

# PACIFIC SEABIRDS
## SURVEY & MONITORING MANUAL

Tools to support seabird conservation across ecosystems in Oceania

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SPREP
Secretariat of the Pacific Regional Environment Programme

Pacific BioScapes

**The Pacific BioScapes Programme** is a European Union (EU) funded action, managed and implemented by the Secretariat of the Pacific Regional Environment Programme (SPREP). It includes 30 focused activities taking place across a diversity of ecosystems in 11 Pacific island countries that are addressing critical issues concerning coastal and marine biodiversity, and ecosystem-based responses to climate change adaptation.

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*Our vision: A resilient Pacific environment sustaining our livelihoods and natural heritage in harmony with our cultures.*

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## Tools to support seabird conservation across ecosystems in Oceania

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# FOREWORD

There are approximately 11,000 species of birds worldwide, but remarkably, only 370 are 'seabirds' (birds that spend most of their lives at sea). Of those, 42 are known to breed within Oceania, with 17 unique to our region. At least 21 other seabird species migrate through the Pacific Ocean utilising a vast oceanic habitat as a key part of their yearly life cycle.

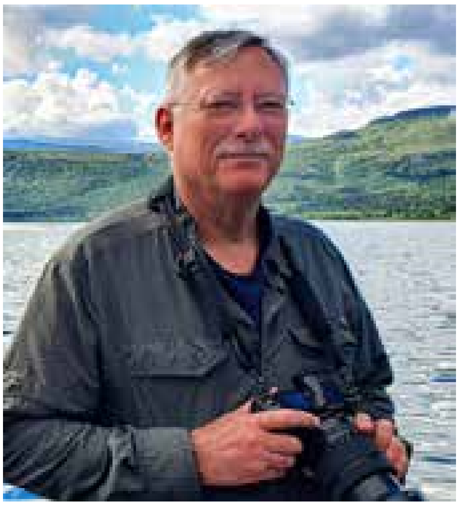
Seabirds are more threatened than any other comparable group of birds and their status continues to deteriorate globally. Across the Pacific, albatrosses, petrels, shearwaters, and storm-petrels in the families Procellaridae and Oceanitidae, in particular, have experienced greater population declines than other bird families. The loss of Oceania's seabirds also represents a loss of cultural and other values for Pacific peoples. Restoring healthy populations of seabirds will help build ecosystem resilience, support terrestrial and nearshore habitats as important carbon sinks, maintain healthy coral reefs and rebuild and retain Pacific peoples' cultural connections with seabirds and the ocean.

However, the distribution of seabirds across the region is poorly known due to its remoteness and inaccessibility as well as the lack of regional capacity for systematic surveys. There are also some species where breeding sites have never been found such as Fiji and Beck's Petrels and the Heinroth's Shearwater. The existence of some species is also still in question such as the Samoan Storm-petrel, known only from one specimen, and potentially other undescribed species still to be discovered.

Seabirds are highly important to heritage, culture, totemic relationships and subsistence for many Pacific peoples. Furthermore, seabirds played a crucial role in the settlement and navigation of the Pacific with early wayfarers using their knowledge of seabirds to help chart paths between islands and across broad stretches of open ocean. Annual harvesting of chicks, adults and eggs continue to be important traditional activities for some Pacific cultures and communities. Seabirds appear in many forms of cultural expressions in the region: chants, dances, oral history, crafts, clan and community motifs and designs.

Seabirds are continuing to decline, often as the result of invasive alien species (IAS) such as cats, rats, dogs, pigs and mongoose and habitat loss from logging, invasive plants and mining. Other threats include sea level rise disturbing atoll nesting seabirds as well as overharvesting, which may be an issue for some species and locations. In addition, direct interactions from fisheries as well as indirect impacts through overfishing and fishing down the food chain may also threaten some species and populations and plastic pollution affects a wide range of seabirds who mistake plastic for food. Climate change is likely to continue to exacerbate impacts e.g. facilitating transfer of disease vectors and invasive alien species and potentially causing changes in the food chain on which these birds rely. Lastly, urbanisation can have serious impacts on seabird populations through light pollution and collisions with powerlines and other human infrastructure.

Seabird faeces (guano) has now been recognised as a critical element in the restoration of islands both on land and in the seas around them. Research has shown that the presence of seabird colonies on islands supports the resilience and recovery of coral reefs through the direct input of nutrients flowing from seabird nesting colonies. Removing predators is vital to support the re-establishment of this vital ecosystem service.



SPREP has recognised the importance of seabirds as a vital component of island biodiversity in the Pacific. For the first time SPREP has produced a Seabird Action Plan as part of the Pacific Islands Regional Marine Species Programme 2022-2026. A key part of this first action plan is to support SPREP Members, partners and others to build capacity on seabird monitoring and research. Supported by the Pacific BioScapes Programme this Seabird Survey and Monitoring Manual for Oceania will I hope provide a useful resource for Pacific people to support their endeavors to learn more about our seabirds and support the ongoing recovery of seabird populations.

*Stuart Chape, Director Island and Ocean Ecosystems, SPREP*

# EXECUTIVE SUMMARY

Welcome to the Pacific Seabird Survey and Monitoring Manual!

The Pacific islands region served by the Secretariat of the Pacific Regional Environment Programme (SPREP) covers 32 million km$^2$ within the largest continuous marine habitat on the planet, the Pacific Ocean. Oceania is the collective name for the islands and island nations scattered across this region. The goal of this manual is to encourage and support seabird conservation and research across the region, particularly in areas where this work is just starting out. We consider all of the proven methods and survey types that are currently in use across the region, to provide readers with the tools required to run successful seabird survey and monitoring programmes. To further illustrate how successful projects can be undertaken, real world case studies are presented – written by experts currently working in the field. By utilising the in-depth knowledge, experience and expertise of people who have worked successfully on a species, group of species or an ecosystem, readers can transfer these tried and tested methods to projects starting out elsewhere in Oceania.

**For ease of use, the manual is presented in five distinct parts:**

## Part 1: OCEANIA SEABIRDS

Seabirds are one of the most important and formative groups of birds in the Pacific, and the Oceania region is no exception. In many ways, these species can be considered the architects of the islands we live on today. In this section we provide information on the species that can be found in the region and their conservation status, as well as their importance to the people living across the Pacific. We discuss the unique features that allow them to utilise the marine environment, and how by doing so they also benefit the terrestrial habitats in which they roost and breed (through the flow of nutrients in that most important of substances – bird poo!). Despite being such formative and important species for the Oceania region, many seabird populations are in decline, in some cases perilously so. This is because of a wide range of threats including introduced predators such as cats and rats, urbanisation, invasive plants and the insidious effects of climate change. Each of these threats is also discussed in this section. Initiating seabird monitoring and research programs as outlined in this manual will allow users to assess and address these threats, with the aim to reverse declines and restore seabird populations to their former glory.

## Part 2: SURVEY TOOLS & TYPES

To develop a successful seabird project, it is important to be aware of the tools that are available to you. What works for one species or situation may not necessarily work in another so understanding the vast (and often overwhelming) area of tools is a key to success. Here, we discuss the tools of the trade that are available to seabird researchers. These include acoustic sensors and remote cameras as well as more specialised or emerging techniques, like the use of drones, radar units and thermal scopes. Remember that while these awesome pieces of equipment can be vital aspects of seabird projects, meeting up with communities living in focal areas may be the key to providing you with the local knowledge and guidance necessary to jumpstart your work. This section also looks at bird capture and tracking techniques, which can be used in a wide variety of ways to gain insight into critical elements of species ecology such as foraging or wintering areas. Lastly we consider the different types of surveys that can be utilized, including rapid assessments, shore-based sea watches and surveys by boat, drone and plane.

## Part 3: MONITORING

This section presents the methods required to gather data from the seabirds themselves, starting with burrow monitoring, then bird handling, taking measurements, banding and sampling, and checking breeding status. These hands-on methods can lead to a wide variety of research studies such as mark-recapture, measuring reproductive (or breeding) success, dietary assessments and investigating the issues of plastics ingestion and contaminants. The section rounds off with monitoring cyclone impacts of seabird populations and measuring the success (or otherwise) of predator control measures. Once again, choosing the appropriate method, will depend on what your research project and monitoring programme is aiming to achieve. When considering the hands-on element to seabird studies, make sure you have the necessary permitting in place, and that the participants handling birds have been trained for the tasks to be undertaken.

## Part 4: MANAGING DATA TO SUPPORT CONSERVATION

Seabird projects result in the accumulation of large amounts of data. This is an excellent problem to have, as it is this data that will help guide your research or conservation project into the future. It helps answer questions such as "Is predator control working" or "Is my study species being affected by plastic pollution or likely to be impacted by climate change." If you don't have the data to assess whether your management techniques are working, then you need to take a step back and understand where you are going wrong. However, data can be overwhelming especially if you are using tools like acoustic sensors or burrow cameras as these can swiftly result in daunting amounts of information. This section discusses how to deal with data management so you can make the most out of your project. We also highlight several international databases where you can also deposit key elements of your data to help guide large scale conservation efforts and regional and global studies. Lastly, we discuss seabird restoration projects that are particularly reliant on good quality data as well as a seabird restoration database where data on these projects are summarised.

## Part 5: RESOURCES

The final section of the manual provides additional resources available to seabird researchers in Oceania. We discuss national bird banding schemes and the creation of the Pacific Seabird Advisory Group (PSAG) and provide two basic identification keys. We also provide a list of other resources, such as online field guides, useful books to look at and reports to download. The manual is available in both printed and online form and aims to facilitate seabird conservation across Oceania and the tropical Pacific Ocean. We sincerely hope you find this manual useful and look forward to seeing you presenting your vital seabird work in a conference or scientific publication in the future!

Figure 1. 'Gull Islets', Suwarrow Atoll, Cook Islands. Photo: Te Ipukarea Society

# PART ONE

## Oceania Seabirds

Lesser Frigatebirds, Kiribati. Photo: Hiroyuki Tanoi.

# 1.0 INTRODUCTION

The goal of this manual is to encourage and support seabird research across Oceania through the adoption of proven methods and survey types, to provide readers with the tools required to run successful seabird survey and monitoring programmes. To further illustrate how these can be carried out we also include case studies - real world examples of active seabird research efforts. The in-depth knowledge, experience and expertise of people who have worked successfully on a species, groups of species or an ecosystem can be transferred to other projects elsewhere in the Oceania.

This manual is intended to be as comprehensive and accessible as possible. However, by using this manual you can pick and choose methods according to your needs, budget, and the skills and capacity available to you. You may find that the best way to initiate a seabird project is to start small and focussed, and then expand with additional methods, survey types and resources as your work develops.

No one needs to work in isolation, and we encourage the development of networks for improved communication, resource sharing, capacity building and further project development. Reach out to other experts in the seabird community to ask questions and explore emerging technology. This is not limited just to researchers but conservation managers, community representatives and others as appropriate.

The SPREP Seabird Action Plan[1] recommended the establishment of a **Pacific Seabird Advisory Group** and a link to this is provided in the resources section (5.2) of this manual. With Oceania's challenging locations, workers need all the help they can get to learn more about what works and what doesn't to further the goal of ensuring that our seabirds persist into the future.
But first, what are seabirds?

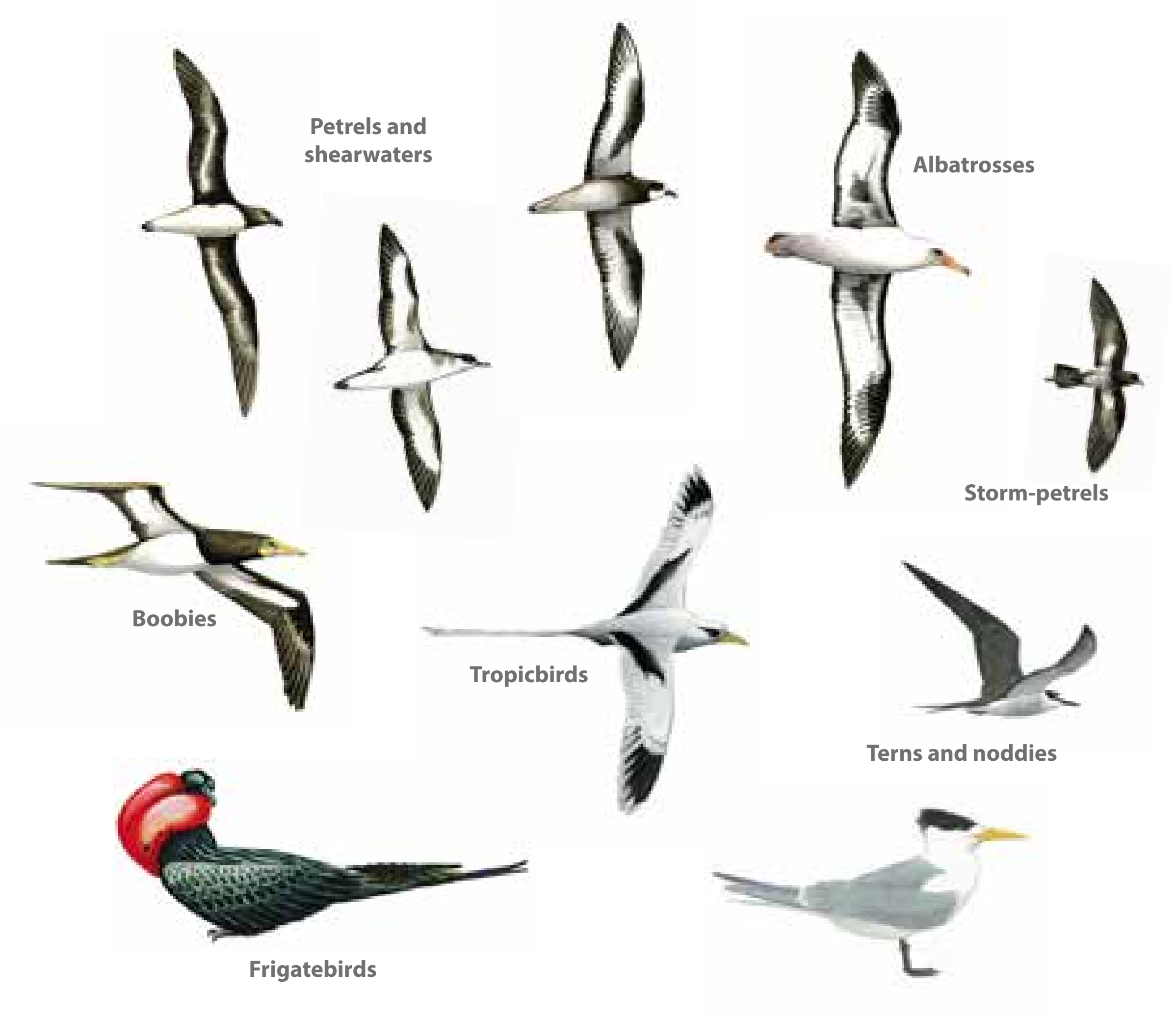


Figure 2. Main Oceania seabird groups. Artwork by Peter Harrison.[2]

## 1.1 SEABIRDS

Seabirds are one of the most important and formative groups of birds in the Oceania region. In many ways, they can be considered the architects of the islands we live on today.

There are just over 11,000 species of birds worldwide. Remarkably, only 3% of the global total of bird species are seabirds. Seabirds have evolved from a wide range of different taxonomic groups. Common to all is that they spend part of their life cycle foraging over aquatic environments, be it open ocean, coastal waters, lakes or rivers. They are essentially marine creatures and possess unique physiological and morphological adaptations to successfully exploit this environment. They can be highly mobile, and in some cases the whole population of a species can travel from one side of an ocean to another during certain times of the year. They come in all shapes and sizes and are often highly specialised.

**Figure 3. Short-tailed Shearwaters on migration, en route from Australia to the North Pacific in April 2024, offshore New Caledonia. Photo: Edin Whitehead.**

### 1.1.1 SEABIRD ECOLOGY

Seabirds have biological characteristics that differ dramatically from most land birds. These characteristics reflect the challenges of finding food from the changing marine environment and the evolution of many species in the absence of mammalian predators. The life-history characteristics of seabirds are often referred to as 'extreme', including long lifespans (20-60 years in the case of Procellariiforms including albatross species), delayed maturity (up to 15 years), small clutch sizes (often a single egg with no replacement in a season), and long chick development periods. These life-history characteristics means they are especially vulnerable to population decline. By comparison, many terrestrial birds have shorter lives, lay larger clutches of eggs, and have chicks that mature more rapidly. The 'slow' lifestyle of seabirds means they are slower to recover after declines, as it takes longer for them to mature and breed.

Figure 4. Masked Booby adult and chick, Genovesa. Galapagos. Photo: André Raine

Figure 5. Hawaiian Petrel chick in burrow, Kaua'i, Hawaii. Photo: André Raine

The feeding habits of seabirds vary. However, seabirds of the Pacific spend most of their life cycle on the open sea, an environment to which they are supremely adapted. Flight for many species is extremely efficient, with momentum gained via dynamic soaring, where birds take advantage of reduced wind speeds near the ocean's surface.

**Figure 6. Beck's Petrel in flight. Photo: Hadoram Shirihai.**

Seabirds can find their food over large distances. Excellent vision keeps them alert to the activities of other seabirds, fishes, dolphins and whales, and a strong sense of smell enables them to detect potential prey upwind. The majority of seabirds have water resistant feathering (from feathers' interlocking structures and preen gland oils), webbed feet for swimming and bills with hooks, points, serrations and/or filters. These adaptations enable seabirds to exploit a variety of prey such as fish, crustaceans (krill) often in association with fish schools, cephalopods (squid), phytoplankton and zooplankton from the surface to deep in the water column. Foraging strategies vary by species, with some picking prey from the surface of the sea, and some diving to depths of 60 metres or more to chase prey below the surface.

**Figure 7. Seabird portraits showing shape of bills: Booby, frigatebird, petrel (left to right, top) shearwater, noddy/tern (left to right, bottom). Photos (clockwise): Edin Whitehead, Mathieu Mathivet, Lucie Faulquier, Eric VanderWerf, Stephen Percival.**

Many seabirds are colonial, aggregating in loose or dense colonies where they find protection from predators through sheer numbers. Species nest either on the surface (terns, albatross), or in vegetation (boobies, noddies, frigatebirds), in rock crevices, or underground in excavated burrows (petrels, shearwaters, storm-petrels). While some species, (e.g., Grey Noddy (*Anous albivitta*), White Tern (*Gygis alba*) and also Kermadec Petrel (*Pterodroma neglecta*) and Tahiti Petrel (*Pseudobulweria rostrata*) may be present all year round, others return to their colonies at the beginning of the breeding season to clean and defend the nest site and re-establish pair bonds. After nest sites have been claimed or burrows re-dug, or cleaned up, birds will copulate at the site. Thereafter the female needs to return to sea to grow the egg. The male needs to also return to sea to gain sufficient fat stores to survive the first incubation shift, once the egg has been laid. This period is the pre-lay exodus or honeymoon period. Previously busy colonies can sometimes appear almost abandoned, necessitating a good knowledge of seabird breeding timing not to misjudge colony activity from inopportune timing of monitoring visits. Many species (including albatross, petrels and shearwaters) have long incubation and chick-rearing phases. For most species, once the chick is large enough to thermoregulate independently it is left unattended whilst both its parents forage at sea. In most species, both parents look after the chicks until they fledge.

However, seabirds are more threatened than any other comparable group of birds and their status has deteriorated faster over recent decades. In Oceania, the petrels, shearwaters and storm-petrels (family Procellariidae) in particular, have lost more populations than any other bird family[3]. This loss of Oceania's unique seabird biodiversity also represents a loss of cultural values, as they have long been an important part of life in the region.  The cultural importance of seabirds includes being a vital food source, as a guide for fishers to locate fish at sea (tuna birds), as elements of legends, totems and chants, and incorporated into clothing, ceremonial dance and art. Seabirds also played a pivotal role in the expansion of Pacific peoples across Oceania by providing signposts for locations of tiny islets in the vastness of the open ocean. Seabird behaviour (whether they roosted on land at night or stayed at sea) was used by Polynesian navigators to find low-lying atolls tens of kilometres away late in the day.

Loss of seabird biodiversity also has impacts on the health of coastal and forest ecosystems where they breed. Seabirds bring marine-derived nutrients to the land via their guano (aka poo), thus helping to feed and nurture near shore coral reef and terrestrial ecosystems; the flow-on effects of this are discussed in Section 1.3. Returning healthy populations of seabirds to Oceania will help build ecosystem resilience and support terrestrial habitats as important carbon sinks, while retaining Pacific people's links with seabirds as ecosystem sentinels.

## 1.2 WHY SURVEY AND MONITOR SEABIRDS?

The first critical step for any new seabird project is to establish its purpose, which will allow you to create a clear and well-designed survey and/or monitoring programme. This involves setting out what you want to survey and monitor and why you want to do so. Identify the question or objective behind your project, such as "In ten years we want to know whether the population of X has increased due to management actions". See Section 1.4 for the key steps in developing a survey and monitoring programme.

Seabirds breed on land and face numerous threats to their survival (see Section 1.6.1 for a detailed discussion).  One of the most prevalent threats is introduced predators, as seabirds evolved without exposure to predatory mammals. The impact of introduced mammalian predators is a well-known and widespread issue facing a wide range of native species, and for seabirds are often the leading cause of their decline, and often even extirpation from islands.  Many seabird conservation projects focus on predator eradication as a pivotal first step because with introduced predators such as rats, pigs, cats and mongooses eradicated, one can often see very quick results - seabirds can breed successfully, raising chicks that would otherwise have been eaten, and populations will naturally increase. There are many excellent examples across the world where the control of introduced predators is having a significant positive impact on seabird species.  All these projects however should have one thing in common – that they have solid follow-up monitoring programmes in place, as without this you have no way of knowing whether your actions are having any impact at all or can alert you to the return of predators or some other negative influence.

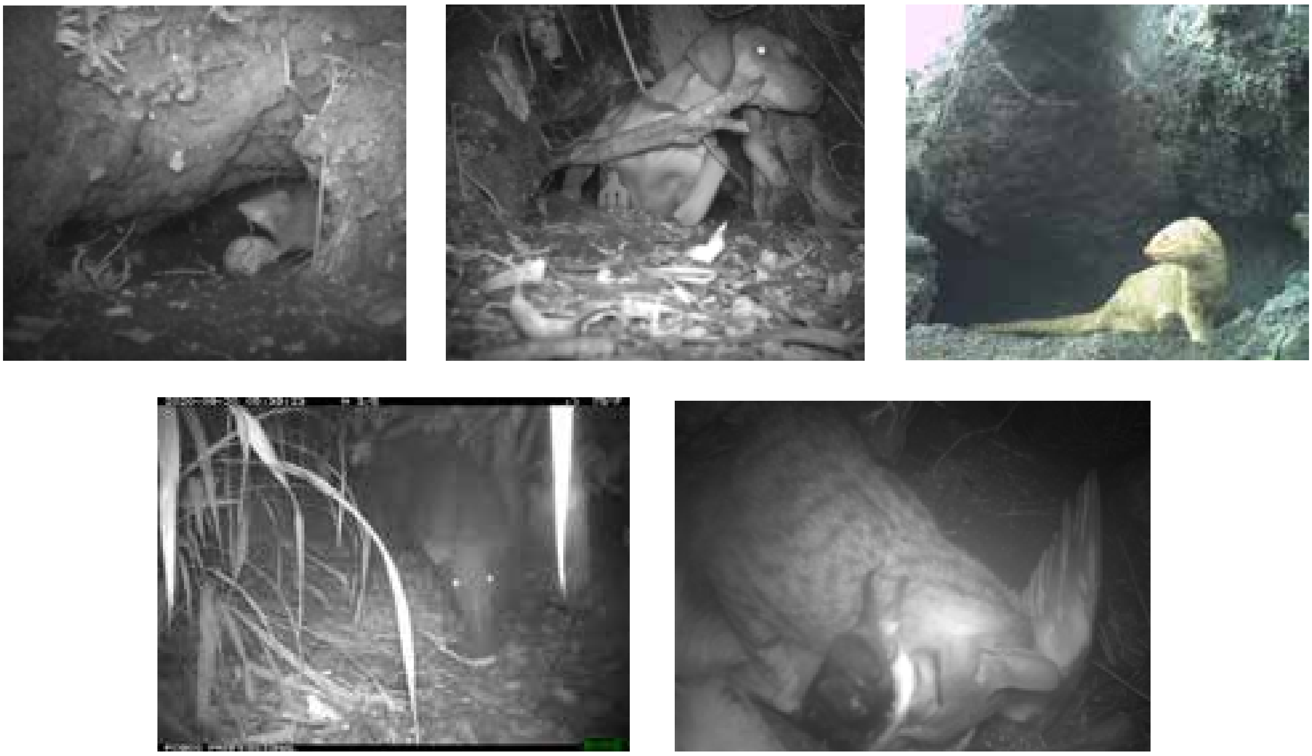


Figure 8. Examples of predation on seabirds. Left to right: rat, dog, mongoose (top), pig and cat (bottom). Photos supplied by Archipelago Research & Conservation and Hawaii DLNR.

However, while controlling or eradicating introduced predators often results in a steady increase in the seabird population being managed, this is not always the case. This is because there may be multiple pressures on the population. Introduced plants could be making breeding areas uninhabitable by excluding seabirds from their nesting areas, birds may be colliding with powerlines or other human infrastructure on their flyway, fledglings may be grounded on their first flight out to sea by the lights of nearby towns, and diseases (such as avian pox or bird flu) may be sporadically wiping out sections of the population. A well-designed monitoring programme may also help to identify whether some other threat is impacting on the birds. You may find that by using burrow cameras, predators and predations are significantly decreased, but despite this burrows are being abandoned by adults, or chicks are not fledging despite regular visits by adults. This data is critical for drawing your attention to the fact that predators were not the only issue facing your birds and allow you to start investigating other potential issues. Is there something along the flyway that could be a problem? Are chicks starving, indicating threats at sea?

Figure 9. Foraging Brown and Red-footed Boobies, and Brown Noddies at sea, Samoa. Photo: Juney Ward, SPREP.

By surveying and monitoring seabirds we can also learn a great deal about the marine environment: where they are foraging, what prey they are catching (both for themselves and their chicks) and how successful they are in raising chicks. We can look at the health of both parent birds and chicks and assess whether populations are increasing or decreasing. Through these collective studies we can learn a great deal, not only about the birds themselves, but about the marine environment on which they and the peoples of the Pacific depend.

The threats at sea for Pacific seabirds also need to be fully understood and assessed. There are a range of threats that face seabirds as they search for food in the marine environment (see Section 1.6.2). These include direct threats such as fisheries bycatch, plastics ingestion, pollution exposure, and indirect threats such as overfishing and the multiple impacts of climate change. Research into each of these can help in identifying improved management measures.

Returning to the question of invasive species, particularly introduced predators, it is important to note that the seabirds that breed across the Pacific are mostly remnants of former populations. Humans have had a huge impact, and species' populations have declined dramatically over the millennia of human expansion across the Pacific. Unfortunately, this decline is continuing, often at an alarming rate. The complete extirpation of seabirds from many islands is highly likely without intervention. This is especially true for the Procellarid family of group of seabirds that include petrels and shearwaters, whose size ranges from the large albatrosses to the diminutive storm petrels. The smaller forms of Procellarids are burrow nesting species, and so are extraordinarily cryptic, and finding where they breed is not always easy. While some colonial-nesting species can be easy to detect (e.g., large ground nesting colonies of terns, noddies, albatrosses and boobies), many are in difficult to access places including offshore islands, scattered through forests, or high in remote mountains. It is remarkable in this day and age that new species are still being discovered, or those thought long lost and extinct are being re-discovered. Surveys are required to search for and find breeding sites, and once located only then can the threats to the birds' survival be fully assessed, leading to planning and instigation of management measures.

Development of national action plans for seabird conservation and management may also be useful for providing long term goals for monitoring and protecting seabirds. The Pacific Islands Regional Marine Species Programme 2022-2026 contains the first Seabird Action Plan for the region and sets out a regional strategy for protecting seabirds. The Action Plan contains general information about seabirds in the region and objectives which may assist with establishing national priorities under the following regional goal "Conserve seabirds and their habitats, recognising the traditions and aspirations of the peoples of the Pacific Ocean and Islands".

