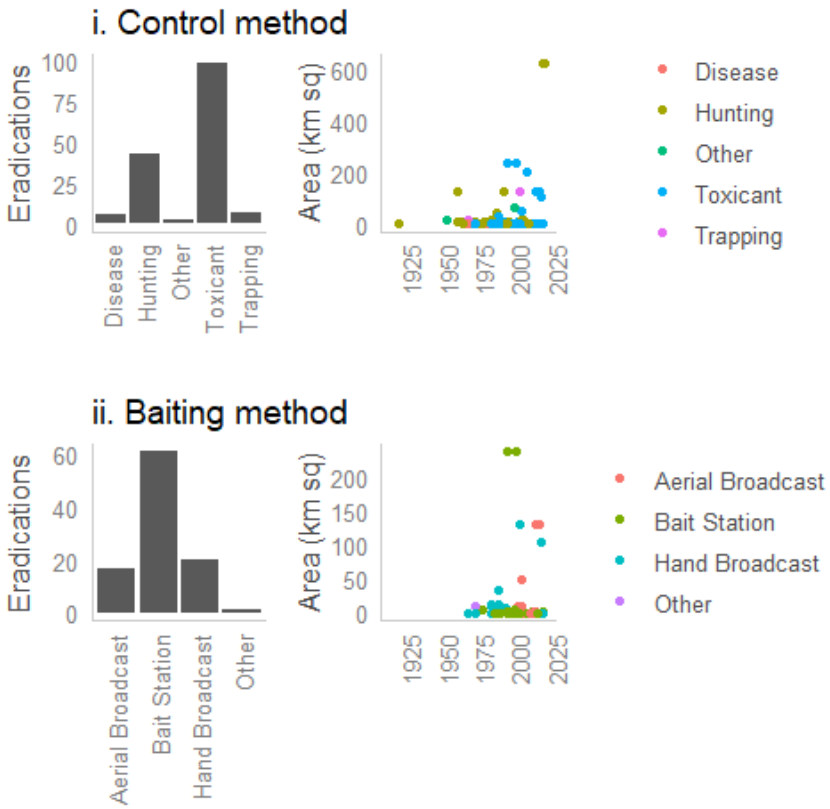

Figure 5. The control methods used to undertake invasive species management on island and the most frequently used methods of applying toxicants for poison baiting.

Objectives for eradication

We searched supporting documents relating to invasive species eradication on Australia's islands. We reviewed 78 eradications, their associated documents, and supporting information. We determined if clear objectives for the eradication project were identified (Figure 6). In the majority of cases objectives were not clearly stated. For some islands there was no clearly outlined objective relating to the project but it was identified in the management plan associated with the island or archipelagos.

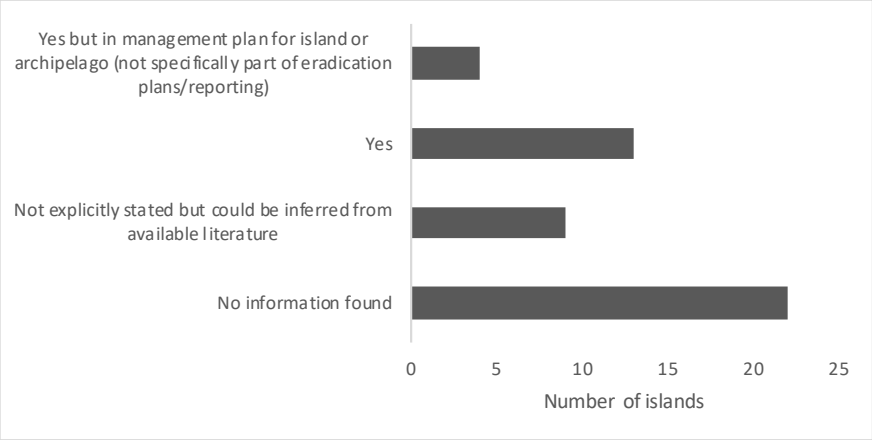

Figure 6. Objective setting for eradication projects, as identified in supporting documents

Where project objectives were identified the most common objective was simply the removal of the target invasive species (Figure 7).

