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# 1 · *Species Conservation*

## Lessons from Islands

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### 1.0 Introduction

Islands and the species they support have provided the inspiration for some of the most important concepts in the theory and practice of conservation biology. Evolutionary biology, biogeography, small-population biology and genetics all owe much to islands for their development. Islands have demonstrated all too clearly the impacts of anthropogenic change on global biodiversity. In particular, island ecosystems have been significantly degraded by the spread of invasive alien species, in part facilitated by human population growth, human demand for local resources and the movement of people and trade goods across the globe. As a counter-narrative, islands are now showing us how a suite of conservation interventions at species to ecosystem levels can buck global trends and provide a more long-term future for small, threatened populations and the habitats on which they depend. Furthermore, they are providing rare examples of how people can be engaged more effectively in conserving threatened species through their direct involvement in conservation projects or indirectly by modifying existing human behaviour. In this introductory chapter, we set the scene for the chapters to follow. We illustrate the importance of islands as centres of learning about life on Earth and our place within it, their role as indicators of the negative impacts of human-induced change and, most importantly, as sentinels of hope for what is possible with appropriate intervention and management.

### 1.1 Islands and the Development of Biological Thought

In 1772, Johann Reinhold Forster accompanied Captain Cook on his expedition to New Zealand and Tahiti. He noted one of the most

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fundamental relationships in biogeography: that the number of species found within a given area is in part at least a function of the size of the area; larger land areas support more species. Decades later, Alfred Russel Wallace, during his year-long exploration of the Malay Archipelago (1854–62), began to document patterns in species distribution and design which he linked to varying environmental pressures, paralleling Charles Darwin's work to define natural selection as a guiding force in shaping the structure and function of species within systems. Darwin is now widely recognised as one of the founding fathers of biology, for his fundamental explanation of evolutionary processes, Wallace being credited as one of the pioneers in the development of biogeography as a scientific discipline. Both Wallace and Darwin derived their inspiration from islands.

In 1967, mathematician Robert MacArthur and evolutionary biologist and natural philosopher E. O. Wilson published their landmark book, *The Theory of Island Biogeography* (MacArthur and Wilson 1967). The theory provided a model to explain why any given island supports a particular number of species at a particular point in time, based on the premise that species number on islands increases with island area but decreases with isolation (see Section 2.2). While the theory has been criticised as being over-simplistic (see Whitakker and Fernández-Palacios 2007 for review), the Equilibrium Theory of Island Biogeography has been one of the most important catalysts for research into minimum viable populations, minimum viable areas and small–population biology, meta-population dynamics and the relative importance of deterministic (e.g. anthropogenic impacts) relative to stochastic (e.g. climatic fluctuations) effects on extinction rates. It has also informed the developing science of ecological restoration (Walker et al. 2007) and the design and development of protected area systems to determine how best to conserve maximum biodiversity. The theory has provided a foundation for global change research, informing hypotheses as to how ecosystems will respond to climate change. For example, the predicted shift of montane woodlands in the south-western United States to higher elevations as the climate warms is expected to result in the loss of up to 62 per cent of the small mammal species currently utilising these habitats (Brown 1995). In Mauritius – a recurring ecological, geographic and historical reference point for this book – climate change appears to result in delayed egg-laying in the Mauritius kestrel and the possibility of reducing chick survival due to heavy rainfall and the start of the cyclone season (Pearce-Higgins and Green 2014).

It was the birdlife of the south-western Pacific, and in particular New Guinea and the Solomon Islands, that inspired Ernst Mayr (1904–2005) to develop the 'biological species concept' ('groups of interbreeding natural populations that are reproductively isolated from other such groups'), a fundamental unit of measurement within conservation biology. Mayr was recognised as 'the Darwin of the 20th Century' (Nevo 2006), doing much to raise the status of biology as a scientific discipline in its own right, not simply a derivative of the physical sciences. Mayr went on to fuse Darwinian evolutionary thought with new developments in molecular biology and genetics to challenge our understanding of species and how they evolve (Box 1.1 for a classification of the lemur species, Madagascar, and Figure 1.1).