## 1.3 SEABIRD-DRIVEN ECOSYSTEMS

The spectacle of seabirds massing over large and thriving colonies such as Kiritimati and Rawaki (Kiribati), Chesterfield Reefs (New Caledonia), Marotiri (French Polynesia), and Oeno and Henderson Islands (Pitcairn islands) can be staggering. Such a spectacle allow us to appreciate why some islands, especially those that are truly oceanic and where seabirds dominate their ecology, can best be regarded as 'seabird islands'.

The word guano, derived from the Inca of South America, means a gift of the gods. In this case, the gift is actually dried seabird droppings, which is of course produced naturally in huge quantities on seabird islands. It has long been utilised by people – for example, guano mined from Nauru was used extensively in New Zealand and Australian agriculture prior to the development of synthetic fertilisers and use of rock phosphate. Perhaps the most visible examples are seen as pungent deposits around surface or tree nesting seabirds, such as at booby and tern colonies or beneath noddy roosts. While these examples are easy to see, the far more widespread examples are hidden within colonies of burrowing seabirds such as petrels and shearwaters. Here the guano is incorporated directly into the soil as the birds return at night, clean their burrows and throw freshly minted compost complete with fertiliser across the forest floor as they dig.

**Figure 10. Rako Buller's Shearwater digging a burrow, Poor Knights Islands, Aotearoa New Zealand. Photo: Trail camera NNZST**

**Figure 11: Petrel burrows on Korapuki Island, Aotearoa New Zealand. Photo: Edin Whitehead.**

Because most seabirds – whether burrowing or not – live in colonies, the localised production of guano can be staggering. Seabird colonies have been estimated to spread up to 100 times more nitrogen and 400 times more phosphorus than is normally applied to agricultural land. On forested islands, the burrowing activities and guano production by seabirds have such profound effects that the birds are often referred to as ecosystem engineers or ecosystem drivers. None of this material is derived from terrestrial sources, as seabirds only feed at sea. The guano is produced from resources gained in oceans and deposited on land, bridging two vastly different ecosystems.

Most likely, many smaller islands within the region were once dominated by enormous numbers of burrowing seabirds. The few islands untouched by introduced predators, and those now recovering after predator removal, provide indications of the interactions within these extraordinary ecosystems. Multidisciplinary studies conducted on many of the islands have demonstrated that the presence of seabirds drives almost every level of ecosystem functioning, including litter decomposition rates and invertebrate abundance and community composition. The nutrient-rich and heavily burrowed soils also promote communities of plants able to withstand disturbance, acidic soils, high nutrient loads and dry conditions. The plants need to be long-lived, able to sprout from the base to overcome the effects of toppling in the loose soils, and able to produce prolific seeds to take advantage of light gaps. Plants living in this environment also need to compensate for very high seedling mortality as the seabirds rip up anything they can find to line their burrow nests.[4]

Seabirds that breed in one place but come ashore to roost in other places can also carry plant seeds from one island to another, thus spreading plant species across island chains and contributing to the botanical diversity of different islands. Indeed, seabirds are one of the ways in which plant species colonise newly formed islands. This can even take a gruesome turn – in the case of the sticky seeds of the Pisonia (or "bird-catcher") tree (found in the Caribbean and Indo-Pacific) the seed load on some birds roosting or nesting on the branches of the tree can be so heavy or sticky that the bird may eventually be unable to fly and will perish. Remarkably however, on some islands Black Noddies (*Anous minutus*) choose to nest in Pisonia trees!

As a result of seabird activity, invertebrates may also face a shortage of leaf litter in which to shelter, except at the foot of slopes. Here litter and rich friable soil accumulates from seabird "gardening" and enormous numbers of invertebrates take advantage of the favourable conditions. Comparisons between islands with and without seabirds have demonstrated the advantages to invertebrates if they can find the right conditions. In places, bright crusts of algae, lichens and mosses on hard surfaces such as tree-trunks and boulders provide evidence of the effects of seabird droppings. At night, these surfaces and seabird carcasses are grazed by beetles, which in turn are food for other fauna, including reptiles if present. This unique combination of the high diversity of nesting seabirds and other fauna provides another reason for the international significance of the islands in the region.

Not all of the nutrients brought to land by seabirds remain there, and some wash off into the coastal oceans. Transport of nutrients from large colonies of seabirds to the nearshore marine environment has been shown to enhance coral reef capacity to accrete with rising sea levels and increase marine productivity for example increasing fish biomass in the adjacent coral reef by 48%[5]. This enhanced coral reef productivity is a measure of ecosystem resilience. Rebuilding coastal seabird colonies through predator control or other mitigation methods would provide increased marine resilience and support local livelihoods through fishing.

### 1.3.1 SEABIRDS AND NEARSHORE ECOSYSTEMS – BI-DIRECTIONAL NUTRIENT FLOW

The circular seabird economy – whereby seabirds feed in the ocean, transport marine-derived nutrients onshore to their breeding colonies, and then seabird-derived nutrients runoff into the ocean, enriching nearshore ecosystems – is a critical driver of biodiversity and functioning on islands and in nearshore marine ecosystems including coral reefs and sea grass beds.

Traces of the marine-derived nutrients deposited by seabirds can be found at every trophic level on these islands, from invertebrates through to plants. The nutrients can be tracked using a peculiarity of nitrogen, which naturally forms stable isotopes (variants). One isotope can be used to track the marine origins of this nutrient. It is now clear that the vegetation cover of islands is not able to use all this material and, therefore, much of it runs off into the coastal environment. Much more is bonded into the soil, some of which washes off during heavy rain.[4]

## CASE STUDY – Palmyra Atoll, Northern Line Islands (US)

### Alex Wegmann, Katie Franklin, Dana Sabine, Nick Holmes (The Nature Conservancy)

Palmyra Atoll ("Palmyra") is at the north end of the Northern Line Island Archipelago lying 1,600 km south of Honolulu, Hawai'i, and 210 km northeast of Teraina Island (KI). It consists of 39 islands totalling 235 ha of land surrounded by 2,600 ha of coral reef. Today, Palmyra is a Nature Preserve managed by The Nature Conservancy within a National Wildlife Refuge managed by the US Fish and Wildlife Service, within a 53,000 km$^2$ marine protected area. Eleven seabird species currently breed and roost at Palmyra and it is thought that eight additional seabird species were extirpated with WWII-era habitat disturbance and the introduction of rats.

For over two decades, a confluence of conservation interventions and scientific investigation at Palmyra has shed light on the functional role of seabirds in atoll ecosystems. A 2012 study[6] described a positively correlated interaction chain whereby native forest habitat is associated with seabird abundance and seabird abundance is associated with beneficial nutrients (N, P) transported by seabirds and deposited as guano. The guano drives primary productivity on islands and in nearshore marine habitat. Related research[7] found that the atoll's tree-nesting seabirds were responsible for the bulk nutrient transport, i.e., Red-footed Boobies (*Sula sula*) and Great Frigatebirds (*Fregata minor*) in particular greatly prefer native tree canopy over coconut palm crowns for nesting and roosting. However, the majority of Palmyra had been converted to a coconut palm plantation, with the result that seabird populations plummeted, and the benefits associated with seabird guano was excluded. This exclusion had cascading effects on soil nutrient loading, terrestrial biodiversity, and overall biomass of native species.

**Figure 12 (below). Palmyra land-sea connectivity panorama: Atoll ecosystems comprise island, lagoon, coral reef, and pelagic habitats all tightly connected through myriad biological interactions and physical processes. Seabird transport of nutrients (N and P) from pelagic foraging grounds to atoll islands subsidises productivity along the entire interaction chain, from forest to reef. Artwork Adi Khen.**

In recognition of the ecological importance of seabirds as connector species integral to island ecosystem resilience to climate impacts,[8] rats were successfully eradicated from Palmyra in 2011[9] and conversion of the atoll's abandoned copra (coconut palm) plantation began in 2019[10]. This work is on-going and continues today.

See section 3.11 Seabird-transported nutrient monitoring for multiple methods for monitoring the functional roles' seabirds play in island and marine ecosystems.

**Figure 13. An abandoned copra (*Cocos nucifera*) plantation at Palmyra Atoll (left) with little to no seabird breeding activity contrasted with native forest (right) with ample seabird breeding and roosting.**
**Photos supplied by: The Nature Conservancy.**

## 1.4 SEABIRDS OF OCEANIA

The modern distribution of seabirds in Oceania is imperfectly known. There are numerous islands scattered throughout Oceania for which we know very little, or in some cases absolutely nothing, because of difficulty of access due to remoteness or natural barriers.

Figure 14. Map shows SPREP member countries and EEZs (orange), SPREP partners Aotearoa New Zealand and Australia (EEZs outlines only), and US Pacific Minor Outlying Islands (EEZs pale yellow) and the US state of Hawaii (EEZ outline only).

**Table 1. Species of seabirds known to be breeding or potentially breeding within the Oceania region.**

| | | PACIFIC ISLAND COUNTRY OR TERRITORY | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SEABIRD SPECIES** | **IUCN Threat** | AS | CI | FSM | FI | FP | GU | KI | MI | NA | NC | NI | NMI | PA | PNG | PI | SA | SI | TOK | TO | TU | VA | WF |
| Murphy's petrel<br>*Pterodroma ultima* | LC | | | | | 🟩 | | | | | | | | | | 🟩 | | | | | | | |
| Kermadec petrel<br>*Pterodroma neglecta* | LC | | | | | 🟩 | | | | | | | | | | 🟩 | | | | | | | |
| Phoenix petrel<br>*Pterodroma alba* | EN | | | | | 🟩 | | 🟩 | | | | | | | | 🟩 | | | | | | | |
| Herald petrel<br>*Pterodroma heraldica* | LC | 🟩 | 🟩 | | | 🟩 | | | | | | | | | | 🟩 | | | | | | | |
| Henderson petrel<br>*Pterodroma atrata* | EN | | | | | | | | | | | | | | | 🟩 | | | | | | | |
| Vanuatu Petrel<br>*Pterodroma occulta* | VU | | | | | | | | | | | | | | | | | | | | | 🟩 | |
| Collared petrel<br>*Pterodroma brevipes* | VU | | | | 🟩 | | | | | | | | | | | | | | | | | 🟩 | |
| Black-winged petrel<br>*Pterodroma nigripennis* | LC | | 🟦 | | | 🟩 | | | | | | | | | | 🟩 | | | | | | | |
| White-winged (New Caledonian) Petrel<br>*Pterodroma leucoptera* | VU | | | | | 🟩 | | | | | 🟩 | | | | | | | | | | | | |
| Fiji petrel<br>*Pseudobulweria macgillivrayi* | CR | | | | 🟦 | | | | | | | | | | | | | | | | | | |
| Bulwer's petrel<br>*Bulweria bulwerii* | LC | | | | | 🟩 | | 🟩 | | | | | | | | | | | | | | | |
| Tahiti petrel<br>*Pseudobulweria rostrata* | NT | 🟩 | | | 🟩 | 🟩 | | | | | 🟩 | | | | | | 🟦 | | | | | | |
| Beck's petrel<br>*Pseudobulweria becki* | CR | | | | | | | | | | | | | | 🟦 | | | 🟦 | | | | | |
| Wedge-tailed shearwater<br>*Ardenna pacifica* | LC | | 🟦 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 | | 🟩 | 🟩 | 🟩 | | 🟩 | | | | | 🟩 | | 🟩 | |
| Christmas Island shearwater<br>*Puffinus nativitatis* | LC | 🟩 | | | | 🟩 | | 🟩 | | | | | | | | 🟩 | | | | 🟩 | | | |
| Heinroth's shearwater<br>*Puffinus heinrothi* | VU | | | | | | | | | | | | | | 🟦 | | | 🟦 | | | | | |
| Tropical shearwater<br>*Puffinus bailloni* | LC | 🟩 | | | | 🟩 | | 🟩 | | | | | | 🟩 | | | 🟦 | 🟩 | | 🟩 | | 🟩 | |
| Rapa shearwater<br>*Puffinus myrtae* | CR | | | | | 🟩 | | | | | | | | | | | | | | | | | |
| White-bellied storm petrel *Fregetta grallaria* | (LC) | | | | | 🟩 | | | | | | | | | | | | | | | | | |
| Coral Sea or New Caledonian Storm-petrel<br>*Fregetta lineata* | NA | | | | | | | | | | 🟦 | | | | | | | | | | | | |

| | | PACIFIC ISLAND COUNTRY OR TERRITORY | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **SEABIRD SPECIES** | **IUCN Threat** | **AS** | **CI** | **FSM** | **FI** | **FP** | **GU** | **KI** | **MI** | **NA** | **NC** | **NI** | **NMI** | **PA** | **PNG** | **PI** | **SA** | **SI** | **TOK** | **TO** | **TU** | **VA** | **WF** |
| Polynesian (White-throated) Storm Petrel *Nesofregetta fuliginosa* | EN | | | | 🟦 | 🟩 | | 🟩 | | | 🟩 | | | | | 🟩 | 🟦 | | | | | | |
| Red-tailed tropicbird *Phaethon rubricauda* | LC | 🟩 | 🟩 | 🟩 | | 🟩 | | 🟩 | 🟩 | | 🟩 | | 🟩 | | | 🟩 | | | | 🟩 | | | |
| White-tailed tropicbird *Phaethon lepturus* | LC | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 |
| Brown booby *Sula leucogaster* | LC | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 |
| Masked booby *Sula dactylatra* | LC | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 | | 🟩 | 🟩 | | | 🟩 | 🟩 | | | | 🟩 | | | |
| Red-footed booby *Sula sula* | LC | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 | | 🟩 | | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 | | 🟩 |
| Great frigatebird *Fregata minor* | LC | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | | | 🟩 | | | 🟩 | | 🟩 | 🟩 | 🟩 | | | 🟩 | | |
| Lesser frigatebird *Fregata ariel* | LC | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | | | 🟩 | | | | 🟩 | | | 🟩 | | 🟩 | | | |
| Little white tern *Gygis microrhyncha* | LC | | | | | 🟩 | | | | | | | | | | | | | | | | | |
| Silver gull *Chroicocephalus novaehollandiae* | LC | | | | | | | | | | 🟩 | | | | | | | | | | | | |
| Brown noddy *Anous stolidus* | LC | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 |
| Black noddy *Anous minutus* | LC | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 |
| Grey/Blue Noddy *Procelsterna albivitta/cerulea* | LC | 🟩 | 🟩 | | 🟩 | 🟩 | | 🟩 | 🟩 | | 🟩 | | | | | 🟩 | | 🟩 | | | | | |
| White tern *Gygis alba* | LC | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 |
| Sooty tern *Onychoprion fuscatus* | LC | 🟩 | 🟩 | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 | | 🟩 | | 🟩 | 🟩 | | | | 🟩 | | 🟩 | | | |
| Grey-backed tern *Onychoprion lunatus* | LC | 🟩 | | 🟩 | | 🟩 | | 🟩 | | | 🟩 | | | 🟩 | | | | | | | | | |
| Roseate tern *Sterna dougallii* | LC | | | | | | | | | | 🟩 | | | | 🟩 | | | 🟩 | | | | | |
| Bridled tern *Onychoprion anaethetus* | LC | | | | 🟩 | | | | | | 🟩 | | | | 🟩 | | | 🟩 | | 🟩 | | | 🟩 |
| Black-naped tern *Sterna sumatrana* | LC | | | | 🟩 | | | 🟩 | 🟩 | | 🟩 | | | | 🟩 | | | 🟩 | | 🟩 | 🟩 | | 🟩 |
| Fairy tern *Sternula nereis* | VU | | | | | | | | | | 🟩 | | | | | | | | | | | | |
| Great crested tern *Thalasseus bergii* | LC | | | 🟩 | 🟩 | 🟩 | | 🟩 | 🟩 | | 🟩 | | | 🟩 | 🟩 | | | 🟩 | | | | | |

🟩 Confirmed breeding

🟦 Resident/Suspected breeding (not confirmed)

American Samoa (AS), Cook Islands (CI), French Polynesia (FP), Federated States of Micronesia (FSM), Guam (GU), Kiribati (KI), Marshall Islands (MI), Nauru (NU), New Caledonia (NC), Niue (NI), Commonwealth of the Northern Marianas Islands (NMI), Palau (PA), Papua New Guinea (PNG), Pitcairn Islands (PI), Samoa (SA), Solomon Islands (SI), Tokelau (TOK), Tonga (TO), Tuvalu (TU), Vanuatu (VA), Wallis and Futuna (WF)

### 1.4.1 SPECIES STATUS IN OCEANIA

Of the species breeding within the region, three are Critically Endangered (Fiji Petrel (*Pseudobulweria macgillivrayi*), Beck's Petrel (*Pseudobulweria becki*), and Rapa Shearwater (*Puffinus myrtae*), three are Endangered (Phoenix Petrel (*Pterodroma alba*), Henderson Petrel (*P. atrata*), and Polynesian Storm Petrel (*Nesofregetta fuliginosa*), five are Vulnerable (Vanuatu Petrel (*Pterodroma occulta*), Collared Petrel (*P. brevipes*), Gould's or White-winged Petrel (*P. leucoptera*), Heinroth's Shearwater (*Puffinus heinrothi*), Fairy Tern (*Sternula nereis*)) and one is Near Threatened (Tahiti Petrel). There is also taxonomic uncertainty over several taxa (Tropical Shearwater (= Melanesian, Micronesian and Polynesian (Tropical) Shearwaters) (*Puffinus ssp.)*, Collared Petrel (= Magnificent Petrel (*Pterodroma magnificens*) and Collared Petrel), White-winged (Gould's) Petrel (= New Caledonian and Gould's Petrel) (*Pterodroma leucoptera ssp*), White-bellied Storm Petrel (= White-bellied Storm-petrel and Titan Storm-petrel) (*Fregetta grallaria ssp*), Fairy Tern). In addition, there are at least two or even three potentially undescribed taxa ('Samoan Storm-petrel', 'Coral Sea' or 'New Caledonian' Storm-petrel and 'Marquesas' Storm-petrel), recently regarded as one taxon, *Fregetta lineata*.[11]

**Figure 15. Fiji Petrel and New Caledonian Storm-petrel (Hadoram Shirihai), Heinroth's Shearwater (Peter Harrison), Phoenix Petrel and Polynesian Storm-petrel (Hiroyuki Tanoi)**

At national levels species status is something that is rarely considered. New Zealand, Australia and the USA have national threat status systems in place, but Pacific countries do not. It could be that a species' status is not threatened on a global scale yet may be highly threatened in individual countries. The loss of a species from a country represents a contraction in range and a loss of biodiversity from that country with all the associated ecosystem benefits.

### 1.4.2 ADDITIONAL SPECIES FOUND IN OCEANIA

There are many seabirds that breed outside the region that have been recorded within the Pacific Island Exclusive Economic Zones (EEZ). These records are either published in scientific papers, journals, citizen science internet databases, or are data derived from species carrying tracking devices. Several species are annual trans-equatorial migrants, which breed mainly in Aotearoa New Zealand and Australia and spend their non-breeding months north of the equator. Species breeding in Japan and Hawaii, such as Streaked Shearwater (*Calonectris leucomelas*), Newell's Shearwater (*Puffinus newelli*), and Wedge-tailed Shearwater (*Ardenna pacifica*), Hawaiian Petrel (*Pterodroma sandwichensis*), and Matsudaira's Storm Petrel (*Hydrobates matsudairae*) range south towards the equator, and in some cases further south in the Southern Hemisphere.

Figure 16. Flesh-footed shearwater off Japan, showing wing moult. These birds breed in New Zealand and Australia during the Austral summer, then migrate to the North Pacific where they undergo a progressive moult. Photo: Hiroyuki Tanoi

### 1.4.3 TERRESTRIAL HABITATS – BREEDING AND ROOSTING LOCATIONS

Breeding habitats for seabirds range from the large mountainous islands (e.g. New Ireland (Papua New Guinea), Bougainville (PNG), Kolambangara (Solomon Islands), Vanua Lava (Vanuatu), Grande Terre (New Caledonia), Taveuni (Fiji), Gau (Fiji), Tahiti (French Polynesia)); to medium and small-sized islands, including (e.g. Mathew and Hunter Islands (New Caledonia), Ata (Tonga), Rarotonga (Cook Islands), Tutuila and Ta'u (American Samoa) and Rapa islets (French Polynesia)); raised atoll islands (makatea) (e.g. Walpole Island (New Caledonia) and Henderson Island (Pitcairn Islands)) and to low-lying atoll islands (e.g. Marshall Islands, Kiritimati and Rawaki, Line Islands (Kiribati), Chesterfield Reef (New Caledonia), Rose Atoll (American Samoa), Oeno (Pitcairn Islands), Ducie (Pitcairn Islands)).

Figure 17. Large mountainous island: Kaua'í, Hawaii. Photo: André Raine.

Figure 18. Raised atoll (makatea) island: Walpole Island, New Caledonia. Photo: Mathieu Mathivet.

Figure 19. Medium-sized island, Rarotonga, Cook Islands. Photo: Te Ipukarea Society.

Figure 20. Small volcanic (active) island: Mathew Island, New Caledonia/Vanuatu. Photo: Mathieu Mathivet.

**Figure 21. Nishinoshima Island, Japan. Photo: Kawakami from the Asahi Shimbun airplane.**

Most Pacific islands are volcanic in origin and the beginnings of their terrestrial ecologies can be due to seabirds, roosting initially, then breeding. Species such as boobies, noddies and terns can roost on vegetated islands, and can transfer seeds to the bare ground on new islands. Nishinoshima Island is an active volcanic island in the Ogasawara Group, Japan. On this island, eruptions have buried all previous seabird breeding grounds in lava. The eruptions are continuing intermittently (2024), but seabirds such as boobies and terns have resumed breeding.

Collectively, Oceania's seabirds use the full spectrum of nesting habitats: nesting above the ground in shrubs and trees, on the ground, and in burrows below the ground's surface. White-tailed Tropicbirds (*Phaethon lepturus*) can nest in hollow trees, in arboreal tree ferns and in overhanging rock cavities. Ground-nesting birds (Brown Booby (*Sula leucogaster*) and Masked Booby (*S. dactylatra*), Red-tailed Tropicbird (*Phaethon rubricauda*), Grey Noddy, Sooty Tern (*Onychoprion fuscata*) and some petrels and shearwaters can be separated into those that nest in open ground and those that prefer shade, finding it under rock overhangs, on ledges with rock overhangs above them, under shrubs or within forest. Those that nest in trees include Red-footed Booby, frigatebirds, Black Noddy and White Tern. Brown Noddies (*Anous stolidus*) nest both in trees and on the ground.

Several petrels, some shearwaters and storm petrels nest in burrows which could be located on small islands or far inland up valleys and on ridges and peaks of the interior of larger islands. The microhabitat of these burrows can be highly varied from coral rubble, barren lava flows (including lava tubes and caves) and sparsely vegetated scree slopes to scrubby shrublands and dense forest vegetation. Colonies can be located in coastal habitats all the way up to many kilometres inland in interior cloud forests and mountain top plateaus. Burrow size can also vary significantly. Smaller species (such as storm-petrels) typically have very narrow entrances and may not even have typical burrows, instead using cracks and crevices or gaps under rock piles. Conversely larger petrels and shearwaters can have wide-mouthed burrows that range from their body size up to cave entrances, and these can be either shallow structures or extend back three or more metres.

When not at their nests, some species (such as boobies, frigatebirds and terns) will roost in other places, on rocks, cliffs or in trees. There are other species that disperse far away from their breeding grounds outside the breeding season, becoming strictly oceanic until the next breeding season (i.e., petrels, shearwaters and storm-petrels).

## 1.5 TRADITIONAL KNOWLEDGE AND CUSTOMS

Seabirds have long played an important role in the culture of communities living in proximity to them. They are found in folklore, totemism, dance and art, as well as providing a subsistence resource for many Pacific peoples. Seabirds played a critical role in the settlement and navigation of the Pacific, including the long-distance voyages that in part utilised seabirds to help guide their paths. Some seafaring peoples used seabirds that they knew would be heading to land to roost at night, such as noddies and white terns, to indicate when they were close to land. Seabird behaviour continues to assist people in finding fish at sea (tuna birds) and provide information on oceanic weather patterns. Annual harvesting of chicks, eggs and in some case adults is also an important traditional activity for several Pacific cultures and communities.

Figure 22. Frigatebird motif on a carved bowl, Marovo Lagoon, Solomon Islands. Photo: Chris Gaskin

### Traditional stories

The SPREP Seabird Action Plan 2022-2026 recommends preserving and protecting the traditional knowledge and values associated with seabirds in stories, artwork, video, audio and publications.[1]

Here we present two examples of traditional stories relating to seabirds. In the first instance, avian behaviour in the Pacific Islands is commonly interpreted as augural with regard to weather changes. In Tonga, when the lofa talamatangi or frigate bird (*Fregata spp.*) is seen to be flying across the land—unusual behaviour for an ocean species—this is interpreted as a sign that a tropical cyclone is developing/approaching, a piece of traditional knowledge captured in the logo of the Tonga Meteorological Service. Similar birds in Fiji are considered manu-ni-cagi ("wind birds") and are recognized throughout the archipelago. There are suggestions from local knowledge holders in the Pacific Islands that these documented uses of avian traditional knowledge represent only a fraction of what remains known and utilised in some communities, similar to those described below.[12]

A second example comes from a story told by villagers at Silur Bay, New Ireland, Papua New Guinea during interviews conducted during the Beck's Petrel Expedition in 2017.[13] This story was mentioned by two different interviewees and was as follows. "The Red-footed Booby is the 'mother of all the seabirds'. She lays an egg, which breaks upon the stones. When it breaks, a Beck's Petrel hatches out. The Beck's Petrel then lays an egg and either a Black Noddy or a Sooty Tern hatches out." The interviewees were not clear on whether or not the noddy or tern then hatches a Red-footed Booby to complete the cycle, although they thought it likely. This story may be a way of explaining the tight association of the different seabird species found feeding together around tuna schools. Local names for seabirds in Silur Bay, New Ireland: Red-footed Booby - 'Ngok Lonbon' or Hornbill of the Sea, Beck's Petrel - 'Pato Lonbon' – Duck of the Sea, Black Noddy (*Anous minutus*) - 'Manamus', Sooty Tern - 'Kanai'.

Fig 23. Identifying seabirds with villagers at Silur Bay, New Ireland, Papua New Guinea. Photo: Bill Morris.

## 1.6 THREATS

Seabirds face a wide and increasing range of human-induced threats to their survival across Oceania.

### 1.6.1 TERRESTRIAL

Introduced predators are one of the most devastating threats to bird species in the world, and their impact on seabirds on islands can be catastrophic. Seabirds breeding on islands are particularly vulnerable to introduced predators. This is due to a number of reasons. Seabirds have evolved without mammalian predators and thus are particularly naive and vulnerable to the threat they pose. This is coupled with the fact that invasive species are usually highly adaptable, can live in a wide range of environments and breed rapidly, meaning they can quickly become widespread. When they are introduced to a new place, they have usually left the diseases and predators that would have kept their numbers under control back in their home range. In the Pacific these species include cats, rats (multiple species including Polynesian, black and Norwegian), mongoose, pigs, goats, dogs, brown tree snake, and various ants (such as Yellow Crazy Ant and Little Fire Ant).

Habitats important to seabirds can be greatly affected by rural and urban development, conversion to plantations, agricultural expansion, mining and logging. This results in seabirds, especially burrowing seabirds, being largely confined to remote islands, small, rugged islets, or at high elevation on large islands which are less developed.

Introduced plants also impact breeding colonies of birds. Invasive species such as Australian tree fern, guava and ginger in Hawaii, for example, are rapidly taking over native vegetation in remote mountain breeding colonies for 'ua'u (Hawaiian Petrel) and 'a'o (Newell's Shearwater), making it impossible for burrow nesting species to continue to use traditional colony areas.

- Light attraction can have a significant impact on certain seabird species, particularly certain shearwaters and petrels. Light pollution can come from a wide range of sources including towns and cities, industry, transport networks, stadiums and sports fields. Light sources at sea (including oil rigs, merchant ships, cruise ships, and fishing vessels) can also lead to mass groundings of fledglings, which get grounded when they leave the darkness of breeding colonies for the first time, are attracted to lights and eventually end up on the ground (either through exhaustion or collision). Once grounded they typically cannot recover flight and die from predation, being run over by cars, or from starvation or dehydration. Bright lights in or near petrel and shearwater colonies can also ground adult birds.