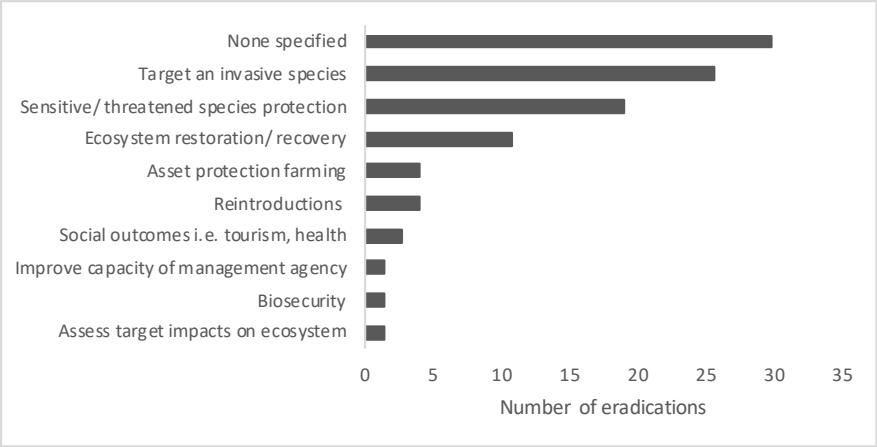

Figure 7. *Eradication objectives identified in supporting documents*

Where objectives were identified (Figure 8), we determined if there were intended beneficiaries (species or species groups). Breeding seabirds were the most common group identified to benefit from the eradication.

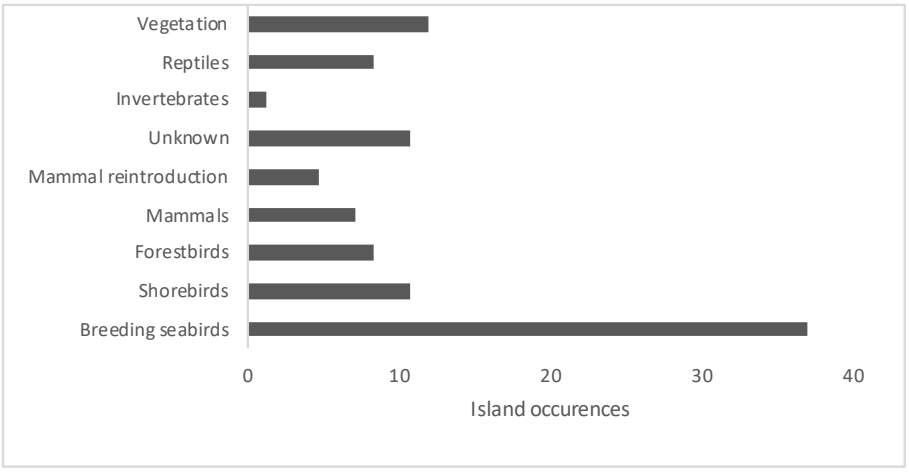

Figure 8. *Species and species groups perceived to benefit from an eradication program*

Monitoring

There was no mention of monitoring associated with the eradication in supporting documents or associated web searches for nearly half of the eradication projects we reviewed. Monitoring and reporting was focused on the targeted invasive species when it did occur, and at the operations level. For example, monitoring objectives included assessing eradication feasibility, recording removal rates, evaluating effectiveness of techniques, secondary impacts of poison baiting to non-targets, guiding effort, confirming eradication success, or determining causes of failure.

Funding

Determining funding sources or budget break downs was challenging with the available information. Very few documents contained budget information. We were able to find clearly outlined budgets for Cabbage Tree Island, NSW, Lord Howe Island, Macquarie Island, Tasman Island and Christmas Island. Overall there was very limited information on budgeting for eradication monitoring or biosecurity following eradication.