Box 1.1 *Lemurs of Madagascar*

The likely origin of the primates of Madagascar is from a single colonisation by an ancestral strepsirrhine from mainland Africa (Stevens and Heesy 2006), although there is some evidence for an Asian origin (Marivaux et al. 2001). This dispersal event is estimated to have occurred 55 to 60 million years ago, shortly after the first primates evolved and significantly earlier than the proposed origins of Madagascar's other terrestrial mammals. The dispersal mechanism responsible for these colonisations has long been controversial. Simpson (1940) famously proposed 'sweepstakes dispersal' by vegetation mats rafting across the Mozambique Channel, although the probabilities of this happening successfully have been considered small (Masters et al. 2006). However, Ali and Huber (2010) provide evidence that during the period (~60–20 million years ago (Mya)) the ocean currents were quite different and would have allowed these rafting events to occur.

While no one can deny the diversity of lemurs – from the recently extinct gorilla-sized Archaeoindris to the world's smallest primate, Berthe's mouse lemur *Microcebus berthae* – the number of extant species is hotly disputed. Largely as a result of molecular genetics, the number of proposed taxa doubled between 1994 and 2010. Mittermeier et al. (2010) recognise 101 distinct taxa. A further 17 species and three entire families of extinct lemurs have been identified from sub-fossil remains (Godfrey and Jungers 2003). This taxonomic upheaval has been particularly acute amongst mouse and sportive lemurs and is certainly not universally accepted (Tattersall 2007). Disagreement is likely to continue until a consensus is reached on the definition of a 'species'.

Lemurs are thought to have radiated into so many unique forms for a number of reasons. Firstly, they have had 55 to 60 million years of relatively low predation and competition pressures. For the first half of this time, there were no other terrestrial mammals, so competition and predation were even lower. Extant lemurs are subject to relatively few predators, primarily the fossa *Cryptoprocta ferox* and several snakes and birds of prey. However, it should be remembered that significantly larger predators of lemurs have existed until recently, for example, the 'giant fossa' *C. spelea* (Burney 2003). It has been suggested that changing predation pressures may also have contributed towards the evolution of cathemerality in some lemurs, although this is disputed (Curtis 2006). Many of Madagascar's ecosystems and therefore ecological niches are different to those found elsewhere, and this is likely to have contributed to the unique forms seen amongst lemurs. The absence of large ungulates has been cited as one contributing factor to the unique ecological landscape (Goodman et al. 2003).

*Figure 1.1* The aye-aye *Daubentonia madagascariensis* of Madagascar. Madagascar supports 21 per cent of the world's primate genera and 36 per cent of primate families, making it the highest priority for primate conservation globally. (Mittermeier et al. 2010; *photo credit*: Georgia Dicks). (A black-and-white version of this figure will appear in some formats. For the colour version, please refer to the plate section.)

Islands have provided the intellectual stimulus for the development of new disciplines and sub-disciplines of biological thought. R. A. Rappaport, for example, played an important role in the emergence of ecological anthropology (study of the relationship between humans and the natural environment) as a discrete branch of anthropology in the early twentieth century. Rappaport's research was based largely on his work with the Tsembaga Maring people of Papua New Guinea. His work focused on the link between culture and economy and the role that ritual plays within this interchange. American anthropologist Julian Steward developed the related field of cultural ecology, placing cultural change within the context of adaptation to the environment. His Puerto Rica research project was the first attempt to study the human cultures of an entire area, considering the economic, political and ecological relationships that existed. This island-based project involving multiple researchers also launched the careers of many eminent anthropologists of the twentieth century.