- Infrastructure collisions. This can be a particular threat to seabirds transiting between the sea and inland breeding colonies at night. Birds are not able to see powerlines or guy wires that stretch across their flight paths, and they collide with the lines and can either die instantly or are injured and die later in their colonies. For populations of rare inland breeding species this can be one of the most critical conservation issues as it can impact large numbers of adult birds. It is also one of the hardest threats to measure, as birds colliding with lines in the darkness are notoriously hard to quantify and require specialised methods.

- Climate change is bringing about significant changes affecting seabirds in the Pacific:

    - Low-lying atoll islands are very susceptible to rising sea levels and storm surge events.[14] In these scenarios, entire colonies can be destroyed as the ground under them literally disappears. In some cases, this could lead to the eventual abandonment of the largest colonies of certain species. For example, sea level rise predictions suggest that millions-strong colonies of Laysan and Black-footed Albatross breeding on islands in Papahānaumokuākea (the North-western Hawaiian Islands) will soon become displaced. The combination of lost nests, reduced reproductive success, and displacement could quickly endanger a species' long-term potential for survival.

    - Burrowing seabirds can be at risk of extreme weather events, such as storms, causing landslips, erosion of burrow habitat and washout of adults, eggs, or chicks, depending on the time of year.

    - Other potential impacts include increases in parasite loads, increase in disease risks and increases in 'natural' predators such as land crabs as they take advantage of different fruiting loads due to increase rainfall events in some locations.

- Harvesting of chicks, adults and eggs are important traditional activities for several Pacific cultures and communities. However, where contemporary populations consist of small remnants or are rapidly declining, harvesting, especially poaching could hasten the extirpation of species in those places where it occurs.

- Disease is a periodic threat to all seabird species, particularly those in dense colonies, and so greater potential for transmission. Outbreaks of disease (such as avian flu and avian pox) are often related to extreme climate events where birds are under stress, weakening their immune capabilities. Disease has the possibility to negatively impact seabird populations by dramatically increasing both adult and chick mortality and can happen within a very short period of time.

- Data deficiency. Although not an obvious and tangible threat, the lack of knowledge of where some species breed, forage, migrate or overwinter and even key life history traits (e.g., Fiji and Beck's Petrels, and Heinroth's Shearwater) means action cannot be taken to halt a decline or even the extinction of a species.

### 1.6.2 MARINE

- Globally, commercial fisheries have had significant impacts on seabird populations. Long-line, gillnet (or setnet) and trawl fisheries have been notorious for pelagic seabird by-catch and overexploitation of fish stocks. Seabirds are opportunistic foragers and are often drawn to discards and offal from working fishing vessels. Reporting from fisheries shows that most seabirds caught within Pacific island countries EEZs are those that breed elsewhere, however bycatch rates of seabirds breeding within the region are largely unknown.
  - Beyond by-catch, fisheries may impact seabird populations by reducing available prey species, particularly at crucial periods of the breeding cycle where parents are foraging for both themselves and a dependent chick (or chicks). Loss of predatory fish removes their natural action of chasing their favoured prey to the surface and thus having these smaller fish available for seabirds[15]. In addition, the large-scale removal of both prey and non-prey species may compound the direct effects that impact seabird populations, where indirect effects result in greater declines.
- Pollution:
  - Marine plastic pollution is a pervasive global issue. Seabirds can ingest plastics mistaken for prey at sea and fed to chicks. Plastics cause internal blockages or perforations or result in gradual starvation by filling the digestive tract in place of food, preventing birds from fledging.
  - Birds can also become entangled in marine debris including abandoned, lost and discarded fishing gear (ALDFG).
  - Oil spills can be caused by vessels wrecking on shorelines or reefs, fouling and killing seabirds foraging in the slicks. There is also an unquantified risk of oil pollution from sunken World War II wrecks in the Pacific, such as at Truk Lagoon. Oil at sea is a threat to seabirds because it forms a thin layer on the water surface where many seabirds spend most of their time. Likewise, other marine life, including prey species for seabirds can be affected. Oil discharges from vessels can be caused by malfunctioning equipment, negligence, or wilful illegal actions including tank washings, dirty ballast, and bilge pumping.
- Deep-sea mining may irreparably harm ocean ecosystems before we have a chance to understand the extent of its impacts, including to seabirds.
- Climate change:
  - Greater storm intensity and frequency will increase the turbidity of coastal waters, which may impact foraging success in visual foragers such as boobies, noddies and terns. It can also have severe impacts on the breeding colonies themselves as noted above.
  - Certain prey species may decline or shift in their distribution, confounding their pulse timing relative to seabird breeding cycles. This could have serious knock-on effects for reproductive success and even make large areas of current breeding distribution no longer suitable for seabirds in the future (particularly species with short foraging ranges). It is possible that other prey species may take their place, potentially ameliorating the loss of one resource with another. The implications of this will depend on whether the replacement is a suitable replacement (similar energy content by foraging effort) to the original prey source, and how this may impact reproductive success and long-term survival. For seabirds that disperse following breeding reduction in available food resources in non-breeding areas could lead to reduction in breeding fitness.

## 1.7 KEY STEPS IN DEVELOPING A SURVEY AND MONITORING PROGRAMME.

Choosing the best method, working within budgets, personnel skill sets, and expertise.

| | **SURVEY PLANNING AND IMPLEMENTATION STAGES** | |
|---|---|---|
| **1** | Establish purpose of survey and/or monitoring programme - need to clearly establish WHAT you want to survey and monitor and WHY (e.g. the question or objective behind it, such as "in 10 years we want to know whether X has increased") | |
| **2** | Species to be studied (if known), location (island, island group, or part of mainland), project partners, funding availability | |
| | **Survey Design** | **Planning/logistics** |
| **3** | Decide on the best methods to use – your tool kit | Identify government agencies / permitting requirements |
| **4** | Identify all your survey equipment requirements (e.g. what to purchase, loan, or use from own stock) | Identify communities in vicinity of site – make contact and gain approvals/support from the community noting most land is communally owned not government owned in Pacific Island Countries and Territories (PICTs). A collaborative approach where community members are involved is often highly appropriate and critical to success. |
| **5** | Draft survey maps | Obtain detailed topographical maps of the site to be surveyed; also, aerial images, or Google Earth imagery |
| **6** | Timing – dependent on species' breeding cycles (are they known for the species population in your area?); are repeat surveys to be worked into the plan? | Timing for conducting fieldwork – e.g. team to assemble, how many field trips |
| **7** | Sampling requirements – which samples need to be taken and for which stage of breeding | Field camp requirements and logistical considerations. |
| **8** | Tracking requirements (if needed) – determine which devices to use and when to deploy | Assess what accommodation is required locally for before start of surveys. |
| **9** | Identify field base sites | Work out travel requirements (e.g., flights, vehicles, boat transfers) |
| **10** | Training – consider capacity building to be incorporated into the survey plan | Personnel – who will lead the survey, how many will be required and who the ideal participants will be. |
| **11** | Travel to survey site and meet with local community leaders; meet and brief local field workers | |
| **12** | Draft your project proposal and finalise the budget | |
| **13** | Secure funding | |
| | Implementation | |
| **14** | Book transport and accommodation | |
| **15** | Equipment purchases | |
| **17** | Provisioning | |
| **18** | Undertake field work | |
| **19** | Results | |

| | Reporting | Conservation management |
|---|---|---|
| **20** | Data management and analysis (See Section – 4.1) | Identify threats (implementation dependent on the severity of risk to seabirds identified) |
| **21** | Report findings to communities | Identify key management actions necessary |
| **22** | Prepare reports for sponsors, Government officials, noting depending on arrangement with government they may require access to raw data as well as reports. | Identify remaining data gaps |
| **23** | Publish results (consider doing so in peer-reviewed open-access journals or as a readily accessible report) and/or management plan | Identify next steps to be taken (including setting up and implementing any ongoing monitoring programmes) |

### 1.7.1 THE IMPORTANCE OF SURVEYS AND MONITORING TO INFORM ADAPTIVE CONSERVATION MANAGEMENT

Adaptive management is a process that promotes flexible decision making in the face of uncertainties as outcomes from management actions and other events become better understood. Surveys and monitoring are critical parts of effective species conservation; however, conservation monitoring programmes must have preplanned interventions and a clear statement about how the information derived from monitoring will help to conserve or otherwise benefit the species. Conservation monitoring programmes and management plans should ideally identify trigger points for prespecified management intervention, in fact this may be the reason for the monitoring project in the first place. Management intervention should be triggered when it becomes apparent that a monitored species is in long term decline,[16] although there is room for adopting a precautionary approach.

For example, Wedge-tailed Shearwaters (*Ardenna pacifica*) ('ua'u kani) are monitored in Maui Nui, Hawaii. The species has not been determined to be in 'long term decline'. However, the species was in the islands in much greater numbers before human alteration of habitat and introduction of predatory mammals. Monitoring, including soil and near shore coral reef habitats for presence and impacts of seabird derived marine nutrients, will provide justification for community/agency support for protection and maintenance of healthy populations[17].

Seabird species most at risk in the Pacific are the petrels, shearwaters and albatrosses, therefore, it is important that sufficient conservation efforts are directed to this order of birds in particular.

## 1.8 WORKING WITHIN OCEANIA COMMUNITIES

Despite all the best intentions, no seabird survey or monitoring programme will succeed in Oceania without the support and engagement in-country of the relevant national and local government agencies, and communities, some of which are very remote and isolated. Critical first steps in project planning are identifying those various agencies and groups, together with identifying the local communities which hold ownership rights to areas where surveys are to take place and full understanding of the permitting requirements. Collaborating with a national or international Non-Governmental Organisation (NGO) group that is active in the areas you want to survey can facilitate the necessary introductions and meetings required to get projects underway.

If you are a local researcher (either working for an NGO or independently) and want to undertake a survey, the stages of planning and implementation set out in the previous section remain essentially the same. The only difference is whether you want to bring in expertise from outside your country or territory. Given the challenges conservation efforts face in Oceania (such as limited in-country capacity in seabird research and conservation management, limited resources including funding, and the equipment needed to run surveys) there are benefits from collaborating externally.

This is where networking can be particularly important. Attendance at seabird symposia, meetings and workshops where you meet experts and others like you working on similar projects will present you with the possibility of making useful contacts that can help you with your project (either as collaborators or advisors). These venues also provide you with the opportunity to see what others are doing, the methods they are employing and the results they are achieving. The proposed establishment of a Pacific Seabird Expert Advisory Group[18] will also be a useful resource (see Section 5.2).

### CASE STUDY - Rapa, seabird restoration and the community

**Tehani Withers, Island Restoration Project Manager, Société d'Ornithologie de Polynésie (SOP Manu)**

Rapa Island in French Polynesia is a very important site for seabirds with 11 species present, mainly composed of petrels, shearwaters and storm-petrels. Three species breeding on its uninhabited motu (reo maohi for 'islets') are now in danger of extinction: the Rapa Shearwater (also known as Kākikāki) the Titan storm-petrel (a subspecies of White-bellied Storm-petrel) (*Fregetta grallaria titan*) and the Polynesian Storm-petrel – the latter two locally named Koru'e. These species are very rare and difficult to observe and are of important scientific interest. Indeed, it is suspected that the Rapa shearwater and the Titan storm-petrel breed nowhere else in the world.

Rapa provides an ideal site for the protection of these species due to its large number of uninhabited motu, its remoteness and the diversity of seabird species present; however, like elsewhere in the Pacific, Rapa's seabirds face a variety of threats. On the islands, invasive animals predate eggs, chicks and adult birds, and invasive plants encroach into and degrade breeding habitat. Therefore, the restoration of Rapa's motu (Tauturou, Karapoo rahi and Rapa iti) - including the removal of invasive animals and plants - are considered essential by the Polynesian Ornithology Society (SOP) Manu and its partner, BirdLife International. Since 2017, SOP Manu have helped the Rapa community to restore uninhabited islets for the protection of seabirds by removing goats. In 2023 a rat eradication project was also initiated, and the success of that project will be assessed in mid-2025.

Figure 24. Looking towards the main island of Rapa from the summit of Tauturou. Photo: Tehani Withers, SOP Manu

Another objective of the seabird restoration work on Rapa is to regularly monitor seabird populations. Monitoring began in 2020 with the help of Raumatariki, an environmental NGO on the island whose objective is biodiversity protection. This was mainly done through ground searches and the use of trail cameras. From this, it was found that Tauturou contains the largest colony of Murphy's Petrel (*Pterodroma ultima*) in French Polynesia (approx. 2800 pairs). A significant decline in Kākikāki colonies was also detected, with a population estimate of less than 200 pairs. This population decline is likely due to the effects of invasive species, but additional pressure is possible through changes in the marine environment surrounding Polynesia such as overfishing and pollution affecting prey species.

In order to discover what might be causing the decline in Kākikāki colonies, a team set out to determine where the birds travelled during December-February each year when they were away from the islands, and therefore what threats they might face at sea. In 2019, a team including Jean-Claude Thibault (ornithologist), members of SOP Manu and Raumatariki field workers attached lightweight GLS tracking devices to 10 Kākikāki to determine their migration routes. The following year, the team tried to recapture the birds to retrieve the devices but were only able to recapture one, as the birds were elusive and difficult to catch on land. Initial results from this device show the Kākikāki travelling south after tagging, and several locations have been recorded around the Pitcairn Islands, New Zealand and Chile.

Raumatariki, with the help of SOP Manu, work hard to preserve Rapa's natural and cultural heritage with the help of local communities. For example, Raumatariki have helped to fence destructive ungulates (oxen, horses and goats) out of endemic forests so that the forests can recover from grazing. They also work with local students to teach them about the biodiversity on the island and why it must be protected by showing them the restoration projects organised by Raumatariki and SOP Manu. The students help to remove invasive grass to protect the koru'e colony at Tarakoi and have visited the petrel colony on Tauturou. Future work to protect Rapa's birds includes eradicating rats from more motu, controlling invasive strawberry guava on Tauturou and fencing more indigenous forest from ungulates. This project was funded in 2023 by Fond Vert (France) and will be carried out by trained local people and overseen by Tehani Withers & SOP Manu from Tahiti.

**Figure 25. Tarakoi habitat restoration (removal of Melinis grass) with the local community of Rapa. Photo: SOP Manu**

### 1.8.1 TRAINING AND CAPACITY BUILDING

The Pacific Regional Seabird Action Plan[1] highlights the importance of capacity building and collaboration with Pacific Island nations and communities through two objectives:

Objective 1: Increase capacity for monitoring and managing seabird populations at community and national levels

Objective 2: Enhance national, regional, and international collaboration

Each objective has specific actions and indicators. Those relevant here are as follows:

1. Help communities to build skills and knowledge in mapping, recording, and monitoring seabird populations, and to participate in conservation programmes (e.g. access to expertise and resources, including possible exchange programmes with countries that have greater expertise).
    (i) Communities supported to build knowledge and skills to manage conservation of seabird colonies, e.g. exchange programmes.
2. Encourage the transfer of seabird knowledge and expertise between projects through exchange opportunities for conservation workers.
    (i) Exchange opportunities are provided for conservation workers.

Figure 26. Searching for Vanuatu Petrel burrows around Qwelraqraq, Vanua Lava. Photo: Monash University

## CASE STUDY: Community engagement in Vanuatu Petrel research

### Peter Allen, Monash University, Australia

A team has been conducting research to clarify the conservation ecology of the Vanuatu Petrel (Qetlap), a gadfly petrel that is a breeding endemic to Vanua Lava, northern Vanuatu. This region is exceptionally remote, so to facilitate long-term conservation outcomes they are working closely with national and local government and remote communities to build monitoring capacity on Vanua Lava.

The team includes staff from the Vanuatu Department of Environmental Protection and Conservation (DEPC), who have been instrumental in managing community relations and launching the project in-country. As well as managing permitting, DEPC staff have accompanied every field trip to liaise with communities and participate in research activities. Benefits to this knowledge-sharing model include streamlining administrative processes, deepening the ability of the team to meaningfully engage with communities, and building skills in contemporary seabird research within the DEPC. Departmental participation in the project has built in-depth knowledge of the Vanuatu Petrel (Qetlap) for future DEPC-led conservation efforts and contributed to skill development for wider application around Vanuatu.

This research is being conducted after a request of the Ventimboso community on Vanua Lava requesting research on the island's seabirds to better understand their population size and ecology on-island, providing solid foundations for access to community lands, and bringing local people onto the team. Nonetheless, active participation in customary practices has been vital to establish the project. This has required close consultation with the DEPC to ensure that community expectations are being met (e.g. participation in kava ceremonies and giving and receiving gifts). This is especially important as the Vanuatu Petrel/Qetlap is culturally iconic, and their breeding area, an active volcanic vent called Qwelraqraq, is a significant site for the community.

**Figure 27. Field team at camp in Qwelraqraq, Vanua Lava. Photo: Monash University**

Knowledge of the importance of the Vanuatu Petrel was only gained after embedding in the local community prior to conducting research. The team spent eight days living in villages to engage in customary practices, leading to many informal conversations and meetings with community members. It was these less structured discussions that contained important insights and evoked more detailed questions about the species. Useful information was gained about historical Vanuatu Petrel harvests, the presence of invasive predators, and bird movements in this way, informing the research approach before any visits to the colony. Such an unhurried approach to engagement is important for success.

Figure 28. Vanuatu Petrel (Qetlap). Photo: Monash University.

Even spending substantial time in communities, the process of establishing good communication can be challenging. Language barriers, cultural differences, and limited forms of digital communication can all hinder open dialogue. This means mistakes can be made, such as important community members being omitted from conversations. When these missteps are identified, a proactive response to resolve them through direct communication is essential. Timely and transparent responses to miscommunications and misunderstandings are key to successful long-term engagement.

Conversations in communities have been vital to identify local members for the project team and understand possibilities around implementing training and long-term monitoring led by local people. To date, a hybrid model has been implemented where local champions with specific interest in the birds or the research are employed to provide logistical field support for the project and participate in research activities concurrently to build technical familiarity. This process is characterised by two-way knowledge flow, with field skills (e.g. locating bird burrows in the environment) from local people complementing modern research approaches and technologies provided by the international team members.

The core lesson garnered from the work on Vanua Lava has been the importance of identifying local needs and interests, and seeking to address those through research, in concert with addressing a priori study questions. For example, it is possible to support local tourism by recommending locations for development in remote parts of Vanua Lava, informed by the understanding of bird movements to minimise impacts from clearing, track opening, and nocturnal lighting. Another critical component to success in this approach has been the international team lead learning the local language to a conversational level, enabling direct communication of project aims, activities, and outcomes. These lessons are informing ongoing engagement and training plans, by developing a communication model in collaboration with DEPC staff and community members to ensure that results and future plans can be widely disseminated in a way that is meaningful for local communities.

# PART TWO

## Survey Tools & Types

Acoustic sensor in situ, Kaua'i, Hawaii. Photo: André Rainé.

## 2.1 SURVEY TOOLS

This section looks at the many different methods that can be used to run successful surveys; think of them as tools for your toolkit. Methods that work well on one species may not work at all for another, so consider your study species carefully. Are you monitoring a colony of thousands of Sooty Terns, a scattered population of cryptic burrow-nesting Tahiti Petrel, or trying to find the breeding site for Fiji Petrel? The tropical Pacific is also a challenging environment in which to work, and it can be tough on survey teams and equipment. There are good reasons for keeping it simple – making sure to choose only those methods that will reliably give you the results you want. It is also vitally important to do a precheck on all of your equipment (e.g., acoustic sensors/recorders, trail cameras, drones) beforehand so it will operate without glitches once deployed. There is nothing more frustrating than getting out to a remote site only to discover a critical piece of equipment is malfunctioning. Problems like that can have serious ramifications on your project's budget, timeline, and effort if you have to go back and do it all again.

### 2.1.1 THE VALUE OF HISTORICAL DATA

Another initial first step for obtaining information about the distribution of seabird breeding sites is to review historical records. Have there been any previous surveys for the species? If so, are there any reports or relevant publications that you could obtain? Historical data helps to focus surveys, as well as providing a potential baseline for your surveys. Additionally, contemporary observations are also extremely helpful – apps such as eBird provide a way of reviewing current records of the species to help guide your surveys, as well as contacting local NGOs or birding groups. Once you have done your review of previously available data, it is time to consider undertaking your own surveys.

The Pacific Seabird Colony Database (see Section 4.2) holds colony count data, all of which are referenced to papers and reports, a lot of them are pre-twentieth century. The database would be a key resource for any proposed survey.

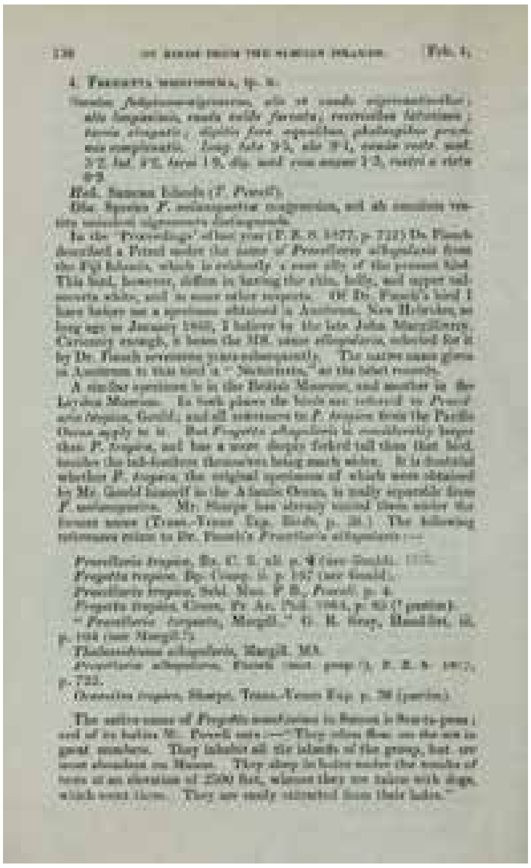


Fig 29. Original description (left)[19] and specimen (above) of the dark-morph Polynesian Storm-petrel, Manua Islands, American Samoa. Photo: British Natural History Museum.

## CASE STUDY – A species lost, rediscovered, or waiting rediscovery?

In 1839, a distinctive streaked storm petrel was collected in Samoa by the naturalist T. R. Peale during the US Exploring Expedition (US Ex Ex). The specimen is held at the National Museum of Natural History, Smithsonian Institution, Washington DC. It was described as a new species *Thalassidroma lineata* (now *Fregetta lineata*).[20]

The original description of this bird includes artwork by Peale. Unfortunately, little was recorded by either of the naturalists of the expedition, other than the following journal entry by Peale: "This bird was frequently seen within the torrid zone, in the Pacific Ocean. A single specimen was obtained at the Island of Upolu, from a native, who represented to us that during the breeding season this species lives in holes, very high up in the mountains." The three expedition vessels were at the Samoa Islands from 8 October to 10 November 1839. Some of that time was spent in American Samoa (Tutuila), with the remainder in Samoa (Western Samoa) visiting both the main islands, Upolu and Savaii, and two of the smaller offshore islands, Manono and Apolima. Where exactly the bird was presented to Peale is not known; however it does appear to have been captured on land. The naturalists and survey parties did visit the island's interior and cross Upolu as well as climbing some of the high points, however the bird could equally have been presented at a village on the coast.

Since that time, five other 'streaked' storm petrel specimens were collected in the Pacific, one in the Marquesas in 1922, three in Aotearoa New Zealand (two in 1829, one in 1895). More recently, sightings of streaked storm petrels at sea have led to the confirmation that the three storm petrels from Aotearoa are the New Zealand Storm-petrel (*Fregetta maoriana*) which have been discovered breeding on Te Hauturu-o-Toi (Little Barrier Island), only 50kms from Auckland.

Furthermore, streaked storm petrels have been seen in recent years off New Caledonia and Australia, dubbed the 'New Caledonian Storm-petrel' or 'Coral Sea Storm-petrel', and a recent paper argues that these birds, along with the specimens from Samoa and Marquesas should be treated as the same species – *Fregetta lineata*.[11] However, although the reasoning is supported by high quality photographs, comparing birds at sea to the museum specimens, remains speculative.. Genetic confirmation is required to determine the taxonomic status of this enigmatic group of small seabirds.

**Figure 30. The only specimen of *Fregetta lineata* is from Upolu, Samoa. Photo: National Museum of Natural History, Smithsonian Institution, Washington DC, United States of America. Art by T.R. Peale.[20]**

### 2.1.2 COMMUNITY SURVEYS

There is a wealth of knowledge about seabirds to be found at the grassroots level within the communities of the Pacific, especially among people who are living in close proximity to the birds you are interested in. Do not underestimate the power of traditional ecological knowledge (TEK); people who have lived in the area you are focussing on for many generations will likely have a deep understanding of the birds, where they live, their seasons, and their ecology. Therefore, community surveys are often a good place to start when assessing an area for the first time.

Birds nesting in trees (such as Black Noddies and Red-footed Boobies) will be well known, as will those birds seen catching fish in lagoons or over the open sea foraging alongside tuna schools. People will see and hear birds calling when flying over villages, both during the daytime, and at night. They might also be familiar with birds they find grounded, such as fledgling petrels and shearwaters attracted to lights of villages and towns. There is the potential to gather data on seabirds and where they might be nesting by visiting communities, through formal meetings and following local protocols, by visiting schools, or talking to people living in isolated places. Social media and printing posters and fliers can also be used to get people to report data on seabirds. If someone has knowledge of where birds are nesting or roosting, then it is the location which is important, so a follow up plan can be made, ideally involving that person as a guide.

**Method**

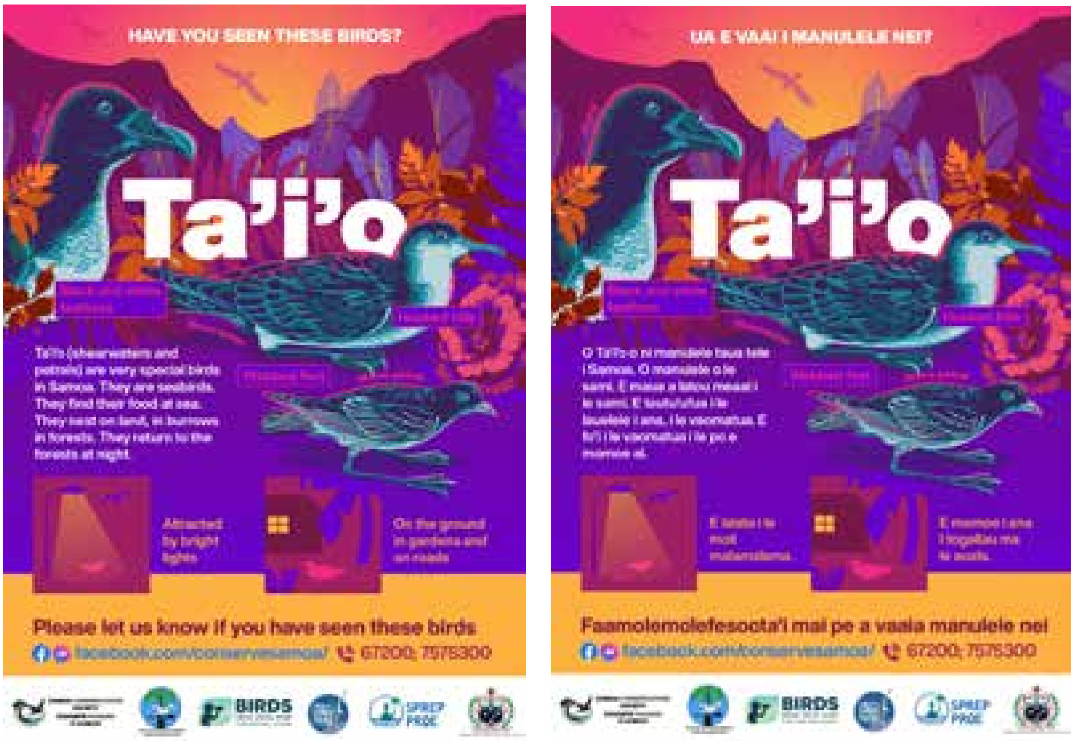
Community surveys typically involve in-person meetings with individuals or groups to assess the prevalence of species, distribution, aspects of their breeding and foraging ecology, rarity, whether or not people are utilising them (e.g., directly for food, or indirectly to find fish) and any potential threats they may be facing. Resources that can be used to help identify seabirds will be required and will need to include accurate illustrations of seabirds from field guides and photographs, with images as hard copy, as posters, on a tablet, or via PowerPoint projected onto a big screen at meetings. Training for the people who will conduct these surveys will be essential. This can be done through workshops, or through mentoring, as well as accompanying an experienced person during community visits. Surveys should be conducted in the language most familiar to the community to be surveyed. If external experts are used, then having at least one person in the survey team fluent in the native language is also essential. There may also be important cultural protocols for how the surveys should be conducted within communities including gaining permission from the village chief and these would need to be strictly followed. Free, prior and informed consent processes should also be followed.