Discussion

Data and monitoring

The DIISE database proved to be the most comprehensive, easily accessible repository of information on eradications undertaken in Australia. Undoubtedly there are some island eradications not captured in the database but the information held in DIISE has been rigorously collected and collated. We acknowledge there are several recent, contemporary projects, and some projects in the planning phase not included in the database.

To date, many eradications have been successfully implemented without fundamental knowledge of invasive or native distributions, density, ecology, interactions and responses at the scale at which management occurs with benefits to species of concern. However, as eradications continue to scale up in size and complexity, such as in multi-invaded ecosystems, the gap in understanding for broader species and ecosystem responses is becoming an increasingly critical omission. Pre- and post-eradication monitoring that allow evaluation of eradication success will be a critical component of island eradications going forward, when successful outcomes are more uncertain.

Tracking ecosystem restoration or recovery is aided by baseline data, or historical datasets. These data can be invaluable for tracking change, although it must be noted that in some instances a lack of detail on how previous estimates were obtained, makes it impossible to reliably determine if there has been discernible change in native species numbers (see Carlile et al. 2019). Much greater investment in data management is required to inform future management and funding. Mechanisms for enabling data storage and curation are critical to ensure ongoing learning and knowledge exchange. While individuals hold considerable amounts of corporate knowledge and expertise, there is a great need to capacity build and share this knowledge more broadly.

Scope of eradication

Undoubtedly, the number of eradications of each invasive vertebrate group reflects their frequency and distribution across Australia's islands. However it is also important to acknowledge that the impact of the invasive species on island species and landscapes, is a significant motivation for eradication, as well as the likelihood of success and the cost (see Helmstedt et al. 2016). The likelihood of success is driven by multiple environmental and social factors and the methodological approach. Cost can be determined by island size, location and methodological approach. Figure 3 shows how targeted invasive species have changed over time, with a drastic increase in rodent and ungulate eradications in recent years. This is due to advances in eradication technology, particularly regarding rodents and the use rodenticides.

Success or failure of management

Success or failure of an eradication is typically determined by the successful or unsuccessful removal of the target invasive species. However, for most projects, no such objective was identified in management documents.

We believe clear objective setting at the outset is a precursor to informing monitoring and subsequent management on islands in response to eradications. Ecosystems are dynamic and may not necessarily respond to an eradication at the rate or in the manner that was anticipated. If eradication objectives are simply to remove invasive species, and an ecosystem lacks the capacity to passively recover post eradication, this may go unnoticed.

Even when judiciously planned and sufficiently resourced, environmental factors out of managers' control can hamper management efforts. Bad weather can influence bait delivery, one evasive single pregnant female can compromise an entire island eradication. There are many different factors that can lead to eradication failure. The public, decision makers and funders are all influenced by stories of eradication failure, which has flow on effects for future eradication projects. It is critical that drivers of failure are documented, given these flow on effects. Failures are important learning opportunities.

As with estimates of cost, continuous estimates of probability of success can be calculated according to statistical models for different classes of invasive species, and different types of islands, based on previous worldwide eradication attempts (e.g. by the method in Gregory et al. 2014). Failures are notoriously underreported.

Unknown consequences of eradications

Simultaneous eradications can be more expensive, and /or take longer to implement (exposing the native species to more predation). Additionally, invasive species have differing impacts on native species (Bonnaud et al. 2011), and therefore we know that there may be greater impetus to remove one species more quickly than another. Mesopredator release and trophic cascades are a concern for island managers, communities, decision makers and the general public. In many instances there is a reliance on modelling to inform managers as to what the likely outcomes of eradication will be. Further investigations of the response of invasive rat populations to cat eradication would assist future decision making, as the question of invasive rats remaining on islands following eradications continues to emerge (Shaw 2020, unpub report to DAWE). Adaptive management approaches that combine single species eradications with monitoring and decision triggers for follow up actions is another strategy (NESP Threatened Species Recovery Hub. 2021. Will feral cat control on Christmas Island lead to an increase in rat impacts on threatened birds? Project 2.3.3 Research findings factsheet).