In later life, E. O. Wilson has promoted the idea of 'biophilia', or the inbuilt urge that living things – including humans – have to associate or to interact with other organisms (Wilson 1984). This perspective came at least in part as a culmination of his studies on island biodiversity and its inescapable link with human life. Finally, one of the greatest impacts that humans have had on the natural world that has subsequently backfired has been the result of species introduced to new lands by people and (sometimes) for people. It was one of the founding fathers of ecology, Charles S. Elton, who developed the sub-discipline invasion ecology – how introduced species become established and can drive others to extinction. In Elton's book, *The Ecology of Invasions by Animals and Plants* – first published in 1958 and subsequently republished multiple times (Elton 2000) – he used examples from oceanic islands (Hawaii, New Zealand, Guam, etc.) to highlight the potential devastation of invasive introduced species as they outcompete and consume native fauna and flora (see Section 4.2).

Islands have therefore provided some of the greatest thinkers in the multidisciplinary field of conservation biology with an experimental playground, a chance to test out 'what if?', to look retrospectively at correlations between events (see Section 5.6) and to theorise about the future fate of life on Earth.

## 1.2 Islands as a Window onto Global Species Decline

Although islands span only approximately three per cent of the world's surface, they support a disproportionate amount of its plant and animal diversity (Kier et al. 2009). However, this rich diversity is rapidly disappearing. Within the last 500 years, more than 75 per cent of recorded vertebrate extinctions and two-thirds of plant extinctions globally have been from islands (Glen et al. 2013; Box 1.2). Future projections point to a shift in the scale of extinction risk, with one prediction suggesting that we are set to lose more than three times the number of vertebrate species than have gone extinct over the last 500 years (Rickets et al. 2005). Thirty-nine per cent of the species facing imminent extinction are island species (Rickets et al. 2005). When corrected for surface area,

Box 1.2 *A Tale of Two Extinctions: The Dodo and the Solitaire*

The dodo *Raphus cucullatus* on Mauritius and the solitaire *Pezophaps solitaria* on the neighbouring island of Rodrigues are believed to have evolved from the ancestors of the modern-day Nicobar pigeon *Caloenas nicobarica* (Grihault 2007). They diverged from this original pigeon stock around 43 million years ago when these birds moved south from the Nicobar Islands along a series of oceanic mountain ridges until they reached the islands of Mauritius and Rodrigues and evolved into two distinct species. Following arrival on their respective mammalian predator–free islands, each species lost the power of flight, there being no selective advantage to maintain this energetically costly means of movement. Without the need to fly, they were able to grow in size – an evolutionary trend in many island species. The solitaire would have been larger than a modern-day turkey, the dodo being slightly smaller at the size of a goose. This increase in size conferred important advantages on the species, likely increasing their life span, increasing their ability to tolerate extreme fluctuations in temperature and enabling them to go for extended periods without food (Livezey 1993).

Within 100 years of the arrival of the Dutch in 1598 (Cheke and Hume 2008), the dodo was extinct on Mauritius. On Rodrigues, the solitaire had all but disappeared within 70 years of the arrival of the French in 1691 (Grihault 2007). Prior to settlement on Mauritius in 1638, the Dutch introduced monkeys (macaques), goats, cattle and pigs. Rats had already been introduced by sporadic voyagers who made landfall on the island. However, as the dodos seemed to still be plentiful on the arrival of the Dutch, it seems unlikely that the rats in this instance had much of an impact. The dodo was initially hunted by the early settlers for food, it being a large bird and relatively easy to catch, and habitat destruction for timber extraction also would have taken its toll. However, it seems likely that the most significant factor causing the decline of the dodo was predation of the young and eggs by pigs.

It is less clear what caused the demise of the solitaire on Rodrigues. Pigs again are likely to have predated on eggs and young, potentially also competing with the birds for fruits and seeds. Cats may well have taken hatchlings, and sailors are likely to have hunted the birds for food, too. It appears that the remaining solitaires retreated to the less-populated south-west of the island where, by chance, a fire may have overtaken them and killed off the remnant population (Grihault 2007).