**Figure 31. Knowledge café on seabirds for community groups across Samoa held at SPREP campus, Apia. Photo: SPREP.**

Lastly, be aware of potential pitfalls for conducting community surveys. For example, people being interviewed may not be able to tell subtle differences between similar species (resulting in misidentification) or may feel compelled to say they have seen a species because they feel under pressure during the interview process. With this in mind, it is important to include photos or illustrations of species not found in the region as a way of testing knowledge and identification skills, and to remember that just because someone says they have seen a particular species in the region it may not actually be the case. Furthermore, raising the profile of seabirds could result in unwelcome responses, such as an increase in harvesting (especially if in the process of interviewing, the interviewer discusses novel capture techniques). That said, these surveys and conversations can bring to light the extent of harvesting by communities, a topic that needs to be handled carefully by people outside those cultures.

**When to use**

A first step is to assess the level of awareness of people living in the area. This could be accomplished by undertaking community surveys, which could take place at any time of the year (there would be no need to consider breeding seasons for example at this early stage). Using this feedback, combined with knowledge of when the species is breeding in other areas, you can then determine the best periods to conduct more comprehensive field-based surveys using methods outlined below, provided there are people available and there's a budget to support the work.



Figures 32 & 33. Posters produced in Samoa to encourage people within the communities to report on seabird sightings, especially grounded petrels and shearwaters, birds attracted to lights. Posters: Samoa Conservation Society/ Samoa Ministry of Natural Resources & Environment.

**Data collection**

All survey results, i.e., records of when/ where birds have seen, should be gathered into a spreadsheet, date, time of day/night, location of what was seen or heard, the name of the person who made the report, contact details, the community's name, and comments on any protocols governing use of the information. Data collected from the communities can lead to follow-up field-based surveys, using any one of the methods covered in the next sections of this manual.

### 2.1.3 ACOUSTIC SURVEYS

Acoustic surveys often follow up on historical records, or from current reports of seabirds. These could be observations of birds during the day or, in the case of many Procellarids, birds flying over and calling at night. In the simplest form it is a case of surveyors heading out at night, going to locations where birds have been reported and listening for their calls. Human hearing can be very acute, allowing a listener to get an idea of the direction and distance from where calls are coming from. Or, if the birds are flying over, observers may ascertain the direction in which they are travelling. These observations can lead to further investigation using acoustic sensors (see next section).

**Nocturnal Surveys**
Many Procellarid species are only active at their colonies during the night, spending the days far out at sea hunting their marine prey. This presents particular challenges for surveying, as well as safety considerations. However, undertaking nocturnal surveys is an important facet of studying these species, as these surveys help to locate breeding colonies and active burrows as well as focus management actions to core activity areas. Nocturnal surveys often include both an auditory component (such as tallies of calls) and a visual component (actual sightings of birds, using specialised equipment like night vision and thermal binoculars/scopes).

It is a good idea to split surveys into discrete sessions (30-minute sessions are a good starting point) and include time within each session to collect weather data. Inclement weather conditions such as wind and rain can impact on the observer's ability to hear distant or faint calls and in some cases may mean there is no point in surveying. Keeping detailed data on the weather conditions throughout your surveys allows you to gauge the reliability of your data later and compatibility with surveys at other locations. For the auditory component, identifying what you are considering as a single data point is also key – classify beforehand what a 'call' is (i.e., a single unbroken note or series of notes). Throughout your surveys, include data on whether your data points relate to auditory or visual records. For each record, collect as much data as possible, including time of observation, species, direction from observer, distance from observer, and for visual records the behaviour of bird (with particular attention paid to activity indicative of breeding, such as circling behaviour and ground-calling). Recording data collection events where no seabirds were detected is also useful, as knowing when birds are not around is equally important.

At the end of each survey, it is also useful to draw polygons of seabird activity on a map (print out detailed topographical maps of your survey site beforehand and bring it with you). Categorise your polygons into levels of intensity (e.g., high, medium and low), draw arrows indicating transit routes, mark on the map where ground-calling was recorded etc. The more detailed it is, the more useful your map will be for guiding burrow searches or management actions.

Some important considerations:

- To carry out nocturnal surveys, it is important to familiarise yourself with your survey area during the day – look at the terrain around your survey location and assess where key features are (ridges, clumps of trees, drainages) relative to your position and how far away they are. This will allow you to better assess where birds are calling from or circling once it gets dark, as well as allowing you to make a safety assessment of the area for when you are moving around after nightfall. Make sure you are in position before it gets dark. Some species begin coming into colonies before dark, so again an understanding of the behaviour of your study species is key.
- Understanding when your species are active in colonies is critical – there is no point conducting surveys during a time of year or a time of night when the birds are not at the colony! If you do not know this, then carry out surveys at multiple points during the night (particularly the first few hours after dark and the first few hours before dawn, which are often periods of high activity within colonies for many Procellarid species). Literature searches could also provide you with useful information on directing your surveys, particularly in terms of breeding phenology data. Colonies are often particularly busy when birds first return to the colony and when sub-adults and prospectors are in attendance. Activity can often drop off as birds start incubating, and vocalisations can decrease when adults are feeding young. For many species there is a marked increase in non-breeder activity around hatching dates as the birds evaluate whether the colony is successful and therefore worth joining.
- Storm-petrels calls are often relatively quiet, and some species may only call frequently when they are on the ground. Conversely, some species can be selected for only aerial calling, for example, New Caledonian Gould's Petrels (*Pterodroma leucoptera caledonica*). This could be a result of the impact of cat predation which has largely killed off the population, so there are fewer birds on the ground vocalising[32].
- Many Procellarids respond to moon phase, with birds becoming quiet during the week before full moon (presumably a predator avoidance tactic). Use a lunar calendar as part of your survey planning process.
- The number of birds in a colony can also impact data collection. For a rare species, where there are only a small number of calls or sightings to record during your survey, you need to collect as much

data as possible.  However, in large colonies, it may not be practical to collect detailed data on every observations – large petrel and shearwater colonies can be overwhelming in the level of noise and activity.  In these scenarios, you can reduce the amount of data collected for each sighting (focus on the most important bits of data you need), utilise multiples (i.e., sightings of 10, 20, 30 birds etc), collect data using a counter, etc.  If you are using night vision or thermal binoculars, consider breaking your survey sessions down into portions where only auditory contacts are collected and those where you use your night vision.  For example, in a 30 min session, you could collect weather data for 5 minutes (which also gives you a chance to pause in frantic seabird data collection), 10 minutes for night vision, and 15 minutes collecting auditory data only.

### 2.1.4 ACOUSTIC SENSORS (REMOTE SOUND RECORDERS)

Acoustic sensors (remote recorders) are very useful tools for seabird researchers who wish to locate or monitor colonies. They provide a way to record seabird calls and can be deployed for long periods of time, allowing studies to span critical periods of when target species' breed, with data that are comparable year on year. They are particularly useful for nocturnal burrowing Procellarid species or large colonial ground nesting species such as terns.

Acoustic sensors can be utilised in four main ways in seabird studies:

1. Locating colonies of rare seabird species,
2. Comparing vocal activity between different colonies (as an inference of relative colony density, or times of year to assess when colonies are most active if breeding timing is unknown),
3. Used as a standardised measure of call rate change over time to assess management efficacy,
4. Assessing seabird collisions with powerlines and other similar infrastructure.

**Method**

Acoustic sensors should be deployed in areas where background noise (such as wind, waterfalls and rivers, roads etc) will least affect recording quality.

In colonies with little vegetation and limited rainfall, units can be set up on the ground and propped upright with rocks. If wind is an issue in this arrangement, a low rock wall can be built around the unit above the level of the microphone, keeping rocks clear of the microphones themselves, or you can install a foam windshield on the microphone itself. In areas with low ground cover but high rainfall, units can be mounted on poles driven into the ground. In these instances, units should be set at least a foot off the ground and attached securely to the poles using cable ties or bungee cords.  If there is vegetation around the microphones, this needs to be removed to prevent noise from leaves or branches touching the microphones or banging against them in the wind. It is recommended that microphones are also covered by a rain guard (such as a length of guttering that shelters the microphones but does not interfere with their recording capabilities). Lastly, acoustic sensors can be mounted on trees, especially in areas with dense ground cover. Again in areas with heavy rainfall, a rain guard is recommended. Make sure prior to deployment that all necessary ports and vent covers are present, and that rubber lining is in good condition to discourage water intrusion.

Best practice is to deploy acoustic sensors in the same way across the entire study area, to ensure that acoustic sensor recordings are comparable between units. Other factors to consider for unit comparison is terrain and surrounding vegetation. For example, are all units positioned on ridges or slopes, are some units under tree canopy and others not, are some units in windier areas than others? All of these elements may affect the soundscape around a unit and thus comparisons between units. It is recommended that photographs are taken of all deployments and that standard measurements are taken of the deployment area including surrounding terrain features, vegetation (canopy, ground cover etc), distance to water sources such as rivers/waterfalls etc.). These kinds of measurements are vital for understanding results during the analysis stage.

Proximity of units to each other is an important consideration. An understanding of how far the calls of the target seabirds can travel (and be reliably recorded by the acoustic sensor) is critical for assessing how far apart units should be deployed and how many units are needed.  To prevent double counting, the spacing of the acoustic units should be considered in the context of how far the species of interest calls travel in the environment (which can be identified during acoustic surveys as outlined in the previous section)

### When to use

Understanding when units should turn on or off is an important aspect of acoustic sensor deployments, as there is a trade-off between collecting data and longevity of batteries. Having sensors turn on when birds are quiet and off when they are vocal would entirely defeat the objective. Understanding the vocal activity times of the study species is therefore very important. Likewise, the focus of the research plays an important role in deciding when to have acoustic sensors recording. If the focus is assessing the impact of management over multiple years in a busy seabird colony where there are lots of birds calling, then having the units record less data each night over multiple months allows for units to make the best use of battery life. In this scenario you may set the unit to record one minute in every ten minutes for three hours after sunset and three hours before dawn. On the other hand, if units are being deployed in areas to assess seabird composition or look for a rare species, then it would be better to record more data each night (to maximise the chance of recording a rare call) at a wider nocturnal spacing. In this scenario you may set the unit to record one minute in every five minutes from sunset to sunrise every other night, or even have it set on continuous recording throughout the night. Lastly, the location of study sites can affect what settings you may use. A site that is logistically easy to access and thus change batteries and SD cards regularly might be set to record more frequently than a remote and difficult to access site that can only be visited every few months. For the latter case, also consider using larger capacity SD cards so the units can store more data.

Figure 34. Examples of acoustic sensor deployments. Top left, on the ground on a dry poorly vegetated island. Top right, mounted on a tree in wet montane colony. Bottom left, on a tree in wet montane colony with dense understory. Bottom right, deployed from a helicopter in a specially designed deployment box. Photos: André Raine.

### Analysis of data

Acoustic sensors can collect an enormous amount of data. For example, if one acoustic sensor is programmed to collect for one minute every ten minutes from dusk until dawn for three months, that equates to thousands of minutes of data. Then consider a project which deploys ten or twenty (or a hundred) units. Analysis of these data is therefore a critical factor when considering the use of acoustic sensors. There are several programmes that can be used to analyse acoustic data including Kaleidoscope by Wildlife Acoustics (https://www.wildlifeacoustics.com/products/kaleidoscope-pro) and the Cornell Lab's Raven software (https://www.birds.cornell.edu/ccb/raven-pro/). There are also companies that specialize in the analysis of acoustic data (such as Conservation Metrics Inc https://conservationmetrics.com/), which may be a viable option depending on the amount of data to be processed and the amount of funding available. However, if you want to do a quick check of some of your recordings then a programme like Audacity is useful – https://www.audacityteam.org/

**Use of recordings**

Recordings can be used for playback purposes including social attraction projects for locating burrows and for seabird restoration projects via playback (see Sections 2.1.5 and 4.4.2).

**Additional information**

Access to areas where the target species are breeding may not always be possible by foot – for example remote mountain tops, narrow dangerous ridges, etc. In these scenarios, if helicopters are available (both logistically and from a funding perspective), acoustic sensors can be deployed via grappling hook. Note that this is a very specialised deployment method that requires a highly capable pilot and should not be undertaken by those who do not have a significant amount of experience working in and around helicopters. Acoustic sensors can be mounted in specially designed boxes with handles (for the grappling hook) and stabilizers (to allow the unit to remain upright once deployed. Sensors are also recovered with the grappling hook.

For assessing collisions by seabirds with infrastructure, a clear understanding of how the sound of a collision is being created is necessary for the correct deployment of acoustic sensors, coupled with the surrounding soundscape. For example, assessing powerline collisions alongside roads may require mounting an acoustic sensor on the pole up into the wire array (and thus requiring the assistance of utility lines people), whereas assessing powerline collisions on spans crossing mountain valleys may involve mounting the unit on a pole at the base of the powerline pole itself. At a transmission tower with multiple guy lines, a single acoustic sensor at the base of the tower may be sufficient. However if there are a large number of guy lines that cover a large area, strategically placing multiple acoustic units may be necessary. Observing strike sounds in the field will help dictate acoustic sensor placement and is a critical component of any study using this technique to allow you to identify which species are colliding with the power lines. Also bear in mind that for units near roads, vehicle noise may be a confounding factor. Security of sensors placed in easy to access areas is also a consideration – to prevent theft or tampering with the units, consider making them harder to find (i.e., don't leave them in an immediately obvious area) and consider the use of locks or theft proof cases.

There are several types of acoustic sensors available on the market, including Song Meters (http://www.wildlifeacoustics.com) and Audio Moth (https://www.openacousticdevices.info/ audiomoth). It should also be noted that individual manufacturers also offer different options. For example, Wildlife Acoustics has SM4, SM Mini 2 AA and Li-ion, SM Micro and SM Micro 2. Not only do these units vary in terms of cost, capability, and battery life, but users should be aware that they may differ in their ability to record seabird calls. Therefore, projects should use only one type of unit across all colonies or years if comparisons are required; otherwise correction factors would need to be calculated.

New Zealand's Department of Conservation produce lightweight acoustic sensors (Fig 35). These have a single microphone, record mono, and have two settings for high and low frequencies. High is generally used for bats. The low setting is very useful for seabirds and has the advantage of being a lot more economical on battery life. They have two time settings which is useful for nocturnal seabirds which call in the evening after sunset and in the hours before dawn. They use four AA batteries and recordings are stored in 15min sets on a single SD cards.

It is important to trial your recorders and get to know their capabilities, especially in terms of battery life, settings, and data storage, so you can service them regularly without missing calling periods.

**Figure 35. One of the DOC acoustic sensors attached to a tree. The cage over the microphone protects it from being damaged (e.g. by parrots). Photo: Chris Gaskin**

## CASE STUDY – Conservation challenges of monitoring seabird collisions with human infrastructure

### Marc Travers, Archipelago Research and Conservation

In the early 1990's, research confirmed that an endangered endemic seabird - the 'a'o (Newell's Shearwater) - collided with powerlines on the island of Kaua'i, Hawaii [21,22]. In these studies, the detection of grounded birds under powerlines was used to confirm powerline collisions. However, they did not reveal the true scale of the problem, nor did they detect any grounded 'ua'u (Hawaiian Petrel) under powerlines, despite 'ua'u having similar overall collision risk factors.

Population trend monitoring indicated that from the early 1990's to 2010 Kaua'i lost 78% and 94% of the 'ua'u and 'a'o respectively[23]. In 2011, renewed interest in understanding the impacts of powerline collisions on endemic seabirds resulted in the initiation of a powerline monitoring program with the goal of developing novel techniques to better estimate collisions at the landscape scale. The result of this effort was the development of the acoustic collision monitoring system, where the sound produced when birds collide with powerlines is recorded by autonomous recording devices[24].

This novel technique involves deploying acoustic sensors at the base of power poles with the sensors programmed to record during the diel and seasonal movement periods of the target species. For the seabirds on Kaua'i, sampling occurs between sunset and sunrise from March to December. The acoustic files are then downloaded and analysed by a computer using machine learning to detect the signature sounds produced when a bird hits a powerline. The strength of this technique is the large geographic and temporal scale at which powerlines can be monitored. On Kaua'i, there are 205 km of powerlines that require collision estimates. The acoustic method facilitates extensive monitoring across the geographic expanse of these powerlines, which in turn provides a rapid indication of seabird collision hotspots across the island.

The acoustic data is also used to develop landscape scales collision estimates for endangered seabirds, which indicate that the true scale of seabirds being grounded by powerline collisions numbered in the thousands each year between 2012-2020[25]. The acoustic grounding estimate was orders of magnitude larger than those estimated in the 1990's. Of great conservation concern is how the initial estimate from the 1990's undercounted the problem to such an extent.

The reason for this is that initial estimates were based on grounded bird detections, which suffer from significant crippling and environmental bias[26]. These biases were evaluated on Kaua'i from 2012-2020 through observations of bird movement at powerlines that were conducted in conjunction with the acoustic collision monitoring. The observations quantified the species-specific movement, timing, flight height and post collision outcomes. Firstly, these data facilitated assigning acoustic collisions sounds proportionally to the species observed hitting powerlines. Secondly, observations of collisions were used to determine acoustic collision detection rates (i.e., site specific performance of the acoustic collision monitoring system). Thirdly, it was observed that most birds were not grounded directly under powerlines but were instead grounded outside of the standardized search spaces (crippling bias) or in habitats that cannot be searched (environmental bias). On average, birds were found grounded 146 meters from powerlines and confirmed grounded up to 1,100 meters away - far outside the boundaries of any standardized search transects[27].

Figure 36. Powerline collision area, Kaua'i, Hawaii. Photo: André Raine.

Additionally, the highest collision rates occurred in either steep mountain terrain which was unsafe to search or over vegetation too thick to search, making it impossible for search studies to accurately quantify these collisions[26]. Lastly, misidentification of the cause of grounding also resulted in undercounting powerline collisions. For example, some birds that hit powerlines were grounded in roadways and were then secondarily hit by cars. The obvious signs of car collision resulted in misidentification of the primary grounding cause (assigned to vehicular collision instead of powerline collision) and significant undercounting of powerline collision for endemic waterbirds on Kaua'i in particular[27].

Underestimating powerline collisions on Kaua'i delayed conservation actions for nearly three decades and was a significant contributor to the massive population declines[26]. Acoustic monitoring paired with observations provided robust data that was required to initiate large scale conservation actions. These data subsequently led to the modification by the power company on Kaua'i of 94% of the powerlines for the protection of birds[28]. A combination of four powerline modification strategies were implemented to match the environmental and species-specific risk factors[29] and have since resulted in a significant decrease in collisions – representing a huge win for seabird conservation on the island. The strategies used to modify powerlines on Kaua'i would represent a good baseline guide to considered elsewhere, when modifying powerlines or any other type of aerial line, such as guy wires on communication towers (see the following reference for details[30]).

### 2.1.5 PLAYBACK

Seabirds can be very noisy at their breeding colonies, especially when gathered in high densities. Their calls are used for individual recognition and are typically emitted during social interactions. The majority of seabirds are very social, and these aural cues form a powerful attractant for a wide range of species. Calls from recordings made during acoustic surveys can be used for playback targeting particular species. The calls can be used for a variety of purposes, including finding birds nesting on the ground or in burrows, attracting flying birds to the ground for mark recapture surveys, tracking studies and other research projects such as genetics and diet studies, setting playback camera traps, and in seabird restoration projects using social attraction (see Section 4.4.2). Here we focus on the first three.

Seabird calls can be played through any device that broadcasts recordings, including mobile phones and MP3 players. However, the calls need to be loud enough to reach the birds you are trying to attract otherwise it won't work. Portable Bluetooth speakers can help project the sound further. A longer lasting option are specialist game callers devised for hunting as they are robust, weather-proof devices that are excellent for use in the field. They can be loaded with a range of calls via USB. An example of this is the Foxpro game caller https://allpredatorcalls.com/foxpro-prowler-electronic-game-call/

**Finding birds nesting on the ground or in burrows**

Playback can be used to locate birds on the ground or in burrows as part of ground searches. Many petrels and shearwaters are very responsive to hearing their calls and will give away their presence by calling back, both during the day and at night. This is especially useful where birds are nesting deep in forests or under dense scrubby vegetation. Ground searches need to be quite localized and are best conducted to follow up on other types of surveys, such as acoustic surveys and reports from communities and others which can narrow down places where seabirds might be breeding. The method is straightforward, playing calls at regular intervals while moving through the area. Playing calls at night has the added advantage with nocturnal species (i.e., birds that return to their colonies at night after feeding at sea) by detecting them while on ground or circling above the forest before landing. An important note however, is that not all species respond to calls so just because you don't get a response, doesn't mean the birds aren't there.

If you are working with a species that has an uncertain response rate, trial the call playback at known burrows that are occupied, at different times of the breeding season. Knowing what your 'hit rate' is from known, occupied burrows can be used as an adjustment factor in burrow surveys of unknown occupancy. Also some species reply by calling in flight or on the ground, and others may fly past but not vocalise. You may also need to try multiple different calls to get a bird to respond – use a mix of calls from an active colony and see which ones elicit the best responses. If you can identify the difference between sexes on your calls, then use a combination of both sexes to ensure that you are attracting both males and females.

**Attracting flying birds to ground**

When seabirds have been detected regularly overflying an area, and if the breeding location of a threatened or rare species of petrel or shearwater is unknown or suspected, then playback can be used to the bring birds to the ground, often in combination with spotlighting or flood lighting at night (see Section 2.1.11 Capture methods).

**Remote playback camera traps**

This method adopts a combination of playback player, speaker, trail camera, and solar panel to allow the system to run for long periods. The solar panel is optional and depends on the length of deployment. The layout of equipment, with trail camera in place, is shown in the figure below. A relatively clear space (stage) is left for the birds to land and approach the speaker.

This method has been used to detect the presence of a target species to extend the range of known breeding areas, or in places where it has not been detected before. The camera provides confirmation of the birds' presence. The components are relatively lightweight except for the 12V battery and can be deployed in remote locations, on ridgelines, summits of peaks, or, if trying to detect flyways, at the entrances to valley systems, or on offshore islands. It does require an automated sound system that can be preset with playing times. The sound anchor system illustrated here was made by Aotearoa New Zealand's Department of Conservation.

Figure 37. Components and layout of a playback camera trap. The camera will record any birds that land and their behaviour in response to the playback. Photos: Chris Gaskin

**When to use**

Knowing when the target species are breeding and the periods when they are most likely to be responsive to playback is critical. This information is obtained through acoustic surveys and prolonged deployment of acoustic sensors, and the subsequent analyses of the recordings. This can include peak periods across the breeding cycle and calling during day and night hours within those periods. Also be aware that this could make attracted birds vulnerable to predation and drawing birds down on the ground where they are more vulnerable. Consider the prevalence of introduced predators in your area before using this technique.

### 2.1.6 CAMERA MONITORING

Camera monitoring has become a critical element of many seabird monitoring projects in recent years, thanks to improvements in technology. Cameras have become better designed to withstand the rigours of the field and to have longer battery life and larger memory capabilities. Improved trigger sensors (both in terms of sensitivity and speed), higher quality photos and videos, increased programming options, and infrared night vision capabilities have greatly enhanced our ability to obtain data for seabird projects. Cameras can be utilised in multiple ways in seabird studies:

1. Obtaining data (including burrow attendance, phenology, and fledging) from nocturnal burrowing Procellarid species where it may not be possible to access the burrow chamber itself
2. Assessing the presence of cryptic species by deploying cameras in areas where it is possible they exist but are not yet confirmed

3. Taking photos of large seabird colonies of surface or cliff-ledge-nesting species at regular intervals to assess population changes over time
4. Identifying predators that are impacting on study species and utilising this information to help guide management actions,
5. Outreach opportunities, by sharing images and videos captured on cameras to social media or news outlets to help the public establish an emotional response with the birds.

Used correctly, cameras can collect a huge wealth of data while minimising human disturbance.

**Choice of camera**
There are a lot of camera options out there, and it can be quite overwhelming to figure out which camera you should be using. There are several considerations that should be taken into account before you decide to purchase cameras for your project. These considerations are as follows:

- Cost, bearing in mind that the cheapest is never the best quality!
- Durability, particularly waterproofing (if using in rainy or foggy environments)
- Trigger speed capabilities, particularly important for catching images of fast-moving species.
- Night vision capabilities, for nocturnal species. In these scenarios it is very important to find a camera with good quality infrared night vision with no ambient glow - clearly you do not want bright flashes or any form of light going off when the camera is taking a photo.
- How quiet is the camera? Some cameras create a sound when a photo is being taken, which can startle a bird approaching or potentially attract a curious predator, such as a cat.
- Photo quality, as not all cameras are created equal!
- Programming options (i.e. can it be set to turn on and off for periods?)
- Video, sound and high-definition imagery capabilities – particularly important if you want to use photos or videos for outreach work.
- Length of warranty, as you will be putting the camera through its paces in the field!
- Repair service options – how easy is it to send a unit back to the company to repair it?
- Get advice. The Pacific Seabird Advisory Group has been set up for this reason (see Section 5.2).

**Figure 38. Setting up a surveillance camera to monitor Band-rumped Storm-petrel activity at a known nest site at Pōhakuloa Training Area, Hawaii. Photo: Centre for Environmental Management of Military Lands.**

## Methods

There are several considerations for deploying cameras in seabird colonies. Cameras can be a source of disturbance, so in surface-nesting seabird colonies, cameras should be deployed before birds return to the colony. Ideally, they would then be left out for the whole season until the birds have left (or at least until chicks have hatched) so ensuring the cameras are set to a lower number of photos per trigger, longer quiet periods, have larger capacity SD cards and on-off periods (if you only want to record activity during the day or night) will conserve battery life and memory space. Likewise for cameras in front of burrows, make sure they are not too close to the burrow mouth or on an obvious ingress route – you don't want to block the bird from getting in, or dissuade it from entering its burrow in any way! For motion-activated settings for cameras used on burrowing species, the best position is for the camera to be facing directly into the burrow.

**Figure 39. Examples of camera deployments. Left, pole mounted in front of a petrel burrow in wet montane forest. Right, on the ground at a social attraction site in a rocky habitat. Photos: André Raine**

Mounting the camera is also a factor. If you are in an area with deep soil, a pole can be sunk into the ground and then the camera mounted on the pole (make sure the pole is secure however and will not fall over or become wobbly). On hard or rocky terrain, cameras can be strapped to rocks or bushes and trees that are unlikely to move in strong winds. Make sure the camera is pointing directly at where you want it to collect data – some cameras have a walk test feature that allows you to see if it will trigger when something moves in front of it (simulated by moving your hand in the area where the bird is likely to pass and seeing a red blinking light on the camera). If the camera does not have this capability, set it up, arm it and then move your hand in the area where the bird will be. You can then open the camera back up afterwards and check the images to see if the camera is properly orientated. Remember there is a balance in setting up cameras. If you set it up too close, the images become blurry, and you run the risk of missing some of the action. Too far and you may find the camera is taking photos of moving vegetation and shadows and missing the bird itself.

When setting up a camera in a wet environment, make sure the camera is not positioned in a way that will increase its chances of being impacted by the weather (water and moisture is not your camera's friend!). Do not have the camera sitting on the ground as water may pool around it and seep in. Likewise, do not have it sitting directly under an overhang or branch where water will funnel down onto your camera. Some cameras have excellent waterproofing, but there is a limit to how much they can take before they start malfunctioning. You could also consider putting a shelter (like half a rain gutter) over the top of the camera to reduce the amount of direct water it receives. Lastly, when checking your camera in wet environments (i.e., changing SD cards or batteries) make sure you shelter the inside of the camera from rain – even if it is only light rain. Use a raincoat or your body to shield the camera's insides as you do whatever it is you have to do.