Not documenting island recovery through monitoring is also a missed opportunity for promoting positive conservation outcomes which generate further investments in island management and on other islands. We found that secondary impacts of eradications on non-target species or ecosystem level responses were not often described or quantified (as Jones et al., 2016, Bird et al., 2019; Jones 2016, Brooke et al 2018). More effort on monitoring how ecosystem respond will aid to inform future eradication projects and our understanding of ecosystem responses.

Giant petrel eats invasive rabbit on Macquarie Island. Image: Drew Lee

Case studies

Trophic cascades – Macquarie Island

Cats on Macquarie threatened burrowing seabirds with extinction in the 1980/90s, whereas rabbits and rodents (*Rattus rattus* and *Mus musculus*) were considered unlikely to drive the species to extinction in the short term. Cats directly reduced breeding success through egg and chick predation (see Brothers 1984). Research identified and quantified cat impacts on petrels on the island. For these reasons cat eradication was prioritised for Macquarie Island. It commenced with cat control in the 1980s continuing through the 1990s, with an eradication program formally commencing in 1999 (Springer 2016). The last cat was shot in 2000 (for detail see Robinson and Copson 2014). There was a 10 year time lag between the last cat being eradicated and the commencement of rabbit and rodent eradication (see Table 1). The decision to eradicate cats prior to rabbits and rodents has been greatly debated in the literature (Bergstrom et al. 2009a; Dowding et al. 2009; Bergstrom et al. 2009b). Perhaps the critical component missing from the debate is the acknowledgement of burrowing petrel approaching extinction on the island. Decision makers were motivated by this fact to implement cat eradication in isolation. At the time there was no prior example of a large scale, successful rodent and rabbit eradication on a sub-Antarctic island. Given the technology available at the time, and a lack of confidence in this technology, only cat eradication was implemented. The subsequent successful eradication of Norway rat (*Rattus norwegicus*) on neighbouring sub-Antarctic Campbell Island in 2001 bolstered decision makers confidence that Macquarie Island rodent and rabbit eradication may be possible. Rabbit and rodent eradication planning commenced in mid-2000, and implementation commenced in 2010 (Springer 2016).

Loading bait on helicopters for eradication of rabbits, rats and mice on Macquarie Island. Image: Courtesy of Parks & Wildlife, Tasmania

Eradication as the first step – Dirk Hartog Island

Eradication of invasive vertebrates may often be the first step in island restoration, it may be necessary to advance further, broader island restoration goals. Removing the impacts of invasive vertebrates (i.e. predation, herbivory, habitat modification) can directly benefit threatened species and broader island biodiversity. It is important to note that in many instances further management maybe required after eradication to restore populations and ecosystems. What management is required varies with island ecosystems, environment and native species on the island. One of the key ways to inform follow up management is through post eradication monitoring. A key example of this is Dirk Hartog Island where the eradication of goats and cats has enable the establishment of the "Dirk Hartog Return to 1616" program, which aims to introduce 12 native mammals and a bird. Eradication was simply the first step to whole island restoration, with ongoing management plan for the island ecosystem post eradication.

Success, failure and biosecurity – Lord Howe Island

The first principle of invasion management is to invest in biosecurity as prevention is cheaper and easier than implementing eradication. Biosecurity is now a guiding principle in the management of Macquarie Island and Dirk Hartog, as it ensures the future of the eradication investment. World Heritage Lord Howe Island was set to be another Australian eradication success story with 1455 ha of forested national park and human settlement subject to rat eradication in 2019, with cats and goats previously eradicated. $15.4 million of conservation investment was made to secure the protection of iconic unique and endemic species, including the LH Phasmid, LH woodhen, LH currawong and endemic Kentia palm. Eradication success was due to be declared in September 2021, however in April 2021 rats were found on Lord Howe and an incursion response was initiated. It was suspected that rats breached biosecurity at the port facilities in mainland NSW and the island. Over the next six months an additional 96 rodents were removed. The risk to the success of the eradication program and additional cost of the incursion highlights the importance of biosecurity to ensure the success of eradications on inhabited islands. Inhabited islands have high re-incursion potential due to the frequency of transport and freight to the island.