Relatives of the solitaire and dodo are alive today, in the forms of the crowned pigeon *Goura victoria* of New Guinea and Samoa's tooth-billed pigeon *Didunculus strigirostris*, as well as its closest extant relative, the Nicobar pigeon. However, populations of all three of these island pigeon species are in decline.

island species are 14 times more likely to be critically endangered than continental species (Tershy et al. 2015), highlighting the pressing need to scale up efforts to reverse population trends on islands. However, the overall shift in extinction risk towards the continents in future years, where the majority of biodiversity remains, and in particular to species experiencing restricted range distributions, should provide the impetus to reach out to islands to understand how certain threats drive population declines.

Alongside habitat loss and over-exploitation (Figure 1.2), the spread of invasive alien species has been a principal driver of species extinction on islands to date and remains a primary threat to many island species and ecosystems (see Chapter 4). Work on islands has shed light on the diverse impacts that invasive species can have, from directly predating on endemic species to disrupting gene flows, altering population dynamics, impacting community composition and function and compromising ecosystem-level processes (e.g. nutrient cycles). Invasion studies on islands are also highlighting how climate change may provide the catalyst for the further spread of invasive species. In South Georgia,


*Figure 1.2* Deforestation in the Comoros. Thirty of the 45 once-permanent rivers on the Comorian island of Anjouan alone now only flow intermittently in large part as a consequence of deforestation. (ECDD 2012; *photo credit:* @Dahari.)

the melting ice sheets could facilitate the movement of rats *Rattus norvegicus* into new, previously inaccessible areas important for breeding seabirds (Petit and Prudent 2008). Such spreading presents a threat not only to species but also to human lives and livelihoods (see Section 4.3). Feral cats *Felis catus* have been implicated in the extinction of 14 per cent of birds, mammals and reptiles globally (Medina et al. 2011). They also represent a threat to human health via the disease toxoplasmosis (Dabritz and Conrad 2010), leading to increased likelihood of schizophrenia (Webster et al. 2006). We therefore need to recognise invasive alien species as a clear and present danger to global biodiversity and of relevance to human lives and livelihoods (see Section 4.3). Lessons from islands are also now showing us that we can begin to do something to control or eradicate this threat, helping to inform conservation projects on other islands and mainland systems where invasive species are threatening restricted-range species.

## 1.3 Islands as Beacons of Hope

In 1979, Norman Myers wrote, ‘We might abandon the Mauritius kestrel to its all but inevitable fate’, as a consequence of its extreme plight in the wild (Jachowski and Kesler 2009, cover image). From a known wild population of four birds (see Section 3.2.1), the population has now been increased to 300 to 400 individuals (Jones et al. 2013) (see Box 3.2). This example illustrates that even the most threatened of species can be brought back from the brink of extinction through intensive management. The Mauritius echo parakeet *Psittacula eques*, pink pigeon *Nesoenas mayeri*, Mallorcan midwife toad *Alytes muletensis*, Cayman blue iguana *Cyclura lewisi* and California Channel Islands fox *Urocyon littoralis* (e.g. Coonan et al. 2010) are a small selection of the species of island fauna that have been recovered from critically low numbers to a position where they now have a long-term future (Table 1.1).

Islands have been the testing ground for new and innovative techniques for understanding population declines through to managing species recovery. Our understanding of the biology of small populations and genetics (Chapters 2 and 3), invasive species ecology (Chapter 4) and the development of ecological histories to better monitor and understand population declines (Chapter 5) has benefitted from work conducted on islands. Through the development of invasive species management techniques (Chapter 7), captive breeding, translocation biology (Chapter 9), restoration ecology (Chapter 10) and human behaviour change (Chapter 11), we are beginning to learn how to more effectively mitigate threats and encourage species recovery and ecological function. Behind these actions, more effective management, leadership (Chapter 8) and planning of conservation projects (Chapter 6) are contributing to growing conservation success. Ultimately, islands have taught us that we should never give up on a species or the habitat on which it and others depend. This book seeks to illustrate how species recovery efforts on islands can inform our understanding of threatened species and habitat recovery and provide lessons for conservation work globally.