False triggers are also a big issue with cameras – they can result in thousands of images of a branch moving (making for extremely tedious viewing!), meaning your SD card fills up and your battery drains more quickly. To minimise this issue there are several things you can do. Firstly, some cameras allow you to reduce the sensitivity of the trigger or set certain points in the camera's field of view where movement will not trigger it. Secondly, make sure there is no vegetation in the way that will move and cause the camera to fire. Clip bits of grass, twigs and leaves out of the view of the camera, but make sure you do not do unnecessary or over-exuberant trimming as the vegetation may be important cover for the bird. Lastly, be aware of what is around the camera. Are there certain areas where there is a lot of bird movement that you aren't interested in (like a booby nest on a shrub to the side of a shearwater burrow)? If so, make sure the camera isn't positioned so that it catches non-target movement. Shadows and clouds can also trigger cameras, so be aware of that as well if part of the camera's view is sky.

If you are deploying cameras in an area where you are trying to ascertain whether a species is present or not, or if there are predators lurking about in your management area, use your knowledge of the species to help guide where you deploy the camera. Look for good breeding habitat, open areas where prospectors (birds seeking burrows or mates) may court or socialise, well-used trails and areas with seabird sign present (guano, digging, footprints etc.). All of these factors can help increase the chances that you will catch something important on camera. In these kinds of studies, the more cameras you deploy the better – each camera increases your odds of confirming presence!

**Analysis of data**

Cameras can produce a LOT of images, and the more units you deploy the larger your image database becomes. This means more data, but it also means more time spent reviewing and rapidly increasing costs of storing all of this data. Furthermore, you may find that at certain times of the year you get more images than others (for example, on a burrow camera where a chick spends hours exercising outside the burrow entrance in front of your camera). Even if a camera only takes 1,000 images over your study period, if you have 15 cameras out, that is still 15,000 images to review. Burrow cameras can take a lot more than that; over 40,000 photos in a month!

Tree-nesting species can give 30-35,000 triggers in a month at any time of the season as adult birds are often present for extended periods of time each and every night.

To analyse camera data, decide what it is you actually need. There is a tendency to want to digitise everything you can from your photos, which is great if you have a lot of time and capacity. But as you start getting overwhelmed with the volume of data, decide whether you really need it all. Do you need to digitise a photo every time a bird enters the burrow, or can you get away with digitising first arrival of the season, first emergence of chick and fledge date? Artificial Intelligence (A.I.) is also becoming more popular for photo review, with the A.I. trained on recognising target species and then digitising sightings for you. This can be really useful for getting through vast numbers of photos. However, be aware that A.I. is never going to be as good as a human reviewer and will miss things, so again an assessment of what you need the data for is going to be key. For example, if you are digitising the number of rats visiting a seabird burrow and there is a lot of rat action, the A.I. missing a few rats is not going to be a major issue. However, if you have eradicated rats from a site and want to monitor for re-invasion, missing a single rat could be catastrophic. Lastly, if you do not mind publicly sharing your photo database, you can also create an internet-based system where you ask volunteers to view photos online and digitise the data for you. This approach has been successfully used by some projects, although carrying out quality control checks will be important.

**Camera brands**

These include Reconyx (https://www.reconyx.com/), Bushnell (https://www.bushnell.com/), Spartan (https://go.spartancamera.com/), Cuddeback (https://www.cuddeback.com/), Browning (https://browningtrailcameras.com/), and GardePro (https://gardeproshop.com/). Swift Enduro cameras have been used in the subantarctic, recording over a year of data in often very wet/foggy weather (https://outdoorcameras.com.au/shop/swift-enduro/)

### 2.1.7 THERMAL IMAGING

As well as night vision (discussed in Section 2.1.3) and the use of trail cameras (Section 2.1.6), the advent of thermal imaging has also provided exciting opportunities for surveys of nocturnal seabird species. This survey method follows on from the use of infrared cameras set up in fixed locations. Trail cameras generally use short wavelength infrared light to illuminate an area of interest. Some of the infrared energy is reflected back to a camera and interpreted to generate an image. Conversely, thermal imaging systems use mid- or long-wavelength infrared energy. Thermal imagers are passive and can only sense differences in heat. These heat signatures are then displayed on a monitor and are usually portrayed as black (cold) and white (hot). However, many devices have the option of allowing you to change the colour palette, so make sure you practice with different options to see what works best for your eyes. Some devices also allow you to record your survey sessions, which can be very useful in busy survey sites.

Figures 40. Tropical Shearwater overflying suburban area of Apia, Samoa. Image: Chris Gaskin

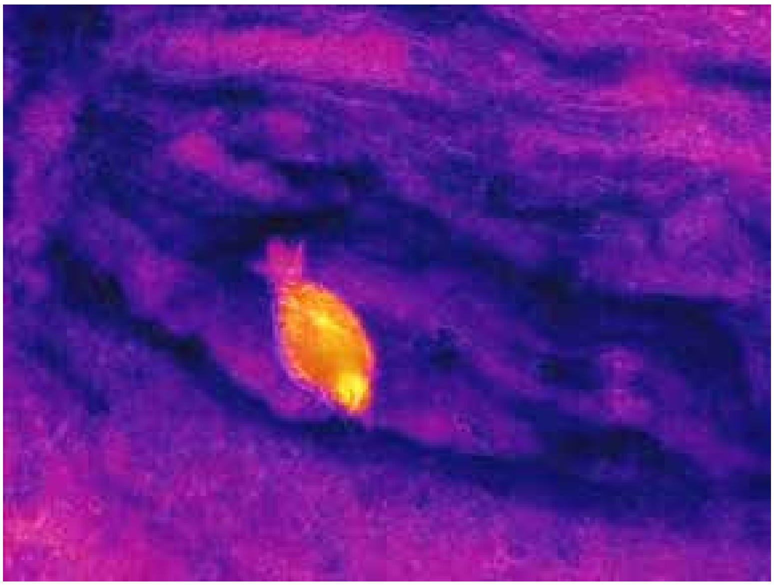


Figure 41. Thermal imaging from a drone showing a Wedge-tailed Shearwater chick. Image: André Raine

### Method

Thermal imaging is very useful for detecting overflying birds, especially when looking for the potential flyways and flight behaviour that could lead to finding otherwise-unknown colonies.

To detect birds in flight, the method involves finding a fixed vantage point on the shore for birds coming from the sea, or a clear area on a ridge or valley floor further inland allowing clear views of potential flight paths. There are two main ways you can use thermal cameras for surveys:

1. Follow the target and record its direction and any changes in flight behaviour. This is useful for working out where birds are going or trying to locate nest sites. Multiple flight paths in the same direction, and circling behaviour, especially linking with other birds, could indicate the location of a breeding site. In forested areas, once birds enter the forest, they can be extremely difficult to locate at night. With thermal imaging it becomes possible to follow a bird dropping through the canopy, walking across the forest floor and if it disappears, for the observer to go over to the location to check for a burrow entrance.
2. Keeping your thermal camera fixed on one location and counting the targets moving past your field of view. A tripod would be helpful in this situation. This is useful if you are trying to obtain measures of abundance of birds flying above a colony, conducting standardised counts between survey areas to compare sites, or to obtain seasonal differences in colony attendance

While thermal imaging can detect birds at a far greater range than other night vision technologies, identifying them to species becomes increasingly difficult with distance. This is particularly true if there are multiple target seabird species, or if there is an abundance of other nocturnal species in the area (such as flying foxes over tropical forests or other nocturnal bird species such as owls). With this in mind, familiarise yourself with your target species via photographs, or videos, to get a clear idea of their shape and behaviour in the air. For example, look at the shape of their wings and bodies and what their flight patterns are like (gliding or rapid wing beats, direct or meandering flight) Make sure you also listen for calls to help confirm the identity of birds viewed through the scope or camera.

One thing to bear in mind is that heat given off by the ground, especially rocks, and also vegetation, can reduce the effectiveness of thermal imaging. However, with altitude and cooler night-time temperatures, the temperature gradient between the two (target and background) increases, allowing the birds to stand out enough to be detected. Finally, using thermal imaging cameras will affect your night vision, and it will take a few minutes for your eyes to readjust to normal.

It is possible to detect using thermal imaging burrow occupancy at higher altitudes where it is cooler, and with lower night-time temperatures.

### 2.1.8 RADAR

Radar is a specialised monitoring technique that can be particularly useful for monitoring nocturnal seabirds, although it can also be used for diurnal species. Radar units transmit high frequency radio waves, which bounce off objects they encounter and return to the antennae – the time this takes is used to calculate the distance to the object. This allows radar units to collect location and velocity (by tracking the object's location between each radar pulse) of objects within scanning range. For seabird monitoring this is particularly useful for locating nocturnal seabirds transiting into breeding colonies, as radar units can scan a large area (several kilometres) for 'targets' which may be identified to species if local species differ in at least one of the following: target speed, time of movement and movement patterns (such as flyways or circling over colonies).

**Equipment**

There are several types of radar units that are utilised for seabird research, either at sea or on land. These are typically small marine radar units that are mounted on vehicles (either on the top of a boat or truck, or in a truck bed). There are also much larger units that on land can be towed behind a vehicle and have their own free-standing system – some of these are even automated to record targets passing through the radar. Radar can be used horizontally to count birds passing across the study area or vertically to obtain a count of birds passing over a fixed point and calculate vertical height, and some units can do both at the same time.

Figure 42. Radar unit mounted on a truck, being used to survey endangered seabirds on Kaua'i. Photo: Stephen Rossiter

Figure 43. Viewing bird movements on screen in truck cab. Photo: Stephen Rossiter

**Uses**

Some of the main uses of radar in seabird studies are (i) counting birds passing over a fixed area, (ii) locating transit routes on land for nocturnal seabirds heading into or leaving colonies, (iii) locating breeding colonies and (iii) charting long term population trends.

**Counting birds.** Radar units deployed at fixed sites (either at sea or on land) can be used to count targets passing through the scanning area. This provides standardised counts, with targets identified to species as outlined above.

**Transit routes.** By conducting radar surveys during peak transit periods at multiple locations along the coast, radar can help identify important flyways and transit routes for seabirds heading inland from the sea. If attempting to understand local maximum numbers, understanding what time of night constitutes peak transit activity is critical to using this technique as you do not want to conduct radar surveys outside of peak transit periods as this could yield artificially repressed numbers. Similarly, if you are comparing data from multiple locations, make sure that you are conducting surveys at the same time of day or night at each location and the same time of year.

**Colony location.** Identifying transit routes via radar can then help direct search effort to locate unknown breeding colonies. By identifying main transit routes and comparing this with potential breeding habitat inland, this will help narrow searches. Alternatively, radar can be deployed at locations on the coast or inland in an attempt to locate concentrations of circling targets that might suggest breeding activity. Again, timing is important, as some species may only be active at colonies during certain periods of the day or night, and this may differ between target species. Furthermore, be aware that radar will not pick up targets flying at a low height (under the radar), so positioning a radar unit above a valley where birds may be breeding will not provide useful data. This will also limit its usefulness for certain research topics, such as assessing powerline collision risk or light attraction studies.

**Assessing long-term population trends.** As radar represents a standardised way to count targets, conducting radar surveys in the same location(s) at the same time for multiple years can be used as a way of measuring long-term population trends. This does, however, rely on the survey site itself remaining unchanged between years – if buildings are built adjacent to the survey site between survey years or trees grow tall enough, they can block portions of the radar survey area (or conversely if trees are removed more lower flying birds may be detected), this will artificially reduce target counts as it will reduce effective survey area.

**Considerations**
Radar can be very useful for surveying large areas and assessing seabird movement. A firm understanding of species movement patterns, speeds and behaviours is critical for identifying targets on the radar to species. Conversely, while radar can be very useful in helping to answer important research questions, it is a highly specialised technique and requires expensive equipment that needs to be operated by trained technicians. This can often preclude its use from studies, especially when there are cheaper and easier survey options available. Lastly, it is important to understand the limitations of radar, as in certain environments and at certain angles to birds there is a risk that birds are passing through an area and are being entirely missed by radar (particularly true for low-flying birds). An example of this would be a study using radar to count birds passing through power lines – if the radar is positioned in such a way that it misses low-flying birds at power line height, then it would be useless at assessing power line collision risk.

### 2.1.9 GROUND COUNTS

**Surface nesters**
For surveys of colonies of surface nesters such as Sooty Tern, Grey-backed Tern (*Onychoprion lunatus*) and Great Crested Tern (*Thalasseus bergii*), and boobies (Red-footed, Brown and Masked) that require repeat counts, it is important to adopt a standardised approach that can be used across each breeding season, and multiple years. What you are counting (i.e., birds on nests/unoccupied nests, adults/chicks) will depend on the purpose of your survey, and also timing within the breeding season.

Choose your method and stick with it. Changing survey methods between years can result in wildly different results that have nothing to do with the birds you are counting. The general method is for the counters to use tripod-mounted spotting scopes, binoculars or the naked eye as appropriate. Hand-held tally counters can be used to assist counting. Observation viewpoints are generally at the same level of the birds (if they are on cliff faces), or at a viewpoint looking down towards a colony (if they are nesting on flat ground). It is good practice to use multiple counters to be able to assess for any observer biases. Many of the ground-nesting species can be sensitive to human disturbance so care is needed to avoid flushing birds from nests. Flushing exposes eggs and chicks to overheating and predators and may cause parents to accidentally damage eggs or injure small chicks or knock them from the nest.

**Figure 44. Sooty Terns, chicks visible walking around in the foreground, frigatebirds in trees in the background; Chesterfield Reef, New Caledonia. Photo: Mathieu Mathivet.**

If it is necessary for monitoring purposes to approach nests of these species and adults are likely to be flushed from nests, visits should be made during the cooler parts of the day and their duration should be as brief as possible to allow adults to return to the nest quickly. Adults and chicks of these species also may regurgitate if approached closely or handled; this can facilitate collection of diet samples, but it also causes stress to the birds and deprives them of food and should be avoided if possible. Ground counts by walking through colonies and marking with spray paint next to nests works well if the species does not show any fear of humans. It also allows banded birds to be observed, and data collected. However, this may not work for most tropical species where human disturbance has been a problem. Remote cameras can be used for monitoring nesting activity including chick development and predators (see previous section).

Several tropical and sub-tropical petrels nest on the surface, under vegetation, often in forest: Kermadec, Herald, Phoenix, Henderson and Murphy's Petrels. Their presence in dense vegetation can be detected using playback of their calls, or even war by whooping, and then can be counted.

**Figure 45. Kermadec Petrel on its nest amongst dense mawhai (a native New Zealand cucumber relative), North Meyer Island, Rangitāhua/Kermadec Islands. Photo: Edin Whitehead.**

Drones or unmanned aerial vehicles (UAVs) represent a new frontier in environmental research. Their use has the potential to revolutionise the field if they prove capable of improving data quality or the ease with which data are collected beyond traditional methods.[31] There is also far less disturbance of nesting and roosting birds, compared to ground counting. With this in mind, we provide a more detailed look at the use of drones for surveying seabirds (See Section 2.2.7). A word of caution, the transition from traditional to new UAV-based monitoring methods requires careful consideration, particularly in terms of maintaining the relevance of historical data that have been collected at substantial time and financial cost. A few seasons of counting with both methods would allow for comparing results between old and new methods.

### Counting tree nesters

For small colonies it might be possible to count every nest, but this depends on accessibility – i.e., tree height, or whether the ground below the trees can be traversed without risk. If a colony is on a very steep slope, find a vantage point with a clear view of both nests and birds flying in and out. In the case of a colony on the steep slope or cliffs above the shore, then use of a boat could be helpful. Alternatively, drones can be used (see Section 2.2.7). Consider using a good-quality camera as well and taking photographs to allow counting back at base camp or the office. Having photographs means you have good baseline reference material for future comparisons and allows for more accurate counting (if the photographs are of sufficient quality). There are multiple good computer programmes used for counting targets on images, including through the use of A.I., for example DotDotGoose https://biodiversityinformatics.amnh.org/open_source/dotdotgoose/

Figure 46. Red-footed Booby colony at Minami-Ioto (Iwo-jima), Japan. Photo: Hiroyuki Tanoi.

For tree-nesting birds, scan each tree several times from different vantage points. Nests are often hidden by branches or leaves, and sunlight can either hide or highlight birds or nests. If part of a tree is completely obscured by lower foliage, estimate the number of obscured nests based on the density of nearby visible branches.

As most tree surveys are done in daylight hours, it is important to remember that some species (such as noddies and boobies) are at their maximum densities at night, leaving at first light and only coming back into colonies sporadically in the afternoon. If you are using daytime presence as an indication of breeding season length, for example, you can misjudge them significantly. [32]

**Ground searches - burrowing seabirds**

Since burrowing petrels nest in underground burrows and cavities, frequently in remote places that are hard to access, obtaining quality data is often much more difficult than for surface-nesting seabirds. This is exacerbated by rarity – locating burrows of coastal-nesting Procellarids nesting in high density is not difficult (although studying them presents its own challenges!), whereas trying to find a single burrow in dense forest on steep terrain can be extremely daunting.

Coupled with a healthy dose of patience, there are many methods that can be employed to locate burrows. Below we outline some steps that you can take when faced with trying to locate the burrow of a rare seabird in a known breeding area.

**Consider using acoustic sensors and cameras**. Deploying acoustic sensors and cameras in a structured way that covers as much of the potential breeding area can help narrow down your search area. Check out the sections we have in this manual on these methods.

**Carry out visual surveys of the breeding area.** Strategically placing surveyors across the breeding site during the peak activity period can also help narrow down your search. As many of these species only come to burrows at night, use night vision and thermal cameras to help spot the birds. Listen for ground-calling; many species will call from the ground next to their burrows and this will help you narrow in on the burrow itself. Other species call in flight repeatedly over top of their nest site attempting to attract a partner or looking for others of the same species in isolated nesting sites.

**Location, location, location!** If you know exactly what your target species prefers to breed in, focus on those areas for your searches. For example, does the species like to nest in the roots of large trees, in thick beds of ferns, at the base of cliff walls, or under rocks? Understanding the microhabitat requirements of your species is very important for locating burrow-nesting birds.

**Figure 47. New Zealand Storm-petrel burrow in crevice between rocks within forest, Te Hauturu-o-Toi/Little Barrier Island. Photo: Chris Gaskin**

**Figure 48. Tahiti Petrel burrow with abandoned egg in entrance, Îlet Nemou, New Caledonia. Photo: Wilfried Weiss**

**Figure 49. Tahiti Petrel burrow, Tutuila, American Samoa. Photo André Raine.**

**Choose the right time of year.** While it's obvious that there is little point in searching outside the breeding season for burrows, even within the breeding season there are better times to concentrate your search. To maximise your chance of locating a burrow, choose your search timing for when the bird has been actively using the burrow for a while, as this increases the chance of there being any signs (see below) for you to locate the burrow itself. Don't search when the bird is on its pre-lay exodus, for example, as there will be little sign for you to find. Rather, wait until incubation or chick-rearing when birds are using the burrows regularly.

**Know what sign to look for.** Take your time working through the habitat, paying close attention to telltale seabird signs – feathers, guano, footprints, and scent. Some species (especially larger petrels and shearwaters) give off a strong seabird scent that can draw you down to their burrow entrance from a distance away.

Using these steps, being observant, and spending in some cases a lot of time and effort, will greatly increase your chances of finding a burrow of your target species. You could also consider tracking options – tagging transiting adults and following them to their burrows via their GPS locations – or the use of trained detection dogs. For that, see other sections in this manual (ections 2.1.10 and 2.1.12). One last point to consider, do you actually need to locate a physical burrow? It may be that knowing the birds are breeding in an area (through repeated calling throughout the breeding season for example) is enough for your research or management needs. While there are a lot of important data that can only be obtained from conducting active burrow monitoring, we would strongly suggest that you only monitor burrows if you have a strong predator control plan in place. Monitoring burrows creates trails to the birds themselves, which leaves them more vulnerable to predation. This is an important management and ethical consideration to locating seabird burrows.

### Timing

For year-round breeders (e.g., Brown Booby, White-tailed Tropicbird, and some shearwaters and petrels) only a portion of the total population is breeding at the time of any census. Such species need to be censused at least 2-3 times a year to determine the spread of breeding. There are no easy ways to extrapolate from "snapshot" census figures to a year-round total population. If some attempt is made to estimate the year-round breeding population, it is still essential to report the results of each census separately, because comparisons among islands and across time are best made using unadjusted raw data[33].

## 2.1.10 DOG SEARCHES

Detection dogs have been used successfully for multiple conservation projects in recent years – relying on the dog's far superior sense of smell to locate a variety of things that might otherwise go undetected by human searchers. These include biosecurity projects (locating invasive plants and mammals), predator control projects (helping hunters locate target animals, such as for rat and mongoose eradication efforts), and disease control (such as locating carcasses during botulism outbreaks). Seabird projects have also started using dogs in multiple ways, not just in direct management actions but also to locate burrows of breeding birds. In these instances, dogs can increase the speed and searcher efficiency of hard-to-find species and being lower to the ground may have an advantage in low hanging vegetation and steep slopes. Examples include the discovery of the first Band-rumped Storm-petrel (*Hydrobates castro*) burrows on Hawaii Island and New Zealand Storm-petrel burrows on Hauturu in Aotearoa New Zealand.

**Figure 50. Petrel detection dog with handler amongst the lava fields within the Pōhakuloa Training Area, on the slopes of Maunu Loa, Hawaii. Photos: Nicole Galase.**

**Figure 51. Found! A Black Petrel chick, extracted from a burrow, Te Hauturu-o-Toi/Little Barrier Island, Aotearoa New Zealand. Photo: Brook Mells, Dabchick NZ.**

Another area where dogs have been used recently is searching for grounded birds during 'fallout' seasons (particularly when fledglings are attracted to bright lights and become grounded in urban areas). Dogs can provide a viable way of finding these birds around hotels, resorts and towns and can even be more effective than humans when it comes to finding birds tucked away under buildings, in drainpipes, or under thick vegetation. As fallout can often be significantly under-estimated by human observers, detection dogs can be a very useful addition to assessing this conservation issue.

While dogs can have multiple uses for seabird projects, there are several considerations. Firstly, this is a highly specialised methodology that requires a well-trained dog (trained specifically on the target species) and an experienced handler. You won't get far trying to use a stray off the street or a pet Pomeranian! This means there may not be a lot of choice (or any) for obtaining the services of a dog, and this can also lead to increased costs. Secondly, dogs may not be the best choice for certain habitats, such as dense understory that they can't get through or hot crumbling rock on a remote island that may damage their paws. In these cases, you may just have to accept that while it was a nice idea to consider hiring the services of a dog, it's actually going to be you that spends days and days in an area searching for your target species!

### 2.1.11 CAPTURE METHODS

To band, track, or collect samples from birds they must first be caught. There are several ways of catching seabirds for research purposes – both on land and at sea. It is important to note that with every method there are risks, and that the bird's health should always be paramount and a primary consideration.

Note, birds should never be captured or handled unless the people involved have been properly trained in the methods being used, understand safe handling techniques, and are aware of how to mitigate any risk to the bird, as well as having the appropriate permitting in place. If you do not know how to catch or handle birds, contact experts and arrange for training sessions. If you do not know what the laws are related to capturing and handling birds for scientific purposes, or what permits may be needed, do your homework first!

**Methods of restraining captured birds**

In each of the examples of capture methods listed below, both on land or at sea, birds once captured will need to be restrained to help calm the birds, and also mitigate against the risk of injury both to the bird and the handler(s). There are kinds of restraint which are used for different handling purposes:

- Bird bags
- Just in the hand
- Tubes
- Sometimes with multiple people
- Boxes

**Capture methods on land**

Use of playback as a capture method has been covered above (see Section 2.1.5) as it is also a survey tool to detect presence of birds. Here we will look at methods that can be used to capture birds, both on land and at sea.

**Floodlighting, spotlighting**

Petrels and shearwaters can be attracted to bright lights, especially young birds. Birds can be found grounded in villages and towns where bright lights are used. Spotlights and floodlights have been used to deliberately attract birds to ground for capture. This method has been used to identify flyways (birds moving from the sea to inland breeding grounds, in the case of species that are nocturnal over land), attachment of tracking devices and to collect samples (blood and feathers) for genetic and diet (stable isotopes) research, for example.

Figure 52. Floodlight on a stand at river mouth, Silur Bay, New Ireland, PNG. Beck's Petrel project. The inverted V shows the location of the floodlight on a stand and the direction of the beam when used after dark. Photo: André Raine.

**Method**
As with the use of floodlights, spotlighting and playback (already discussed in Section 2.1.5), the primary capture location requires an open space for the positioning of your flood light. The flood light is then positioned in the centre of the capture area with a baffle cone to direct light upwards in the sky so as not to impact the night vision of field workers. There are a variety of very powerful lights now available on the market – some require a generator, others do not.

A typical capture/recapture session will start with turning on the floodlight and a playback speaker playing the calls of the target species previously recorded at a known breeding site. When a bird is attracted and sighted in the flood light, field workers use two high powered torches or spotlights, as well as headlamps, to attempt to disorientate the bird to bring it to ground in an open area.
When using spotlights or floodlights, care must be taken to ensure birds coming into land don't crash into anything (e.g., trees, fences, buildings).

Captured birds should then be banded with a unique metal band, the breeding status of captured birds assessed through evaluation of the brood patch, moult scores, and samples (if required) taken. A quick and easy way of assessing whether the same bird is captured again that session is mark the bird's head with a stripe of white correction fluid, allowing for quick visual assessment if it is captured again.
It is then important to go to a release site that is well away from the capture area, to avoid birds flying back in and getting recaptured. If this is not possible, turn off playback and lights while you release the bird, wait five minutes, and then start again. Also, be mindful of any avian predators (e.g., owls at night) which could target birds that are sitting on the ground and reorientating, before flying off.

**Figure 53. Storm-petrel caught in the light of a high-powered torch spiralling down to ground. The floodlight serves to attract birds into view. New Zealand Storm-petrel project. Photo: Edin Whitehead.**

**When to use**
Research has demonstrated extreme aversion of some petrels and shearwaters to moonlight over land. Accordingly, most field trips using this method should be based around the new moon, with capture attempts finishing earlier or starting later in the night to account for moon rise and set. Also, as with the previous method, be aware that this method results in birds that are potentially disorientated and dazzled. Misty nights, with good cloud cover can improve the success of this method.

If you are considering using this method, first consider whether you really need to do it – bear in mind you are bringing flying birds down to the ground so you should carefully consider whether your project really needs to do this. Secondly, make sure the people doing the work have been trained in this method, as it requires skill and an in-depth knowledge of the technique to ensure birds aren't injured. Lastly, refrain from doing this in an area where the general public can see what you are doing. As this is an effective capture technique, it could be used by people to harvest birds, which would not help their conservation!

**Mist nets**

This method can be used on land for capturing small seabirds such as storm-petrels, and potentially small petrels and shearwaters. Combined with playback and also spotlighting, mist nets are safe and effective when used by trained researchers but can be lethal in unskilled hands. In other words, mist nets must only be used by people with considerable experience in their use and hold certification for mist nets through a national bird banding and handling scheme.

The following is adapted from the New Zealand Bird Bander's Manual[34]

Mist-nets are fine mesh nets. Usually, they are set between two poles to capture birds in flight. When set against a dark background such as vegetation they are virtually invisible during the day, and after dark for nocturnal captures the mesh will be invisible. The mesh of the net is supported on two or more horizontal 'shelf strings', which have a loop at each end to attach the net to the poles. The netting mesh is strung in such a way that it forms deep pockets that a bird falls into when flying into the net. Note that nets come in different mesh sizes, and this is an important consideration for your target species (using the wrong mesh size can result in birds escaping, or birds becoming seriously entangled or even injured).

The height at which the net is set will depend on the expected flight paths of the target species. When using playback and spotlights birds that are attracted to the lights and playback will circle lower and lower. That means the nets can be set at a height that makes it easy for them to be checked and the birds extracted. Once the nets have been erected, they must be supervised at all times. This may mean keeping the nets in view continuously in some situations, such as when using playback, and when targeting a threatened species. If predators (e.g., owls) are drawn to the capture site, it may be necessary to close the nets and turn off the playback.