Distributing rat bait on Lord Howe Island. Image: Courtesy of Rodent Eradication Program, LHI

Recommendations for future eradications

Data management

Centralised, accessible data on Australia's island biodiversity is lacking, for both invasive and native species, across taxonomic levels. The most comprehensive accessible repository of data on invasive species eradications on Australian islands was DIISE database. It is an excellent resource of eradications undertaken to date. We note that the custodians of this data are motivated to share data and ensure it accessible. From an Australian perspective there is no centralised, maintained, accessible repository of data on Australia's islands. Effort and support should be made to ensure that this is improved and that data continues to be captured.

Objective setting

Clear objectives must be set out in the planning phase of an eradication program and is essential to delivering successful outcomes, especially in complex ecosystems. Eradication success should be considered in the context of the wider ecosystem recovery.

Reporting

Guidelines for project reporting are advisable. If an eradication is being undertaken there should be a requirement for standard reporting on operational implementation and ecosystem responses. This should include clear and defined objectives, intended beneficiaries and outcomes. In complex ecosystems such as multi-invaded ecosystems where we are still learning, additional information is desirable to facilitate learning and reduce the risk of adverse outcomes.

Monitoring

There is no standardised approach to monitoring ecosystem responses to eradication, which is not surprising given the vast diversity of island ecosystems for which eradication have been implemented. However, we note that a small number of invasive vertebrates are repeatedly targeted. There is a considerable amount of practitioner knowledge that is shared within the eradication implementation community. This has driven much of the success in eradicating invasive species on Australia's islands. Knowledge gaps persist around the perceived impacts of eradications on ecosystems and ecosystem responses to eradication. We propose that monitoring should be incorporated into eradication planning and budgeted for. It should align with the objective of the eradication and be able to inform and direct adaptive management following eradication and identify future restoration requirements. We are seeing larger, more complex, inhabited islands undergoing invasive vertebrate eradications, this will present more challenges than the previously on small single species islands. This pre-eradication and post-eradication is essential.

Informing trophic cascades and mesopredator release

Many community groups raise concerns about issues of trophic cascades and mesopredator release as a result of eradication. Monitoring of pre and post eradication ecosystems will contribute to informing how ecosystems respond to change. We propose protocols for monitoring species of concern (invasive rats, native predatory birds) be devised and be funded as part of eradication programs. This will address concerns and inform future eradication programs. We also highlight there are numerous islands where cats were eradicated but invasive rats were left to persist. These islands provide a great opportunity to investigate the response and impacts of other invasive species. Such research could be undertaken on multi-invaded islands, where only one of several invasive species are eradicated, to better enable us to determine what the impacts of single-invasive vertebrate species are in different ecosystem types.

Biosecurity

Biosecurity must be an integrated component of any island eradication plan. Biosecurity plans should be required as part of project funding requirements. It is important that biosecurity planning and implementation is budgeted and evaluated as part of the eradication project, especially for the first 2 years, so investment into eradication is secured. This is critical in the period of time before the eradication is officially declared a success. Evidence based understanding of if/how specific biosecurity measures/actions reduce risk need to be explored prior to the eradication being implemented. This ensures managers are able make cost- benefit decisions as to whether eradications are worthwhile investments given potentially high and ongoing biosecurity costs, and allow appropriate funding allocation in budgets. It would also facilitate learning and tightening of biosecurity protocol while the stakes of an incursion are lower. Increasing information exchange between the biosecurity planning/ eradication and biosecurity implementation phases of a project, and between island eradications to facilitate best practise would also improve the quality and effectiveness of biosecurity operations.

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