## 1.4 Rationale for Chapter Development

In this book we do not seek to provide a comprehensive overview of species recovery projects on islands. Instead, we wish to illustrate through examples what we believe to be helpful guiding principles and practices that can inform our conservation efforts. Species conservation projects operate, like other conservation work, within complex systems involving biological, ecological, geophysical and,

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Table 1.1 *Example Vertebrate Species' Recovery Success on Islands*

| Species | Location | Population change in the wild known population size (year) recent population size (year) c IUCN Red List status change) |
|---|---|---|
| Mauritius pink pigeon *Nesoenas mayeri* | Mauritius, Indian Ocean | 9 (1990) to 446 (2011) |
| Echo parakeet *Psittacula eques* | Mauritius, Indian Ocean | 12–25 (1990s) to >500 (2010) |
| Rodrigues warbler *Acrocephalus rodericanus* | Rodrigues, Indian Ocean | c. 17 (1979) to 3,000+ (2010) |
| Rodrigues fody *Foudia flavicans* | Rodrigues, Indian Ocean | 10–12 (1968) to 8,000 (2010) |
| Seychelles magpie robin *Copsychus sechellarum* | Seychelles, Indian Ocean | 12–15 (1965) to 200 (2009) |
| Mallorcan midwife toad *Alytes muletensis* | Mallorca, Mediterranean | Cr[b] (1994) to Vu (2004) (incre |
| Cayman blue iguana *Cyclura lewisi* | Cayman Islands, Caribbean | 25 (2002) to 443 (2012) |
| Kakapo[a] *Strigops habroptila* | New Zealand | 18 (1976) to 126 (2014) |
| California Channel Islands fox *Urocyon littoralis* | California Channel Islands | Cr (2004) to NT (2013) |

[a] Extinct in the wild (EW) in 1994 according to the International Union for Conservation of I

[b] Cr, Vu and NT are abbreviations of Critically Endangered (an extremely high risk of extinct extinction in the wild) and Near Threatened (likely to qualify for a threatened category in the IUCN (see www.iucnredlist.org for further details) (IUCN 2012).

where humans have an impact, sociological processes. To influence these systems, we must understand the underlying drivers of species decline, be equipped with a suite of intervention techniques to reverse the situation and appreciate how we organise and manage the resources at our disposal – the most significant one being people – to achieve success. This final point is expanded upon in this book to help us appreciate how we can influence our own practice and that of others with whom we work. We draw upon Beckhard's organisational design model (Beckhard 1972) to provide what we see as a helpful structure on which to hang our understanding of how threatened species recovery projects function (see Figure 12.1). The model contends that projects are composed of five elements: *purpose* (a long-term view as to why we do what we do), *goals* (the quantitative or qualitative descriptions that focus our work and by which we assess whether we are succeeding), the clarity of *roles* that people play within projects, the *processes* (namely, our activities and the organised order and flow of those activities) that we apply to get the work done, and finally, the *relationships* between the people involved. Each chapter either explicitly or implicitly considers one or more of the elements of this model through a conservation lens, with Chapter 12 revisiting the model and highlighting examples drawn from the book. The chapters are designed to capture knowledge from diverse disciplines and sub-disciplines ranging from the biology of small populations and genetics to invasion ecology, project management and planning and thereafter to social marketing and behavioural change. Throughout we refer to examples of either good or misguided practice, drawing on lessons from islands.