Extracting birds from mist nets is a skill that requires manual dexterity and a great deal of patience—not everyone is suited to using this capture method. Each bird caught presents a novel problem to the bander and no amount of written material can substitute for hands-on experience. During the extraction, take great care not to move wings, legs and joints into unnatural positions, as this may cause damage to the bird and increase stress. However, flight feathers can be bent in gentle curves.

If using at night other nocturnal animals can be caught, bats and owls for example. It is vitally important that when the catching is finished for the night the net should be taken down, so birds are not captured when the net is unsupervised. In windy offshore environments, no amount of furling of net (and taped or tied shut) can stop pockets of the net forming potential capture points.

**Figure 54. Mist net set up at a New Zealand Storm-petrel catching site; used with flood and spotlights, Te Hauturu-o-Toi/ Little Barrier Island. Photo: Steffi Ismar.**

**Figure 55. Example of a non-target bird species captured when using a mist net, Ruru or morepork (native owl), Te Hauturu-o-Toi/Little Barrier Island. Photo: Steffi Ismar.**

### Noose or crook on long pole

This method can be used for catching boobies and gannets which nest on the ground. Approaching from the windward side to where the birds is sitting, either at the nest or roosting site and avoiding capture attempts on low-wind days will reduce avoidance behaviour prior to capture attempts. Capture is accomplished by carefully manoeuvring the pole toward the chosen bird to try not to spook it or its neighbours. Then either the crook (hook) is gently placed around its neck, or the noose is gently draped over the bird's head and drawn gently closed. With the crook, the bird is pulled towards the catcher. The noose is fitted with a stopper so that it can never be pulled too tight. The bird is then pulled out of the colony, quite unceremoniously, along the ground (so it can continue to take its own weight) towards the catcher. Now the bird can be carefully brought under control where it can, depending on the purpose of the research to be undertaken, be banded, measurements, weight and samples taken, tracking devices fitted.

**Figure 56. Australasian gannet about to be captured using a hook fixed to a long bamboo pole, Hauraki Gulf, Aotearoa New Zealand. Photo: Nigel Adams.**

**Capture by hand**
A number of surface nesting seabirds can be captured by hand, such as Red-tailed Tropicbird, Kermadec Petrel (*Pterodroma neglecta*), Herald Petrel (*P. heraldica*), Henderson Petrel, Phoenix Petrel, Murphy's Petrel (*P. ultima*), and Christmas Shearwater (*Puffinus nativitatis*). This can be done by carefully approaching the birds, walking very slowly, no sudden movements and crouching when getting close to the bird on the nest. If it looks as though it will take fright and abandon its nest, potentially damaging its egg or chick, take a step back and go down into a crouch and wait for the bird to relax (or abort the capture entirely). When picking up a bird place both hands across its back and, holding its wings tight to its body, carefully pick it up and transfer it to a bird bag head first. Use an item of clothing, e.g., a cap or hat, to cover the exposed egg in the nest against unwanted attention from ground avian predators such as swamphens and rails.

**Burrow-nesting seabirds present a different challenge**
Birds can be caught while visiting (adults) or present (adults and chicks) in underground breeding burrows. Generally, the tunnels are too narrow to extract the birds with your hands around the body and wings. The standard method is to let the bird bite down on a finger (gloves can be useful) and then apply gentle traction on the bill. The wings of the bird stretch backwards (a normal wing posture when tree climbing for example). Then the body and wings are quickly restrained once they are out of the burrow, as the bill is released. If the bird gets caught up by a root for example, allow it to back up and try again until it comes free and is brought up to the entrance.

To limit distress, the bird needs to be restrained in a dark cotton bag while weighing, sampling, banding, and in some cases, while attaching tracking devices takes place. The bird is then returned to the burrow, placed head-first into the burrow entrance so that it can walk back up the burrow on its own. Chicks need to be carefully lifted from the nest by supporting the body and placed in a dark cotton bag for measuring, sampling and banding. Extra care needs to be taken with chicks – if they have been recently fed, they have a higher tendency to vomit, and their feathers may still be in pin and thus more fragile. Burrow traps or gates can also be installed, which is particularly helpful when recapture of specific birds is important (e.g., to retrieve tracking devices), provided on-site monitoring be maintained during their deployment. Burrow traps can be made with relative ease, for example utilizing a section of Novacoil drainage tube with a swinging gate made from clear acrylic at one end. This is held open with a stick and the gate drops when the bird pushes past it. The design of the gate is such that it only swings inward and cannot be opened from the inside, thus trapping the bird.

The bird is held in the burrow until it has been captured and processed. After processing, the bird is either returned to the burrow (if it is still nighttime) or released in the open to fly back out to sea (during the day). Burrow traps are a particularly useful tool for species that can return to their burrow at any time of night and for species that have very short feeding or stop-over visits to their burrows. During chick feeding, burrow traps are also useful because they allow the adult to enter and feed their chick undisturbed. The adult can then be extracted afterwards – this minimizes the chance of regurgitation of food at a critical stage of chick development.

For species that move fast as soon as they emerge from a burrow if the burrow gate is removed, fish landing nets with soft mesh can be placed over the burrow entrances to catch birds. The mesh needs to be held clear enough over the entrance so that the departing bird can poke its head out and not touch the mesh. Once it emerges then the net can be dropped, and the bird restrained by hands over the net and around the bird.

Figure 57. Burrow traps (gates) in a high-density Buller's Shearwater colony. Photo Edin Whitehead

Figure 58. Burrow trap (gate) at entrance to a Hawaiian Petrel burrow. Photo: André Rainé

### Capture methods at sea

For captures at sea, the target birds need to be attracted within range of the device being used: <3m for hoop and throw net, and <10m for a net gun.

Note that all of these methods are highly specialised and should only be carried out by trained personnel familiar with the technique. If you have not done this before, contact experts in the field and seek their assistance in advice and training.

### Hoop net

Important factors in making hoop nets include: (1) hoop size, shape, and material for ease of throwing, (2) mesh size to minimize entanglement, and (3) addition of a weighted skirt to reduce probability of escape by diving (e.g., shearwaters, cormorants).

Once a bird is in range, the net is thrown rapidly in a swirling motion, low and parallel to the water, allowing the skirt of the net to open. With the target situated within the perimeter of the hoop, the lead line is able to sink, thus enveloping the bird. The birds' buoyancy and lightweight pipe frame keep the net afloat as it is drawn to the boat using the attached nylon line. When within reach (<1 m), birds are then gently restrained in the netting as the hoop-net is lifted into the boat. Once in the boat, the bird is then removed from the netting and placed in a bird bag[35].

### Cast or throw net

A hand cast net (2m diameter) with monofilament mesh has also been used for catching petrels and shearwaters in Aotearoa New Zealand (e.g., Black Petrel (*Procellaria parkinsoni*) and Flesh-footed Shearwater (*Ardenna carneipes*)). In this case, the net is thrown by one person from the back of the boat, whilst the other team members throw bait or chum to attract birds within range (i.e., chumming) and/or help with processing the captured birds. Once a bird is targeted with chum, it is lured in until it is within range of the cast net thrower. The cast net is then pulled tight once over the bird(s) to seal them inside and bring them back on to the boat, similar to catching small bait fish. The bird(s) is carefully retrieved from the net by hand, and then each bird is placed into an individual drawstring bag for processing later[36].

### Net gun

The net gun fires a net from an open holder fixed between four barrels. The safest and most commonly used propellants are compressed air, with the net gun filled from a dive tank. Projectiles in the barrels are attached by cord to the four corners of the net. When the trigger is released, the propellant forces the projectiles out from the barrels, dragging the net with it. The barrels are angled out so that the net opens and expands as it moves towards the target. The angle between the barrels and the power of the net gun determine the distance the net flies before reaching its maximum extent. Beyond that point the net will start to close in on itself while still in flight, so birds are captured before the net reaches that extent.

Various designs of net guns have been developed specifically for the capture of seabirds at sea, principally in Aotearoa New Zealand since 2006 with application internationally. While many species can be attracted to chum, and to come close to the boat (i.e., within range of the net gun), the net guns have proved to be particularly useful for capturing highly manoeuvrable birds such as petrels, shearwaters, storm-petrels and even shags (cormorants) in flight.

As with some of the other methods described in this manual this is a very specialised capture method and requires specific training.

Figure 59. Use of a net gun for the capture of a Black Petrel from a vessel for a mark recapture population study, three albatross in proximity, undisturbed, northern Aotearoa New Zealand. Photo: Edin Whitehead.

**Other methods**
In some cases, birds come so close they can be picked up by hand. For example during migration periods when birds are very hungry, some species (such as Great Shearwaters) can be attracted to the side of the boat with chum and captured by hand while they are still sitting on the water. Night captures are possible when boat lights dazzle birds, causing them to land on the deck, allowing them to be captured by hand.

### 2.1.12 BIRD-BORNE TRACKING

There are three different types of technologies used for tracking seabirds, VHF radio, Global Positioning System (GPS), Platform Transmitting Terminal (PTT) and Global Light Sensor (GLS). Choosing the best technology and device will depend on the purpose of your tracking project and the size of the species you are studying. A variety of methods are used to attach the devices to the birds, taped to back or tail feathers, chest and leg harnesses, and suturing (this section below). General best practice is for the tag weight not to exceed 3% of body weight to minimise the impact of carrying additional weight. Be aware that any attachment will have some impact on a bird's behaviour. This section serves as an introduction to tracking and provides examples (case studies) of tracking projects using different types of devices.

It is important to note that with every method there are risks, and that the bird's health should always be paramount and a primary consideration. Furthermore, it must be stressed that birds should never be captured or handled unless the people involved have been properly trained in the attachment methods being used, understand safe handling techniques, and are aware of how to mitigate any risk to the bird, as well as having the appropriate permitting in place. If you do not know how to catch or handle birds, contact experts in the field and arrange for training sessions. If you do not know what the laws are related to capturing and tracking birds for scientific purposes, or what permits may be needed, do your homework first!

**Telemetry – VHF and UHF radio transmitters (tags)**
Radio is an excellent type of signal to use when tracking animals, in part because radio waves can transmit information rapidly and through long distances in air. In order to track a bird using radio technology you need to equip the bird with a transmitter that can send you a signal. This signal will require that you have a receiver that will detect the radio signal sent by the transmitter. Both the transmitter and the receiver use antennas to aid in sending and receiving the animal radio signal. Another significant advance in radio tracking technology has been the miniaturization of the tags.

## CASE STUDY – Use of VHF telemetry to discover breeding sites of New Zealand Storm-petrel

There are several species in the Pacific whose breeding sites are unknown (Fiji and Beck's Petrels, Heinroth's Shearwater, and New Caledonian Storm-petrel), although sightings at sea give hints to where they could be breeding.

The New Zealand Storm-petrel was thought to be extinct (known only from three museum specimens collected in the 19th century), until one was photographed at sea in northern Aotearoa New Zealand in 2003[37]. More sightings followed. Confirmation that the birds being seen at sea were the same species as existing museum specimens required birds to be captured at sea to allow for blood and feather samples to be collected, followed by genetic analysis[38].

Figure 60. New Zealand Storm-petrel. Photo: Edin Whitehead

While species confirmation was subsequently achieved, it was another ten years before their breeding grounds were located. The first step was to obtain an understanding of breeding phenology, particularly understanding when the birds would be laying and incubating eggs and raising chicks. This was achieved in 2012 by capturing birds at sea across several months and checking brood patches (see Section 3.4). By the end of that study, it was clear their breeding timing was much later than originally thought, with laying likely through February[39]. This meant tracking the birds would be best undertaken from the end of January and into February. The capture trips also allowed for at sea observations close to islands to try and detect storm-petrels flying towards shore late in the day, at dusk and then using spotlights at night. Repeated sightings narrowed down potential search areas around one large island, Te Hauturu-o-Toi (Little Barrier Island). These observations were also used to work out where best to locate remote telemetry stations and plan for a major island- and boat-based telemetry operation[40].

The following season in 2013, 24 New Zealand Storm-petrels were captured at sea and fitted with miniature coded VHF radio tags. The remote telemetry stations had been set up on two headlands and after eight days the first of the captured birds was detected at night at one of the stations. In the following twelve nights, eleven of the 24 captured birds fitted with transmitters were detected at the remote stations. At the same time ground and boat-based parties using hand-held antennae were deployed and birds were detected over the island, from shore to the summits (650m asl). Unlike the remote stations, the hand-held receivers were unable to identify individual birds, however, that was secondary to finding birds on the ground or in burrows. Eventually two birds were tracked by ground parties to burrows in the forest using telemetry. One more burrow was found when a ground party saw a bird disappearing into a crevice close to one of the first burrows, and two more were found using a dog trained to seek out petrels later that season[41].

**Figure 61. Radio tracking on the summit of Hauturu. New Zealand Storm-petrel were detected at sea, and also flying over the summit peaks. Photo: Arno Gasteiger, NZ Geographic**

While radiotelemetry was effective in enabling discovery of New Zealand Storm-petrel breeding sites, it also provided the first data on the species' breeding biology without major intervention in the fragile breeding habitat and at a time of year when storm-petrels can be sensitive to disturbance. This was achieved by using a remote VHF receiver set up close to the first occupied nest site found, logging visitation by the tagged bird over several weeks[41].

In the ten years since 2013, over 500 New Zealand Storm-petrels have been captured on the island, and a mark recapture study has provided a population estimate[42]. Their calls have been recorded and used in a social attraction experiment to set up an artificial colony. While the latter has not been successful to date, their overall population appears to be steadily increasing[43]. A genomics study was conducted in 2021, comparing the DNA of birds from locations at sea up to 250 kilometres from the island and the Hauraki Gulf, confirming that Hauturu remains the only likely breeding site[44].

Hauturu was declared predator-free in 2004, after first cats and then rats were eradicated. Released from predation-pressure, the storm-petrel's population appears to be increasing. In this case, the survival of a presumed extinct species can be considered an unintended benefit of the coincidental protection of its breeding habitat, knowledge of which was made possible by using the very small 0.67g VHF tags and a major field tracking effort.

**GPS tracking studies**

Advances in technology have meant satellite tags and data loggers are becoming small enough to be fitted to a wide range of seabird species to provide Global Positioning System (GPS)-level data on their movements[45]. Both types of tags also often contain solar panels, allowing for extended tracking periods that are not solely relying on the power from a single internal battery. Satellite tags are particularly useful for birds that are likely to range far and for which there is limited to no chance they will be caught again, such as fledglings or birds caught away from burrows. This is because locational data are sent to a satellite and then downloaded onto a computer at your leisure. The limitation of satellite tags is that they give locational fixes at widely spaced intervals over each 24-hour period, meaning that fine-scale movements (such as transit routes over land) are not easily obtained.

Conversely, data loggers give GPS-level locational data on a very fine scale – many tags are capable of taking locational points every minute. However, many data loggers require the bird to be recaptured. This reduces the number of projects they can be used in by restricting them to scenarios where you can be assured that you will recapture the bird (i.e., by tagging them at known burrows). To circumvent this downside, some data loggers are now available with download stations – static devices with antennae that download data to the station as the bird flies past. Others connect into mobile networks allowing positions to be sent through to your phone.

Once data are retrieved researchers are able to plot the latitude and longitude of the bird's locations and better understand their distributions. Such information can be used for a wide range of scenarios, including identifying key foraging grounds, wintering locations and migratory routes. The data can also be used to assess the birds' behaviour and the way in which they utilise their surrounding environment.

In some scenarios, data loggers have also been used to back-track transiting birds to locate as-yet-unidentified colonies (e.g., Hawaiian Petrel, see Case Study below). In these scenarios, birds flying overhead were attracted to floodlights and spotlights, grounded and then had data loggers attached to them. When tracks of the birds were subsequently collected from the base stations, they were then used to zero in on burrows and successfully locate them.

## CASE STUDY – Using tracking technology to locate endangered ‘ua’u (Hawaiian Petrel) burrows

The ‘ua’u (Hawaiian Petrel) is an endangered Procellarid endemic to the Hawaiian Islands. Although its distribution on some of the islands is well documented, on larger islands such as Hawai’i there are significant distribution gaps. Previous work within the Pu’u O ‘Umi Natural Area Reserve (NAR) on Hawai’i strongly suggested that a breeding colony of the species was present, but active burrows had not been located making it difficult to focus management actions. Searching for burrows of this nocturnal burrow-nesting seabird had been particularly challenging in the NAR, as the birds are very rare, widely dispersed, and breeding in remote areas with dense vegetation and challenging topography.

To locate active burrows, tracking devices were used to track breeding adults back to their burrows. Transiting birds heading to unknown breeding colonies were caught over the course of two years (2018 and 2019) using a spotlight (Grandlumen 240W High Bay LED UFO shop Light) and powerful hand held flashlights, combined with speakers playing ‘ua’u calls. In total six birds were caught, and a data logger (e-obs Bird Solar 10g) was attached to each bird via back sutures. Four base stations were then deployed on likely transit routes – these base stations allow for automatic data download from the tag to the base station whenever a bird came in range of the station[46].

Data were downloaded from four of six (66.7%) birds, but complete tracks were only recovered for two (33.3%) birds (#6507 and #7238). A total of 23,627 locational fixes were downloaded from tagged birds, with 1773 (7.5%) locational fixes recorded over land. Overland locational data was then interrogated for concentrated areas of circling and ground activity. This resulted in several areas of concentrated activity and two different locations where tracked birds ended up transmitting from the ground. Burrow searching teams were then deployed to these areas and an active ‘ua’u burrow was located. This represents the first active burrow ever documented in the NAR and the entirety of Kohala Mountain. Management actions have since been initiated to protect birds breeding within the areas defined by the tracking data.

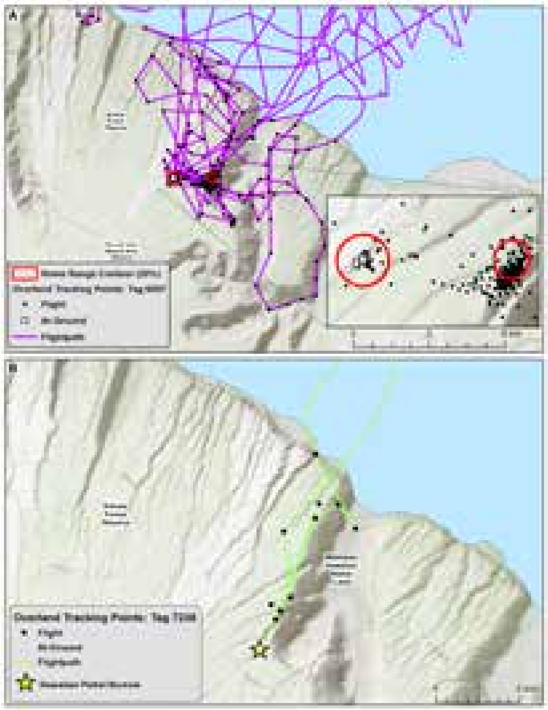


**Figure 62. Maps showing overland tracking data and eventual location of the ‘ua’u that was located by this technique.**

## CASE STUDY – Gaining invaluable insights into the foraging behavior through tracking.

### Andreas Ravache, Bird Conservation New Caledonia

The Tahiti Petrel (*Pseudobulweria rostrata*) is a Procellarid seabird species whose breeding populations are known from only a few islands in the tropical Pacific, including New Caledonia. The Pseudobulweria genus hosts four extant species, with one already extinct. Beck's Petrel, Fiji Petrel (*P. macgillivrayi*), and Mascarene Petrel *(P. aterrima*) are classified as 'Critically Endangered' on the IUCN Red List, while the Tahiti Petrel is currently labelled as 'Near Threatened' due to limited data availability. However, as highlighted by recent studies, this species has to cope with several at-sea and on-land threats, undoubtedly contributing to its overall population decline.

**Figure 63. Tahiti Petrel off New Caledonia. Photo: Edin Whitehead.**

Tahiti Petrels have received limited research attention, and their foraging ecology remained largely unknown for years, with available information primarily derived from at-sea observations. The recent development and miniaturization of GPS-tracking devices has allowed researchers to obtain precise information on the at-sea movement of this species. Combining algorithms for inferring behaviour from GPS locations with molecular analyses has allowed for vital new insights into its at-sea foraging behaviour and diet. Studies conducted at multiple sites in New Caledonia from 2017 to 2019 revealed that birds undertook notably lengthy foraging trips during the chick-rearing period, averaging more than a thousand kilometres per journey.

During these excursions, Tahiti Petrels predominantly foraged during daylight hours, although they also engaged in bouts of nocturnal foraging. As indicated by their extensive travel distances, prevalent extensive foraging patterns, and prey items identified through molecular analyses, Tahiti Petrels appear to exhibit opportunistic feeding behaviour. They are actively scavenging for dead prey near the water's surface, which highlights a potential vulnerability to fisheries bycatch. When compared to the Wedge-tailed Shearwater, a similarly sized Procellarid species breeding in sympatry in New Caledonia, GPS tracking of both species revealed clear differences in foraging strategies, likely contributing to their coexistence within the archipelago.

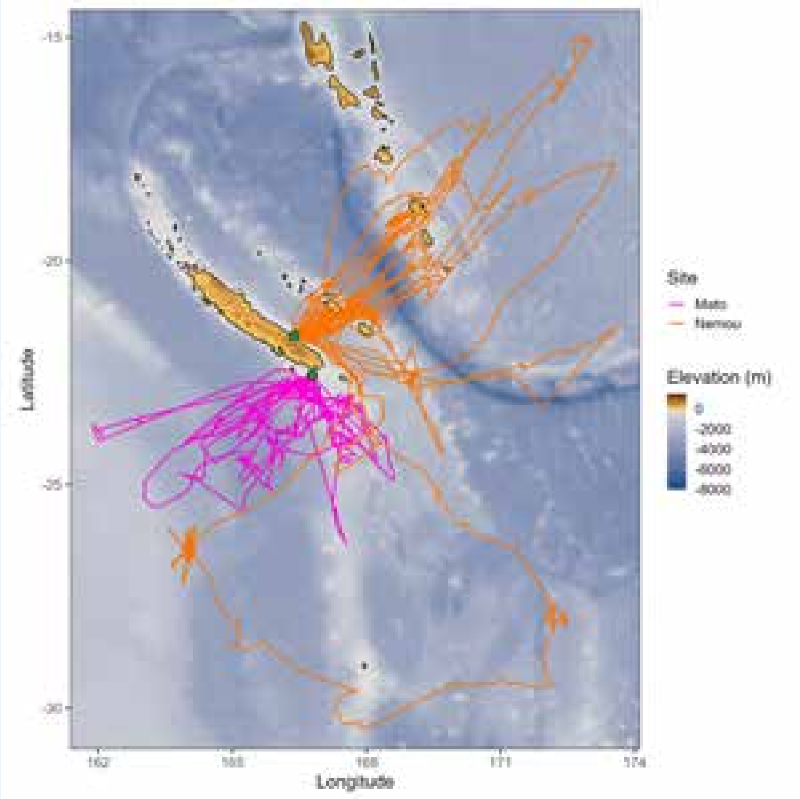


**Figure 64. Foraging trips of GPS-tracked Tahiti Petrel from Îlet Nemou (orange tracks) and Mato (pink). The three islands close to New Caledonia north coast are the Loyalty Islands, the islands further north are part of the Vanuatu archipelago.**

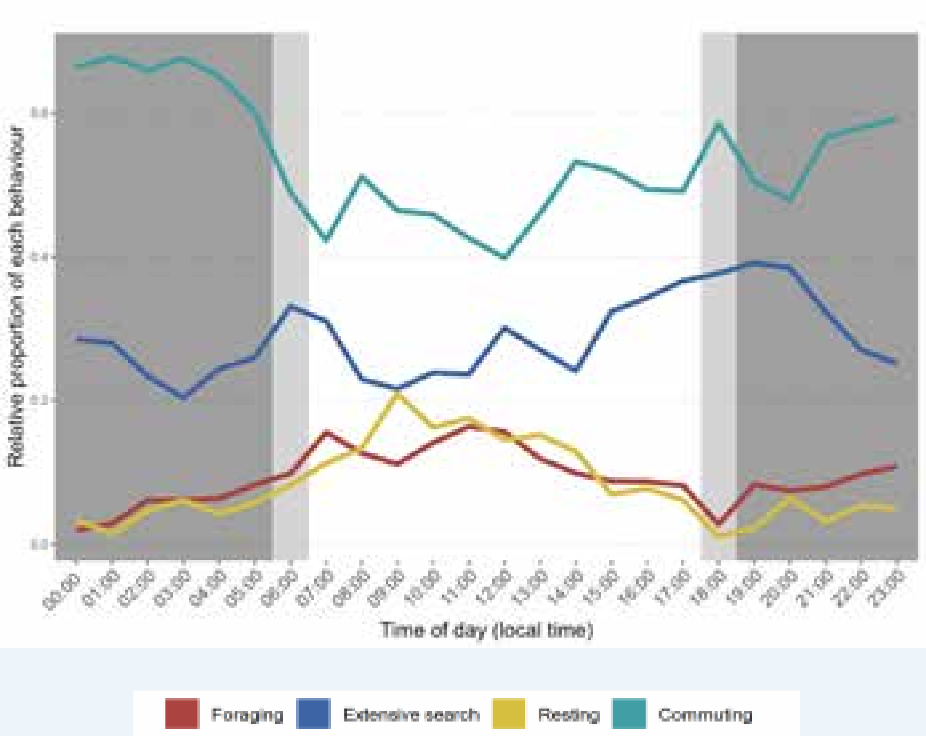


**Figure 65. Percentage of time allocated to each behaviour by breeding Tahiti Petrels.**

Collectively, these findings offer invaluable insights into the foraging behaviour of this elusive species. Gaining a deeper understanding of its at-sea distribution and foraging techniques will enable the identification of potential threats within New Caledonian and surrounding waters, which could direct conservation efforts for the species.

## CASE STUDY – Migration and non-breeding habitat of Beck's Petrel (PTT)

The Beck's Petrel is a poorly known, Critically Endangered seabird rediscovered in the early 2000s in the waters off Papua New Guinea. In 2017 an expedition was launched to visit the last confirmed locations of this enigmatic seabird to gather more information on their distribution and attach satellite tags to adult birds in an effort to locate their breeding grounds (which were unknown). During the expedition a single Beck's was captured at sea off New Ireland Papua New Guinea and fitted with a Platform Transmitting Terminal (PTT) satellite-based device (mounted on the back via a chest harness). The Argos satellite tag deployed uses a Doppler effect to determine best location as the satellite moves overhead. The bird was subsequently tracked for eight months, where it maintained a core distribution off the south-east coast of New Ireland and north of Bougainville for 122 days. During this period, the petrel was also located over land at night seven times - predominantly over southern New Ireland, where the signal was also lost for extended periods suggesting occupancy of an underground burrow[47].

As well as providing data on potential breeding grounds, this tracking study also provided additional valuable information about the species during the non-breeding period. After its prolonged residency east of New Ireland, it rapidly migrated 1,400 km along the northern coasts of New Britain and mainland Papua New Guinea to the waters north of West Papua, Indonesia. As this case study demonstrates, data obtained from tracking studies can shed light on the location of unknown breeding colonies, key foraging areas, and migratory routes for species for which almost nothing is known. By gathering these data, conservation efforts can then be better focused in the areas where they are needed the most[47].

**Figure 66. Movements of PTT tracked Beck's Petrel westwards from New Ireland and the Bismarck Archipelago (capture location shown as grey square) showing core habitat (25% kernel solid white line, 50% kernel hashed white line) off the eastern coast of Pulau Supiori in West Papua. Map source: Rayner et al (2019).**

## Global Light Sensor (GLS) Tracking studies

**Nicholas Carlile, Æstrelata Restorations**

Compared to the previous tracking technologies, Global Light Sensor (GLS) technology is significantly less accurate than GPS tracking devices. While GPS devices are accurate to a few meters in many cases, GLS tags provide locational fixes that are more in the range of 150 km, but up to 450 km in some instances.[48] They also require the bird to be recaptured to obtain the tag and thus the data. On the upside however, they are relatively cheap and can be produced with a mass as little as 0.5g enabling the smallest species to be tracked at sea. The low cost of the tags also means that more individuals can be simultaneously tracked to gain a population-wide assessment of movements from single or multiple colonies within the same time-period. With the low tag weight (and thus burden to the bird) the same individual can be tracked throughout the year and for several seasons with significantly less stress than a larger tag.

Unlike satellite tags and data loggers, geolocation technology relies on accurate measurements of changes in light intensity, usually at 10 min intervals, to obtain locational data. Depending on the analysis software, this light curve representation can also be used to infer the timing of changes in behaviour of surface-nesting species (whether at-sea, on-island or commencement or ceasing of incubating/brooding behaviour). Alternatively, for nocturnal burrow-nesting species, light level data can also be used to obtain information on burrow attendance patterns (recorded by changes in light levels and sustained periods of dry conditions/stable temperatures). The GLS units are also often fitted with other measuring equipment that can indicate frequency of water immersion, water temperature and sometimes water depth. All data are stored within an on-board microchip.

## CASE STUDY – Monitoring surface-nesting behaviour of Kermadec Petrels

### Nicholas Carlile, Æstrelata Restorations

The surface nesting Kermadec Petrel is dispersed on remote islands throughout the tropics and sub-tropics. In this case study, their breeding ecology was examined on Phillip Island, Norfolk Group in the South Pacific[49]. Based on observations of 60 pairs and data gleaned from GLS devices, it was determined that breeding (incubation and provisioning) occurs in all calendar months of the year, with a laying peak in the late austral spring. This broad period of on-island activity is unlike most other petrel species.

The GLS devices used had a guaranteed 3-year battery life and 3-5 years of data storage capacity depending on settings. They were attached either using a hook and loop (Velcro) cuff fitted to the lower leg or a cable-tie arrangement using two Darvic[50] bands glued end-on to increase the base platform size on the bird's leg.

Where possible, nests were monitored using surveillance cameras generally set to record images hourly. These allowed hatching and fledgling dates to be accurately recorded. At specifically selected nest sites (where false camera triggers were likely to be a minimum) cameras were set to trigger based on movements. These additional units allowed incubation shift changes and subsequent provisioning visits to be recorded. This information allowed calibration with GLS-derived data when both adults carried the devices. Cameras were serviced bi-monthly. The graphical interpretation of the data was used to assess whether birds were at sea or on-island.

A range of behaviour of breeding birds carrying GLS devices could be gleaned over several seasons of monitoring due to their surface nesting behaviour. Table x indicates the level of detail collected on Kermadec Petrels. Determination of provisioning activities was not possible as these occurred both during daylight and nocturnal periods. It could also not be determined when adult visits were without actual provisioning (just visits). The low number of surveillance camera monitored nests (using movement triggers rather than time lapse) during this study period did not allow the inclusion of this information.

**Table 2: Island attendance and pre-chick provisioning activities of Kermadec petrels from 4.5 years of surveys (January 2017 to June 2021) on Phillip Island, Norfolk Group**

| Behaviour* | sex | n | Days | range |
|---|---|---|---|---|
| **Pre-honeymoon** | males | 19 | 2.6 | 2 - 4 |
| **Pre-honeymoon** | females | 14 | 3.0 | 1 - 6 |
| **Honeymoon** | males | 17 | 40.5 | 37 - 47 |
| **Honeymoon** | females | 11 | 39.7 | 34 - 47 |
| **1st shift (prior to egg laying)** | males | 14 | 14.3 | 12 - 17 |
| **2nd shift** | males | 14 | 12.3 | 6 - 18 |
| **3rd shift** | males | 4 | 4.0 | 3 - 7 |
| **Egg laying** | females | 9 | 1.2 | 1 - 2 |
| **1st shift** | females | 9 | 13.3 | 7 - 22 |
| **2nd shift** | females | 5 | 10.2 | 8 - 14 |

* Refer to Section 1.1.1 Seabird ecology for explanation of terms used in the first column.

Because of year-round breeding, visits to the colony were bi-monthly to necessitate both breeding activities of individual nests and to maximise the attachment and recovery of GLS devices. Between January 2017 and January 2024, 117 loggers were fitted to breeding birds. Sixty-five were subsequently recovered with multiple tracked individuals collecting over 65,000 estimated at-sea positions. Time coverage from combined fittings equates to 100 years of at-sea positions. The core breeding distribution at sea (core 50% kernel) covered 1.3 million square kilometres around Norfolk Island Group. The non-breeding movements of Kermadec petrel from Philip Island, Norfolk included territorial waters of China, Japan, and the Philippines in southeast Asia as well as the south and mid-Pacific island groups of Papua and New Guinea, Solomon Islands, New Caledonia, Vanuatu, New Zealand, Fiji, Samoa, and Hawaii.

### Methods for attaching tracking devices

Attachment methods will be guided by the type of tag, the behaviour and size of the species in question, and the duration for which you want to collect data. While it is great to have extended data sets spanning a long time period, bear in mind that the additional weight of the tag can have negative consequences for the bird.

If a device is known to impact breeding in any way, it should not be used. No data are worth the losses of individual birds (adults or chicks). If there is some concern that this maybe the case, all devices should be carefully trialled to show there is no impact before a research programme is rolled out.
It is also important to minimize the amount of time the bird is carrying the tag (especially for larger, bulkier devices), so make sure your attachment method reflects this. Additionally, tag attachments are specialised techniques and should only be carried out by people who have received sufficient training to be undertaking the work.

There is a wide range of attachment methods for the tracking devices outlined above. Any attachment must not be attempted without attendance, at the time of first applications, by a person previously experienced in the method. Common attachment methods include:

- **Leg:** Particularly used for GLS tags (as they are so light), tags are attached to metal leg bands, plastic colour bands or custom-made devices (like Velcro cuffs) via cable ties. Make sure that the cable ties are rated UV stable.

Figure 67. Adult Kermadec Petrel fitted with a Velcro cuff attached GLS device. Photo: Nicholas Carlile.

Figure 68. GLS attached directly to the metal band. Photo: André Raine.

**Tail feathers:** For seabirds with longer tail feathers, tags can be attached to the central tail feathers, at the base. A classic way to do so is to use TESA tape, which is wrapped around two (or four) central tail feathers and the tag itself. If the tag has a solar panel, make sure the solar panel is not covered by the tape (and that feathers do not obscure the panel either)! A base plate can aid in attaching the tag. If the tail is short, this attachment method could interfere with the bird's flight ability. Placement should also be made in such a way that the tag is close to the base of the tail to reduce impacts to balance. At the same time, care must also be taken not to impact the bird's ability to access its preen gland, located above the base of the tail.

Figure 69. Galapagos (White-vented) Storm-petrel with VHF transmitter taped to central tail feathers before release. The antenna extends beyond tail. Photo: Chris Gaskin

Figure 70. Tail-mounted GPS logger attached to central tail feathers of an Australasian Gannet. Photo: Edin Whitehead.

**Back feathers:** Another position for tags is on the bird's back. As with the previous method, tags are attached to back feathers via TESA tape. This position keeps the tag in a central position, reducing the chance that the tag weight will affect the bird's balance and flying ability. In this scenario, sufficient feathers should be used to keep the tag in place. Bear in mind that when the tags eventually come off, the glue from the tape may have an impact on the waterproofing of the bird's back feathers.

Figure 71. GPS logger attached to the back feathers of a Balearic Shearwater with TESA tape. A base plate has been glued to the bottom of the logger in this case to facilitate attachment. Photo: Chris Gaskin.

**Harness:** Harnesses are a more specialised method, where the tag is mounted on a harness (made from Teflon ribbon or similar) and then the harness is attached to the bird. Harnesses often fit over the bird's shoulders and hold the tag in place on the back, or they can be looped over the bird's thighs. Harnesses that are used on seabirds that dive, must be fitted to ensure they do not slip over the bird's wings during diving and entangle the bird in the process. Harnesses can be made to stay on the bird for years, or they can have a link, or threads woven into them that are designed to snap after a certain amount of time, allowing the tag to eventually fall off.

Please note: Harnesses should only be used by seabird researchers with experience in this technique as they are more risky than other attachment methods

**Suturing:** Another very specialised attachment method, suturing involves attaching the tag to a bird's back via the application of multiple surgical sutures. With this method, the tag is stitched into the bird's back, with the sutures sliding under the birds skin. This attachment method should last longer than tags attached via tape, allowing for longer tracking time periods. Sutures designed to dissolve over time assure the tag will fall off if the bird is not recaptured and tag removed. Even with non-dissolvable sutures, eventually the movement of the bird results in the suture snapping and the tag falling off.

Please note: Suturing should only be used by seabird researchers with experience in this technique as it is more risky than other attachment methods

**Figure 72. Satellite tag being sutured to the back of a Hawaiian Petrel. Threads are still visible before trimming. Photo: André Raine.**

**Passive Integrated Transponder (PIT) tag:** Although not a tracking device, another useful piece of technology is the PIT tag. This tiny little tag can be attached to the leg of a bird by either super gluing it to a plastic band or even sealing into a custom 3D printed leg band (such as in the photo below). PIT tags can also be surgically implanted under the skin between the shoulder blades, below the back of the neck. A PIT tag reader is then installed at the mouth of the bird's burrow. Whenever the bird enters or exits its burrow, the PIT tag is scanned (just like in a supermarket checkout) by the reader, which collects data on the date and time of the entry or exit of the individual. As the PIT tag is uniquely numbered and thus easily cross-referenced with the bird's metal band number, PIT tags provide information on the burrow activity of a breeding pair throughout the season without the need to continuously check on burrow contents and risk disturbing the bird. PIT readers need constant power supply, so good solar access for panels to supply each unit or group of units is necessary for this to be a useful method.

Figure 73. PIT tag attached using a 3D-printed PIT tag holder. Photo: André Raine.

Lesser Frigatebirds and Red-footed Boobies, with a small number of Brown Boobies on ground nests away from shrubs. Clip from drone footage, West Island, Ashmore Reef in the Timor Sea. Monash University.

## 2.2 SURVEY TYPES

This section covers the key types of surveys that can be adopted to establish seabird presence, and population counts/trends, within the context of habitats and ecosystems, both on land and at sea.

### 2.2.1 RAPID ASSESSMENTS/RECONNAISSANCE SURVEYS

Scattered across the Pacific are numerous islands where there are limited or no data is available on seabird populations. Obtaining data on these islands is important for global conservation, and rapid assessments provide a quick way of obtaining a snapshot on species composition and distribution in time. These can be exciting surveys, as you never know what you may find. They can also represent daunting tasks, as surveying seabirds requires a good working knowledge of the species likely to be present and what their breeding phenology is. So, how do you deal with what is effectively a blank slate?

**Do your homework.** Rapid assessments of remote and unexplored islands can require huge amounts of planning and logistics, so you want to maximise your chances that you will obtain the best data possible. Undertake a literature search to find out what has been done in the area, be they scientific papers, technical reports or even old trip reports. Assess what species are potentially present in the area (although of course don't limit yourself to these, think outside the box), and whether there are any data is available on their breeding phenology from nearby areas. Clearly you don't want to be conducting your surveys when key species are away at sea in wintering grounds, for example.

**Consider appropriate methodologies**. If you are searching for nocturnal species, acoustic sensors are an incredibly useful tool. These can be left in appropriate areas for several months and the data then analysed to see what species are vocalising (see Sections 2.1.3 and 2.1.4). This is a particularly useful technique for rare nocturnal species, as these can easily be missed over the course of a few nights of surveys using observers. If the area is small, and there are ground nesting species present, using drones may give you a quick and efficient way of cataloguing and counting everything that is present (see Section 2.2.7). On-the-ground assessments are also incredibly useful, with surveyors covering as much ground as possible, and as many different types of habitats as exist on the island to look for seabird sign. Shoreline counts at strategic points will provide data on birds foraging in the near shore areas, or nocturnal species amassing in the latter part of the day in preparation for flying into colonies. Likewise, nocturnal counts using thermal or night vision will help provide additional data on birds coming in under the cover of darkness. If you have access to a boat, circumnavigating small islands increases your chances of obtaining a full assessment of seabird activity in the region (although remember that just because a seabird is foraging around an island, it does not necessarily mean it is breeding there).

**Survey at different times of the day.** Activity patterns vary dramatically between species, so make sure you conduct surveys in different periods of the day. Diurnal colony nesting species may depart early in the morning for foraging areas, meaning that counts in the middle of the day may under-estimate colony sizes. Nocturnal species are, as the name suggests, far out at sea during the day and only come in after dark. Furthermore, different species may have different vocalization periods during the night – a species that is vocal after dusk may be entirely silent before dawn, while the reverse may be true for another species in the area. Shearwaters are well known to be active callers pre-dawn as they depart to sea.

**Multiple visits.** While it may not always be possible, it is worth undertaking several visits to an area at different times of the year. As breeding seasons are often not in sync between different species, this will increase your chances of obtaining a full assessment of all the seabirds breeding in the area.

**Opportunistic surveys.** There are many places where seabirds (e.g., White-tailed Tropicbirds, White Terns, Brown Noddies) breed well inland and away from the coast. These are quite often in steep-walled forest valleys with challenging access. These birds are mostly tree nesters, making getting accurate estimates of numbers extremely difficult. If breeding sites like this are located they should be recorded, if possible, from a vantage point that allows a clear view where the birds are likely breeding. For example, above Apia, Samoa there are two valleys where the three species above are breeding, and it is possible from a public lookout at one (Fig. 74) and café deck at another to work out where most of the activity is focussed and plotted in GIS accordingly.

Figure 74. View from Malololelei, looking down the forest escarpment, ridges and valleys that drop away steeply to Apia city. Photo: Chris Gaskin

Figure 75. White-tailed Tropicbird over land, through trees, Malololelei, Samoa. Photo: Edin Whitehead.

Figure 76. Brown Noddy flying to roost, Tiapapata, Samoa. Photo: Edin Whitehead.

## 2.2.2 THREATS ASSESSMENTS – STAGES OF INTERVENTION

**Paula A. Castaño, Paul Jacques, Richard Griffiths, Island Conservation**

As previously indicated within this manual, seabirds face a wide and increasing range of human-induced threats to their survival worldwide. One thing all seabirds have in common is that they must come ashore to breed, and it is during this period that they are often the most vulnerable. On land, introduced and invasive alien species are the most prevalent threat to breeding seabird populations, although urbanization (including threats such as powerline collisions), disturbance light pollution and illegal or unsustainable harvesting of eggs, chicks and adults can also be problematic (see section 1.6.1).

In this section we describe how to conduct a terrestrial threat assessment for seabirds with a particular focus on invasive species. Terrestrial threat assessments are a critical component for any seabird recovery planning and should be conducted as early as possible, as the type and severity of the threat could influence recovery actions required for the species' long-term survival. It is also important to acknowledge that threats can change over time, so seabird recovery plans, including threat assessments, must be adaptable and evaluated periodically (at a minimum of 5 years) to ensure proposed conservation efforts match the need.

Management actions such as invasive species eradication or control also need to be well considered as unintended consequences are possible. For example, targeting just one or a subset of invasive predators (e.g. feral cats) present on an island, can result in unforeseen impacts. One example of this is "mesopredator release"[51], where a mesopredator becomes more abundant and increases its impact on seabirds when another species is removed - although this impact is typically less significant than when the initial invasive species was also present.

**Threat assessment analysis, tools, and resources**

When undertaking the terrestrial threat assessment, a decision will need to be made on whether the threats are to be evaluated at the population or species level (e.g. an island population or across a species entire geographical range), as this will have implications for the scale of the response and the resources and coordination needed. Additionally, basic information on the seabird species of concern, such as its life cycle and breeding location will be required to determine how best to focus effort. If it is unknown where a species breeds, there may be little point in conducting a terrestrial threat assessment as interventions may not be possible. In these cases, the focus should be on collecting basic ecological data about the species.

**Step 1**

A terrestrial threat assessment has a number of stages, and the first begins before conducting any site visits, which is the literature review. A literature review examining all available information on the seabird species or related species, the targeted geographic area, and previous conservation efforts is critical to securing information on potential threats and knowledge gaps, information that will be critical when it comes to planning a site visit. Although time-consuming, literature reviews are valuable, as often they can be the only source of information on the conservation target species and the threats they face.

For example, a species impacted by high predation from invasive predators could be pushed to the limit, remaining only on inaccessible areas within an island or territory (rocky shorelines), and, therefore, could be easily considered extinct with no immediate action taken to support its protection and recovery. A prime example is Auckland Island, Aotearoa New Zealand, where feral cats and pigs have been present for over 200 years and have almost entirely extirpated ground and burrow-nesting seabirds from accessible parts of the island. A remnant colony of White-capped Albatross (Thalassarche cauta), also known locally as White-capped Mollymawk, remains on the cliffs at the south-western point of the island, where they are largely inaccessible to pigs, and likely, small populations of other smaller burrow nesting species (including petrels, shearwaters, and prions) survive amongst the precipitous western cliffs[52].

A literature review can be completed by accessing a range of sources, including published (e.g., scientific papers, technical reports, public databases) and unpublished "grey" literature (e.g., old trip reports, government reports). Additionally, you can design specific surveys for conservation practitioners, scientists, resource managers, or local community members that could be e-mailed to gather additional information and locate data sources that are not readily accessible. Once this step is completed, you can use this information to develop an initial threat matrix, including all threats identified and determining for each of them the likelihood of occurrence, level of impact at the population and species level focusing on scope (i.e., the proportion of the total population affected), and severity (i.e., the overall decline caused by the threat), any interventions implemented to date to manage that threat if any, and data gaps that will be important to consider for a site visit.

**Step 2**

With the initial stage of a terrestrial threat assessment completed, site visit planning can start. The main objective of the site visit is to gather additional information on the threats, confirming the presence or absence of a particular threat and, if not previously completed, identification of stakeholders that could support or be impacted by your survey plan efforts and any future threat management action. Given the remoteness of some sites, this on-site data collection can be paired with a trip to collect other valuable data on the species (such as breeding habitat and information on life cycle), and when meeting with local stakeholders.

Tools and resources that can be used to assess threats to a seabird species on-site include interviews with local stakeholders, site-based observations, traps and trail cameras for documenting the presence and impact of invasive species. Other technologies such as Environmental DNA (eDNA), detection dogs and thermal detection systems, if affordable, may also be of use. All of these techniques are covered elsewhere in this manual.

Interviews with local stakeholders are a valuable tool and are strongly recommended regardless of whether the island or area of study is uninhabited. Meeting local communities (e.g., fishermen, conservation practitioners, scientists, and government agency staff) to gather additional information on the threats your species of concern faces will provide valuable information that otherwise may not be available. It may also encourage them to engage with your seabird survey plan and any interventions you seek to implement to support that species or other species within the region.

**Step 3**

Site-based observations are incredibly important as they provide direct evidence of threats. However, when visiting a site, personnel should take the utmost care to minimise the risk of introducing invasive species. Observing biosecurity protocols such as checking all clothing and footwear for dirt and weed seeds, confirming the boat or ship has no ants, reptiles or rodents on board and packing all gear into secure containers for travel is critical. Caution should also be taken when conducting assessments to minimise site disturbance such as opening up new trails that could then be exploited by invasive species or humans harvesting seabirds. Within seabird colonies, damage to burrows and disturbance to breeding individuals is a high risk and care should be taken to minimise these impacts. More specifics can be found on section 3.1.4 of this manual.

If possible, visit the site when the birds are present, as this is the time predation will occur. Look and document any evidence of predation by invasive species. Often what is left of a carcass can provide an indication of the predator involved (Fig 77). For example, feral cats are often messy eaters that will tear chunks out of the breast as well as biting off the back of the head, whereas a predatory bird will neatly pluck the breast clean and strip the sides of the neck. Additionally, identification of paw prints or faeces can be instructive.

**Figure 77. First image shows the remains of a White Tern, the result of cat predation in Wallis and Futuna. Second and third images show the remains of a wing-set of an Antarctic Prion and an unknown seabird species predated by a cat on Auckland Island, New Zealand. Photos: Island Conservation.**

**Step 4**

If you have prior knowledge of the invasive species that may be impacting the seabird species of concern, traps can be placed in or around breeding sites to confirm its presence or absence. Traps should ideally be species specific and housed to minimise risk to non-target native species. Sufficient traps should be deployed to provide confidence that an invasive species is present, and traps may need to be run for a period of time (days to weeks) to confirm species presence.

Trail cameras should be deployed by a trained operator who knows how to position and set up the camera to secure good quality images. Avoiding moving vegetation and or light changes is necessary to avoid generating a large number of images that provide little to no information. Cameras can be set to operate only when seabirds are present and should be placed in breeding areas preferably focused on a burrow or nest site although wider angles may be necessary to detect an invasive species. Cameras can be lured to specifically target an invasive species if you just want to confirm presence or absence.

The use of eDNA is a highly effective tool to confirm the presence or absence of an invasive species but does require knowledge of where DNA is best found in the environment. The method is currently expensive, but costs are likely to diminish overtime. Indicator dogs are extremely sensitive and may be worthwhile exploring if time on site is extremely limited. Thermal detection equipment is also valuable if you are reliant on observations only. Drones with thermal cameras can be used to detect some invasive species within some habitats and may have utility across sites that are inaccessible.

**Step 5**
Upon return from your site visit or visits, incorporate all data collected into the threat assessment matrix (see example below). This will be valuable to prioritize the need for intervention at the population or species level. As previously indicated, management actions such as predator control or eradication could be refined by additional site visits to secure more specific data. If control is the management tool selected, the sustainability of this option should be considered as benefits can be eroded if control is stopped[53].

Eradication of invasive predators, if feasible, is ideal as it permanently removes the threat and often enables rapid recovery of seabirds without any further management intervention. However, eradication is not possible at every site. For many islands, particularly large complex sites, a feasibility assessment will be required to determine whether eradication of the target pest species is possible, considering factors including the limitations of current tools, the scale and remoteness of the site, social acceptability, sustainability of funding and biosecurity (i.e. our ability to defend the site from reinvasion)[54].

### Threat assessment matrix example

Table 3. An example of a threat matrix; for Galapagos Petrel on Floreana Island, Galapagos Islands.

| Threat | Likelihood of occurrence | Level of impact – population/ species | Scope | Severity | Interventions | Knowledge gaps |
|---|---|---|---|---|---|---|
| Black rat predation of eggs and chicks | High | Population (Floreana) and at species level (Galapagos islands) | 100% (Flo. population) and 60% (species) | Medium to high without control | Control with anticoagulant rodenticides on Cerro Pajas (main breeding colony) | Uknown percentage of population breeding outside main colony on Floreana. |
| House mouse predation of eggs and chicks | Unknown | Population (Floreana) and at species level (Galapagos islands) | 100% (Flo. population) and 60% (species) | Low – Medium? | Control with anticoagulant rodenticides on Cerro Pajas (main breeding colony) | Unknown if the species predate on eggs or chicks |
| Cat predation of chicks | High | Population (Floreana) and at species level (Galapagos islands) | 100% (Flo. population) and 60% (species) | High | Secondary exposure to rodenticides | - |
| Cat predation of adults | Medium | Population (Floreana) and at species level (Galapagos islands) | 100% (Flo. population) and 60% (species) | Low-Medium? | Secondary exposure to rodenticides | Unsure of how often adults get predated by cats |

**Step 6**
If control or eradication is one of the proposed interventions for managing any threats to seabirds, it is also recommended in addition to your threat assessment to conduct a non-target risk assessment to identify unintentional impacts from the invasive predator control or eradication effort to ensure those risks are properly managed through the more suitable non-target mitigation strategy and tactic, as well as understood by all project partners. For additional details and considerations regarding this type of assessment and possible mitigation actions to implement you can review[55,56].

### 2.2.3 VEGETATION COMMUNITIES INFLUENCING COLONY BOUNDARIES

A range of factors influence where seabirds breed. In the case of burrowing seabirds, these can include angle of slope, substrate, soil depth and hardness, drainage, forest type, and altitude - factors which vary from species to species. Tree nesting seabirds such as Red-footed Boobies, noddies and White Terns will favour particular tree species. Surface nesters such as Brown and Masked boobies, as well as Sooty Terns may favour open ground. Frigatebirds can be either surface-nesters or they may nest on top of shrubs. A number of tropical petrels are also surface nesters, albeit under the cover of understory vegetation. Christmas Shearwaters (*Puffinus nativitatis)* also nest on the ground under dense vegetation or rock outcroppings.

Understanding vegetation communities and how they can influence colony boundaries allows a short-cut approach to assessing where seabirds could be breeding in a target area. Before you start, do your homework. Use the literature to gain an understanding of what your species needs in terms of nesting vegetation. You can then use this information to help design your study as outlined below.

**Method**
You can incorporate an assessment of vegetation communities into your study in several ways. These include both desk- and field-based approaches.

**Desk-based approach.** If you have a solid understanding of the vegetation that your species needs, you can consider undertaking a desk-based assessment to define potential colony boundaries within your study area. This can be undertaken by using Google Earth imagery (as recent as possible), aerial photographs or GIS vegetation layers to plot the vegetation communities.

**Field approaches.** While carrying out desk-based modelling exercises can be extremely useful, particularly for large-scale assessments, nothing compares to going into the field – either to ground truth modelling results, or by collecting the initial data needed to create habitat models (if the breeding preferences of your species are poorly known). By undertaking an initial sample of colonies using transects, for example, the vegetation communities that influence presence-absence of colonies can be quickly revealed. Surveying using ground-search methods is demanding, so to speed the process up it can be combined with the use of a drone. In this scenario, a drone could be used to provide potential colony boundaries with only ground truthing verification required to ascertain certainty of occurrence.

The above approaches can be taken one step further by adding long-term monitoring of the vegetation and invertebrates around colonies to your seabird survey programme. By doing so, it becomes possible to monitor the extent to which the ecological functions that seabirds offer are being fulfilled which in turn reinforces the importance of seabird conservation. And as we now know from studies in places like Palmyra, seabird conservation on islands has a profound impact on the surrounding marine environment as well, so the marine environment adds another interesting element to consider (see Section 3.11 Seabird-transported nutrient monitoring).

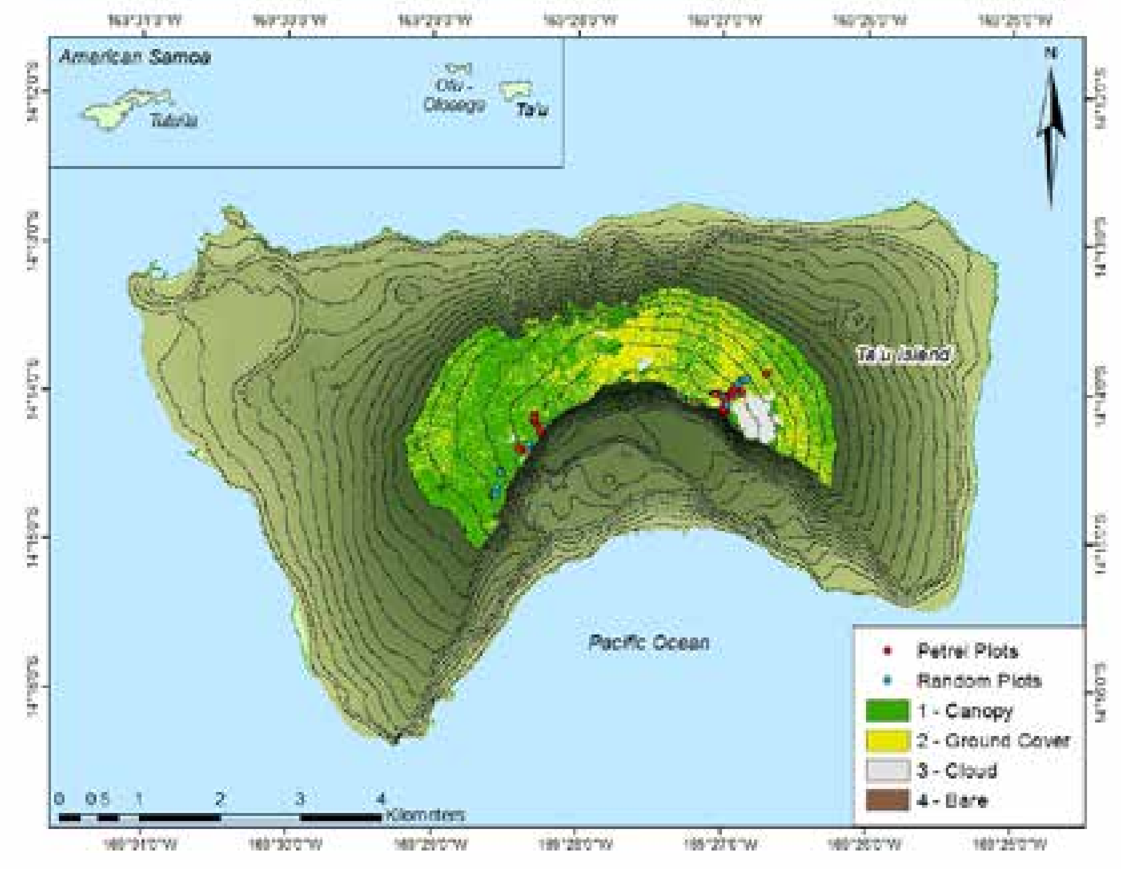


Figure 78. Map of Ta'ū Island, American Samoa, with the summit montane habitat classified by the presence of trees (bright green) or open ground cover (yellow). Also shown are the locations of habitat classification plots (both random and petrel burrow)[57].