In Chapter 2, we begin by identifying some of the defining characteristics of island species developed as a consequence of evolution in isolation. We explore the development of evolutionary theory driven by studies on islands and end with a reflection on how this understanding can inform our appreciation of how to manage threatened small populations. This narrative is developed further in Chapter 3, where we consider how small, restricted populations can be influenced by genetic factors. We look at how these factors operate under emerging threats such as disease outbreaks and climate change and conclude by describing some of the practical implications of genetic management in the conservation of small, threatened populations. Chapter 4 brings us up to date with the topic of invasion ecology and the rationale for continuing to take the threat posed by invasive species seriously, exploring some of the multifaceted impacts they have on species, systems and human communities. We draw out what is known about the invasion process that can help to inform how we might intervene from a management perspective. We go on to reflect on some of the characteristics of islands that may predispose them to invasion and end by emphasising that far from considering invasive species as a threat that has passed, it has possibly only just begun.

Chapter 5 takes a step back from internal and external threats facing small populations to consider how we understand the process of population decline and distribution change from a historical perspective. We begin with a critical review of techniques used to help us reconstruct ecological histories for currently threatened (or extinct) species, such as the analysis of sub-fossil remains and the use of travellers' notebooks and maps. We consider how these approaches can help to inform our understanding of the cause(s) of population decline and so identify what remedial actions we may take. We review the range of methods used today to monitor current or recent population declines, touching on citizen science as well as more sophisticated monitoring techniques that account for imperfect detection. We summarise the components of an effective monitoring programme and end with a reflection on some of the steps we can take to infer or identify the causes behind the current status of threatened species.

In Chapter 6 we begin our analysis of how people within conservation projects can be better managed to enable them to be more effective in their work. We highlight the importance of considering upfront foreseeable issues that can undermine project outcomes and the need for regular monitoring and review. We introduce a range of project management tools to equip conservation managers with a kit to help manage the work, the people and the processes that enable the project to be completed. Finally, we reflect on methods for evaluating project outcomes, focusing on one particular model that provides a structure for examining project function. Given the importance of invasive species management in the recovery of threatened species worldwide, Chapter 7 takes some time to identify some of the key steps involved in planning for the eradication of sustained control, with a particular focus on invasive alien mammals. By the end of the chapter, we hope for readers to be clearer about key points to consider if faced with an invasive vertebrate management project. Chapter 8 devotes much-needed time to our understanding of leadership as a core discipline within species conservation. We provide a synopsis of central leadership theories and stress the importance of how to create, manage and motivate teams under what are often tiring and stressful conditions. We recognise that projects have natural high and low points and place emphasis on the value of 'systems thinking' as a helpful way of viewing projects from a leadership perspective. We end with consideration of 'project champions' and their important role in providing both leadership and encouragement throughout the process.

In Chapter 9 we focus in on the intensive species management approaches, often developed first on islands, that have led to the recovery of some of the world's most enigmatic species. The chapter draw heavily on our experience working on islands in New Zealand and the Mascarenes, experience that we feel is relevant to the process of species recovery worldwide and in particular for highly threatened species. We present a general approach used to evaluate new recovery opportunities and how we make decisions on which course of action to take. Chapter 10 reflects on how we should view species and their recovery within the context of their role within ecosystems. We consider the extent to which we can restore historical systems through habitat management and the recovery or replacement of threatened or lost species. We summarise some fundamental stages in habitat restoration, recognising the order in which we can put back the pieces of the puzzle and, where necessary, create new pieces that fit the space. We spend some time introducing the controversial concept of 'ecological replacement' and reflect on the fact that the *introduction* of novel species to systems may become more common practice as we seek to restore functioning ecosystems, more resilient to future shocks.

Throughout we draw on lessons from islands to inform our thinking as to how to achieve our conservation goals. Where helpful, we draw readers' attention to related text, examples or figures in other chapters. We include a range of case-study boxes to illustrate points raised in the chapters or to introduce approaches that we think are helpful in better understanding how to apply the principles in practice. We hope that readers find the topics covered within this book useful in developing their own thinking about how we understand, plan and deliver on conservation projects. In some small way, we hope that this book contributes to reversing the global trend in biodiversity loss that we are experiencing and, true to the mission of the Durrell Wildlife Conservation Trust, 'saving species from extinction'.

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