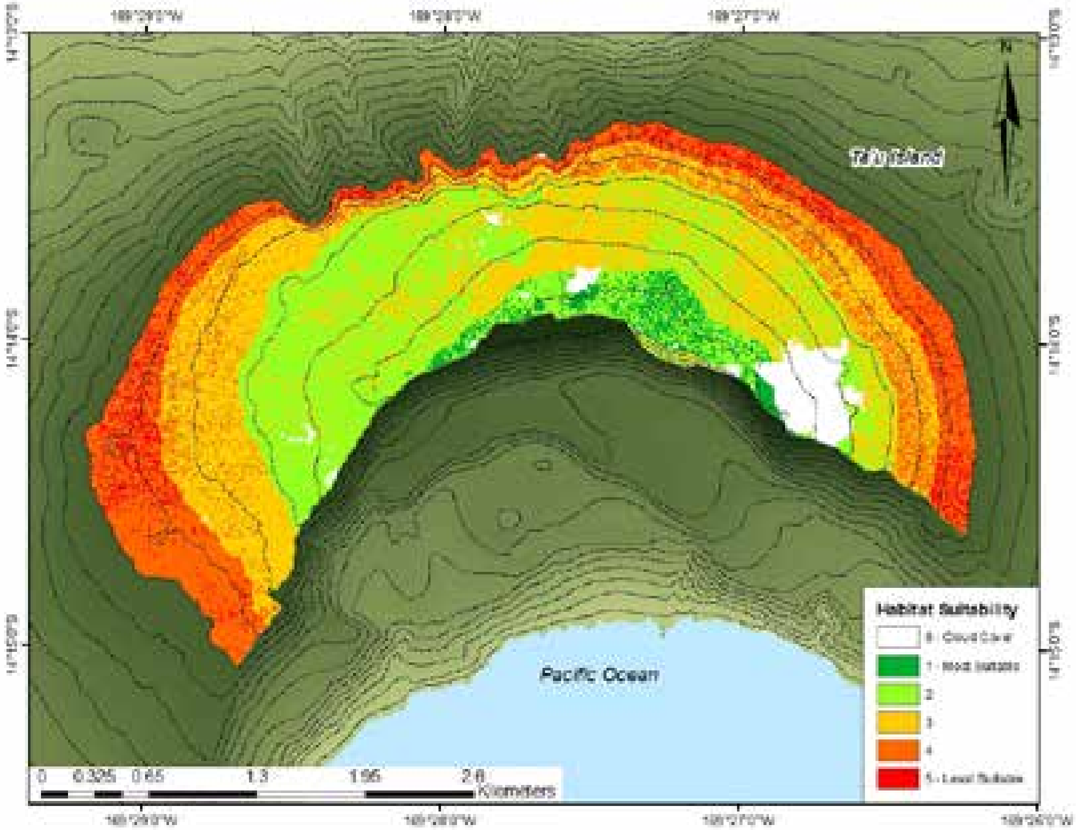


Figure 79. Map of Ta'ū Island summit montane habitat classified by habitat suitability. The most suitable habitat (categories 1, 2) is presented in green, and the least suitable habitat (categories 4, 5) is presented in red[57].

### 2.2.4 SPECIES-SPECIFIC COLONY SURVEYING

Measuring population size and trends is fundamental to understanding the status and conservation needs of a species and designing effective management strategies. Population size is often measured first because many methods of measuring population trend require repeated measures of some aspect of population size. A complete census of all individuals in a population is very difficult to obtain, and in some cases only a portion of the population can be counted, such as breeders when they are in the colony. Furthermore, certain seabirds can be particularly tricky to obtain a population estimate, such as rare nocturnal burrow nesting Procellariforms.

Two case studies here illustrate surveys to establish population estimates and habitat use on a large scale for two species, in both cases whole islands, both in Aotearoa New Zealand. The first, Te Hauturu-o-Toi/Little Barrier Island (hereafter Hauturu) is a 3000-hectare rugged island, whose highest point is 752m asl. The second case study is for the Poor Knights Islands, where the two main islands were surveyed: Tawhiti Rahi (163 ha) and Aorangi (110 ha), with the highest point 216m asl. Both surveys' estimates were based on habitat modelling and randomised quantitative sampling and represent repeatable assessments of the breeding population for both species. Major surveys like these also provide excellent opportunities to gather other data, provided that the expertise is available to conduct them (see some of the sections in Part Three).

#### CASE STUDY – Tītī / Cook's petrel, Hauturu, Aotearoa New Zealand

**Matt Rayner, Auckland War Memorial Museum (Tāmaki Paenga Hira)/University of Auckland**

Cook's Petrel (*Pterodroma cookii*) is an Aotearoa New Zealand endemic and endangered species (Vulnerable – IUCN Red List). It is restricted to breeding sites at the northern and southern extremes of its former range, with the world's largest breeding population found on Hauturu[58].

To improve the limited knowledge of the breeding habitat of this species, an island-wide survey was combined with GIS mapping techniques and logistic regression data analysis techniques to examine burrow distribution and habitat use of the species. Using a GIS and digital elevation model of Hauturu, a boundary was selected based on largely botanical information dividing the island into two strata (i.e., below and above 300m), and survey plots were generated using randomly selected coordinates. A total of 104 plots within each stratum. To minimise spatial autocorrelation in burrow counts a minimum distance rule of 100 m between sites was applied. Fieldwork for the island-wide survey was conducted during the breeding season of Cook's Petrel. The following habitat variables were recorded within each plot:

- Canopy cover
- Canopy height
- Number of stems within the plot between 1 and 20 cm diameter at breast height (dbh)
- Number of stems within plot > 20 cm dbh
- Slope
- Aspect

Results showed that, on Hauturu, Cook's Petrel were breeding predominantly above 300 m asl with burrows situated on steeper slopes, closer to ridge tops, and in unmodified forest habitats with low and open canopies and greater numbers of large stems compared to the available terrain and habitat. The current distribution of this population is a result of habitat selection and historical human-mediated impacts. Mature forest habitats, proximity to ridge tops, and steep slopes are key habitat requirements for this species. A large amount of suitable habitat is available for Cook's Petrel on Hauturu and the recent removal of introduced predators was expected to result in an expansion of this population. These results provide useful information to aid in the restoration of former colony sites on other islands and the New Zealand mainland[58].

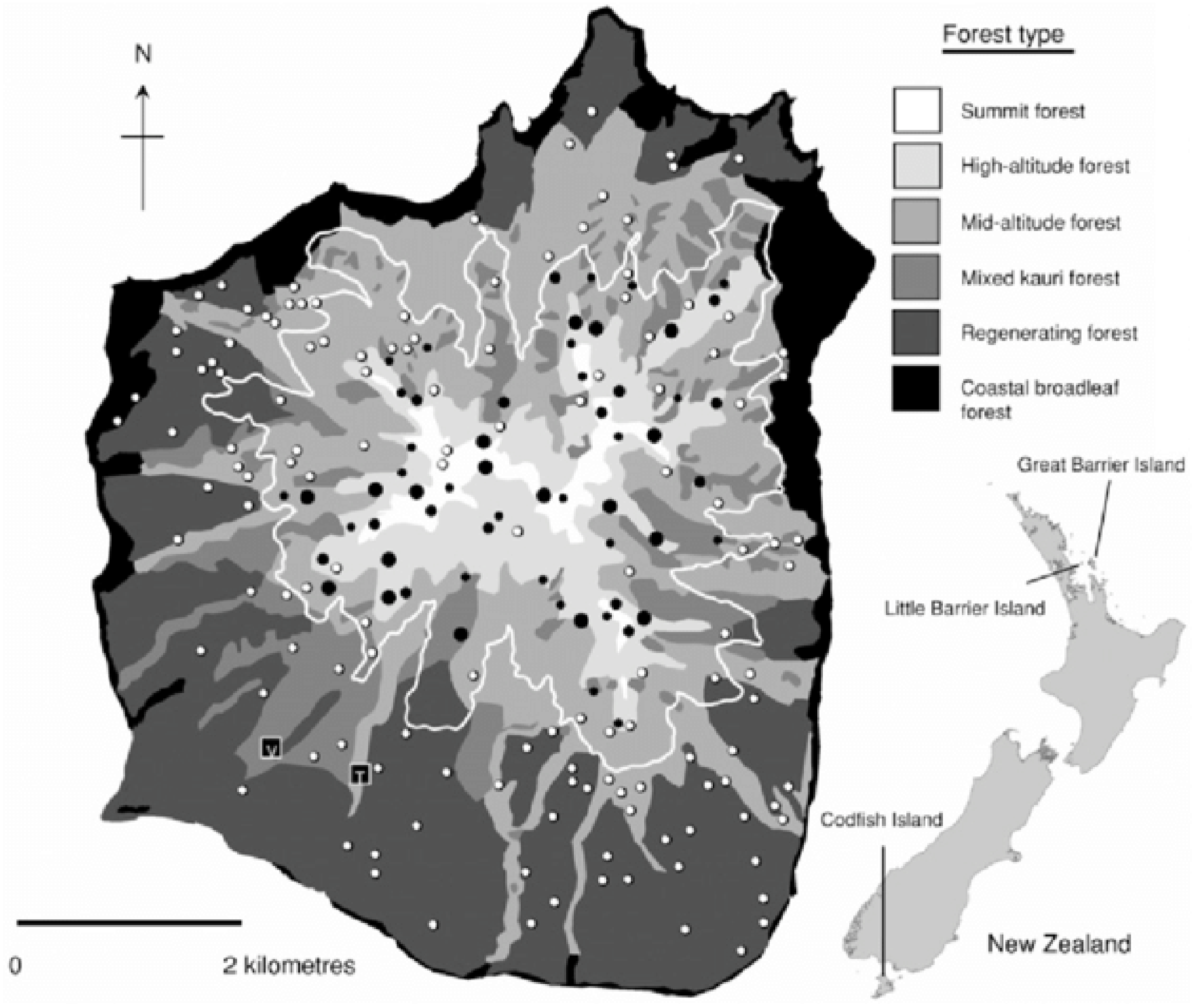


**Figure 80. Map of Hauturu showing its position within New Zealand, the location of the stratified survey plots (n = 194), forest types, the 300-m altitude contour and strata boundary (white line), plots with 0, 1, 2, 3 burrows present, and the low-altitude Valley (V) and Tirikakawa (T) colonies[58].**

## CASE STUDY – Rako / Buller's Shearwater, Poor Knights Islands, Aotearoa New Zealand

### Megan Friesen, St Martins University / University of Auckland

Rako, or Buller's Shearwaters (*Ardenna bulleri*) (Vulnerable – IUCN Red List), breed only on the Poor Knights Islands in the northern Hauraki Gulf, 22 km offshore from the North Island of New Zealand. These islands are strictly protected as nature reserves and are predator-free. The island group is comprised of two main islands, Tawhiti Rahi (163 ha) and Aorangi (110 ha), as well as several small islets. This survey covered the two main islands, with visits to each in December and April during the incubation and chick provisioning periods respectively[59].

The aim of the survey was to estimate the breeding population size of Buller's Shearwater using a repeatable method that accounted for habitat preference and incorporated baseline information on breeding activity. The results would provide a baseline estimate of pairs in their core breeding habitat, allowing future population trends to be determined and inferences made on marine ecosystem health.

**Survey methods employed were as follows:**

**Burrow density:** Three-metre radius plots were selected using a random number generator corresponding to a numbered grid (50 plots per island) mapped to a GPS point. At each plot, all Buller's Shearwater burrows were counted, including burrow entrances that were more than halfway within the boundary of the plot. Buller's Shearwaters dominate the burrowing seabird fauna on the Poor Knights Islands to the extent that very few other seabird species were encountered (burrows less than ~10 cm in width were considered to be other species). The dominant vegetation and general topography (ridge, plateau, mid slope, or gully) were also recorded.

**Burrow occupancy:** On each island, 10 transects were laid out at selected intervals (~200 m apart) across the main ridgeline, extending 150 m. Three survey points were established along the transect, at 50 m, 100 m and 150 m. At each survey point occupancy was recorded of the two nearest burrows. Burrows were only considered occupied if a bird was confirmed by hand or using a burrow scope. Burrow occupancy was calculated as the percentage of occupied burrows out of all the burrows sampled. Additionally, habitat and topography data were collected, including canopy height, dominant vegetation, elevation, and slope.

**Breeding activity:** On each island, three 25 m × 25 m plots were established to provide an index of nesting success. The plots were sited in areas of differing habitat structure: plateau/ridge top, near cliff, and valley. All burrows within the plot were surveyed for activity in December (post-laying) and again in March, midway through the chick-rearing period. Burrows were considered active during the December survey if an adult was present during the day or if there were other obvious signs of breeding (e.g., sitting on an egg, nest cleared out and scratching observed, or fresh excrement found in the burrow entrance). Nests were considered to be active during the March survey if a chick was present.

**Habitat modelling:** A habitat model was used to estimate population size and was based on one created to estimate Cook's Petrel populations[58]. The following data were combined - burrow density, occupancy, and topographic raster layers: elevation, slope and aspect.

**Figure 81. Counting burrows in 3m radius (circular) random density plot during 2024 resurvey. Photo Edin Whitehead.**

The survey's results revealed that the breeding population of the Buller's Shearwater was substantially lower than some earlier estimates (which did not incorporate habitat preferences). The number of active burrows of Buller's Shearwater estimated in this study – considered to be approximate to the breeding population – is within the range of estimates made in previous, recent rapid land-based surveys (for Aorangi only) but much lower than the coarse estimates made in the 1980s (which presumably included non-breeding individuals). It is important to note that the population estimate did not include difficult-to- access sites on steep, fragile slopes, which were not included in the survey. However, unlike previous studies, the survey's estimate was based on both habitat modelling and randomised quantitative sampling and represents a repeatable assessment of the breeding population for Buller's Shearwaters.

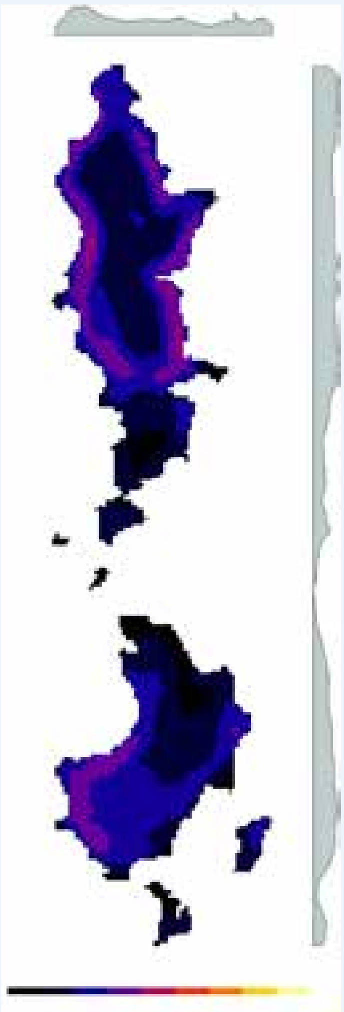


**Figure 82. Predicted number of Buller's Shearwater burrows per 25 m$^2$ cell based on habitat modelling for both Tawhiti Rahi (a) and Aorangi (b) with topography (grey)[59].**

## 2.2.5 LARGE SCALE (e.g., WHOLE ISLAND) BIODIVERSITY SURVEYING

The approach taken in both the above case studies can be applied to large scale biodiversity surveys. These surveys can be extremely ambitious, involving whole islands (or part of much larger main islands) and involve teams of people with a range of expertise and skills. As highlighted earlier, how many people and what expertise is required will depend on what the survey aims to achieve and how much funding and time is available. When considering an emphasis on the contribution of seabirds to terrestrial ecosystems, there is great value in mapping out vegetation communities, invertebrates, other avian species, terrestrial fauna, and even the marine environment. If you have the resources, time, and funding don't be afraid to think big!

### 2.2.6 eDNA SURVEYING

There is an increasing demand for rapid biodiversity assessment tools that have a broad taxonomic coverage. The assessment of DNA obtained from environmental samples, or "environmental DNA" (eDNA), has shown great promise as a non-invasive method for monitoring terrestrial biodiversity. With only trace amounts of DNA needed to identify species, the data obtained can strengthen biodiversity assessments through improving the detection and monitoring of rare, cryptic, or protected species, increasing the taxonomic resolution of biodiversity surveys, allowing for increased sampling of inhospitable or challenging environments to survey, and aiding in the early detection of invasive species.

Within terrestrial systems careful consideration of the targeted substrate/s is essential (water and soil are the most commonly used substrates) because each type will likely sample different components of the biodiversity, depending on how the species are interacting with that specific substrate.

After DNA has been deposited in the environment, it starts degrading, but the rate at which this occurs differs between sample types and environmental conditions. The variability in DNA degradation rates influences the effectiveness of a sample type as a successful agent for eDNA biomonitoring. For these reasons, new eDNA substrates are continually being explored, and eDNA-based biomonitoring using water, soil, ingested or invertebrate-derived DNA (iDNA) are now common. Recently, the detection of species through airborne DNA has also been trialled to detect vertebrate taxa, using air samplers and spiders' webs[60].

To date, eDNA has been largely untested for detection of seabirds, especially those species in scattered and small populations, in remote locations. For example, it has been found that terrestrial birds and seabirds don't tend to show up very reliably in the aquatic eDNA samples (for example), due to their minimal inputs of faecal matter and other DNA into fresh water sources.

However, one study in Australia's subantarctic, on Macquarie Island, an island with known major seabird provenance, detected several uncommon species amongst the more common species. In that case, discarded feathers and faeces provided high quality DNA for species identification, assisting in detection of new species arrivals and new breeding sites[61].

### 2.2.7 MONITORING TROPICAL SEABIRDS USING DRONES

**Rohan Clarke and Karina Sorrell, Monash University**

#### Overview

Drones have rapidly advanced wildlife monitoring in recent years. For surface-nesting seabirds that form large aggregations in open terrain, drones are especially useful[62, 63] and can be operated safely within breeding colonies[64]. Generally, a drone aircraft is flown over the target area of nesting birds along a pre-determined flight route to collect a series of images that look directly down on the colony. The height and speed of the aircraft, image overlap, and camera settings are pre-programmed into the flight plan. Specialised software is then used to stitch images using tie points (points that do not differ between images) to form a single georeferenced orthomosaic image of the entire mapping area. Tags can then be placed on the orthomosaic to count different species, age classes, and nesting stages (depending on the resolution of imagery). Whilst drone operators are on-ground collecting drone imagery, ground truthing should be undertaken to confirm which species of seabird are present at the site. Ground truthing by experienced seabird observers assists with subsequent species identification and behaviours visible in the collected imagery.

#### Equipment and flight planning

There are a variety of drone aircraft that are suitable for monitoring seabirds. Lightweight quadcopter aircrafts are well-suited, with current popular models including the DJI Phantom 4 RTK (1.391 kg) and DJI Mavic 3 Pro (0.958 kg) (Dà-Jiāng Innovations (DJI), Shenzen, China). Flights are designed in purpose-built flight planning software on either the in-built controller screen, or an external tablet. To designate the flight area, a polygon is drawn around the seabird colony area of interest using a satellite image base map as a guide. Flight parameters are set within the flight-planning software. General camera settings for drone flights include Camera gimbal angle -90° (nadir), white balance either 'sunny' or 'cloudy' (according to the weather conditions at the start of the flight); shutter speed priority fixed at 1/1000 second to minimise image blur; aperture and ISO set to automatically adjust to variable light conditions within the flight; and focus set to infinity. Suitable image capture setting are 90% front- and 75% side-overlap to allow adequate post-flight generation of orthomosaics.

Survey height is an important consideration for any drone operation, where image resolution, battery limitations, and disturbance to the seabirds and any other wildlife should all be accounted for. Smaller species, such as terns, may require a lower flight height to achieve an acceptable level of image resolution for identification in the final orthomosaic image. However, as outlined in the SPREP document "Responsible Marine Wildlife Viewing Guidelines", an appropriate flight height above seabird colonies of 50m is recommended. Prior to commencing formal surveys, a trial flight may be required where images are taken at different flight heights to assess image resolution and inform survey flight height.

Topography, vegetation, and seabird nesting behaviour also impact flight planning – specifically survey height. For seabird species that nest on the ground in open terrain, or on top of low vegetation in low-relief landscapes, a simple flight plan where the aircraft is flown at a consistent height would be suitable. For seabird species that nest in tree canopies, the height between the top of the canopy and aircraft should inform flight height (not the height above ground) to achieve an appropriate image resolution and avoid collisions. Where the topography is highly variable within the survey area (e.g., seabirds nesting in trees in a terraced landscape), a drone capable of terrain tracking should be used to allow mapping with a variable flight height. This method allows the aircraft to maintain a constant height above the ground or tree canopy.

Figure 83. Monitoring a drone flight. Photo: Monash University.

**Image processing**

Post-flight processing of aerial images should be undertaken in software that is capable of stitching multiple images together e.g., Agisoft Metashape, Pix4D Capture. These software programs automatically align images based on geolocation data and then stitch all images together to produce a final orthomosaic image of the survey area. This orthomosaic can then be used to mark the birds to obtain final counts.

**Digital image tagging**

Birds may be tagged in orthomosaics using either manual tagging, or automated image recognition. Geographic Information System (GIS) software (e.g., ArcGIS and QGIS), are suitable software packages for manually tagging orthomosaic images. A 10 x 10 m grid (or similar) overlaid on the orthomosaic may aid observers to systematically count grid-cells. However, tagging orthomosaics is a time-consuming task when completed manually. That is, each digital tag that is placed on a bird must be individually positioned and labelled by species and with an optional series of additional attributes that may include nesting status, behaviour, age, sex, etc. With advancements in automatic image recognition, this process is becoming more efficient whereby an algorithm is trained to automatically detect and assign attributes to birds in images[65, 66]. Ultimately, for drone surveys to be deployed as a practical and efficient tool for the ongoing monitoring of large aggregations of breeding seabirds, automatic detection and identification is critical to the workflow. Small breeding colonies may be counted manually; however, the task becomes onerous once seabird numbers exceed ~1,000. The development of this automatic detection process is underway for some seabird species globally, but for most species is not yet complete and/or publicly available.

**Species suitability**

Some species cannot be effectively monitored using drone surveys. This may be for a variety of reasons such as behaviour that precludes detection from above (e.g., seabird species that nest underneath vegetation or in burrows) or multiple species that lack identification features that facilitate assignment between similar species from above (e.g., Black Noddy and Lesser Noddy). Ultimately, these species will vary by location and require a case-by-case suitability assessment for drone surveys. Timing of colony formation and breeding will also be an important factor to consider here. For example, two species with similar appearances may not be able to be identified in the same image if they have overlapping breeding seasons. However, if the breeding timing is known and occurs at distinct times of the year, identification may be assumed based on an assessment of timing paired with ground-truthing expert observers at the time of drone surveys.

**Benefits**

Recent research underscores these benefits with paired drone and ground surveys of Greater Crested Terns and Lesser Frigatebirds in the tropics (and penguins on Sub-Antarctic islands) demonstrating that drones detected more nesting seabirds and improved monitoring precision (i.e., sample variance) by an order of magnitude when compared with traditional methods[62]. Subsequently, colony counts were demonstrated to be more accurate (i.e., closer to the true population number) than traditional counts using models to mimic seabird colony structures[63].

To illustrate the practical application of drones in seabird monitoring, drones now serve as the standard tool for population monitoring at a number of tropical seabird islands in the Indo-Pacific region. Of note are programs to monitor ground nesting Greater Crested Terns which form dense and relatively uniform nesting aggregations (e.g., Great Barrier Reef Islands), shrub and tree-nesting frigatebirds whose colony structure often involves clusters of nests within a broader colony area (e.g., Ashmore Reef), and tree-nesting Red-footed Boobies whose colonies can span many 10s of hectares (e.g., Pulu Keeling). These distinct nesting habitats present different backgrounds in aerial images, which can complicate ground-based counts. However, drone surveys can be readily modified to accommodate these variations, capturing high-resolution images that allow for the correct assignment of species and ultimately monitoring programs underpinned by precise and accurate techniques. A key advantage of drones is that images can be stored and viewed later whereas counts by ground observers depend on the experience of the field team and cannot be verified by future workers.

**Figure 84. Nesting Lesser Frigatebirds, West Island, Ashmore Reef, Australia. Clips from drone footage: Monash University.**

Beyond improving monitoring outcomes, drones also offer several additional benefits when used to monitor seabird colonies. When paired with automated techniques to rapidly count focal species, considerable efficiency can be achieved. For example, by focusing solely on data capture in the field (with a post-processing workflow delivered at a later date) remote sites may now be surveyed within a much shorter period of time. Studies have also shown that drone operations cause minimal disturbance to the birds: often less than that caused by human presence during ground counts at equivalent colonies. This is particularly important for sensitive species that might abandon nests if repeatedly disturbed by observers that are on foot. Furthermore, contrary to common perceptions, the risk of drones colliding with seabirds has been demonstrated to be extremely low, with safe and routine operation of drones being readily achieved in areas with high densities of flying seabirds[64, 67]. That said, with some species, a pilot study prior to implementation should be considered as disturbance could vary according to breeding stage.

Finally, archived images and orthomosaics provide further benefit. First, they provide a permanent record of past surveys, including a capacity to deliver quality assurance (QA) processes that are rarely practical with ground counts. Second, should new and improved automated counting processes be developed, such techniques can be retrospectively applied to archived imagery such that baselines remain consistent with current methods.

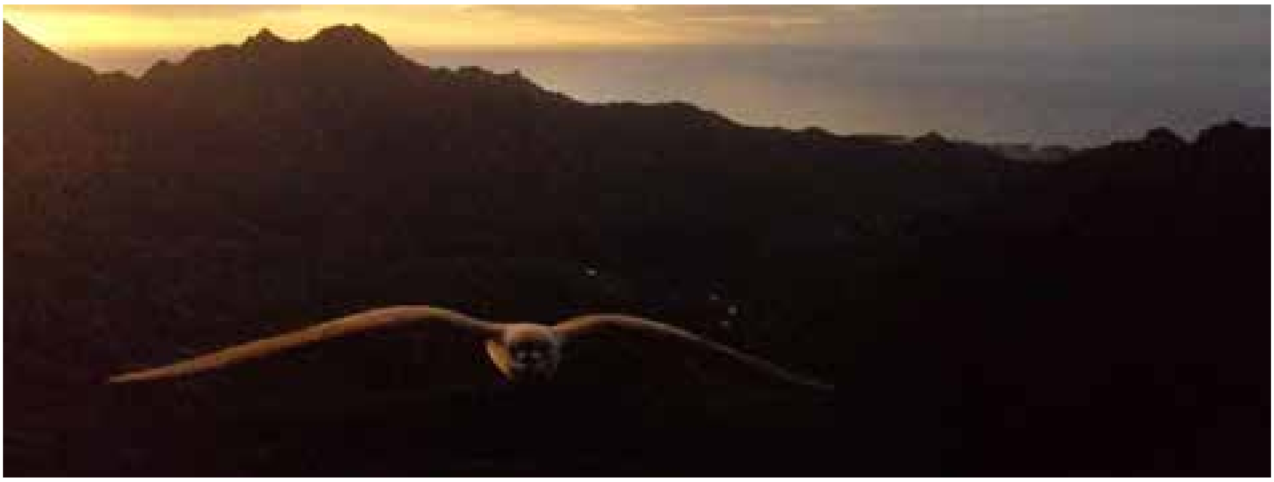


**Figure 85. Herald Petrel approaching a drone in flight, Rarotonga. Photo: Benjamin Evans.**

A note of caution when considering the use of drones for seabird surveys. Make sure you are fully aware of the legal requirements for undertaking surveys with drones in your area, and ensure you operate in an ethical way that does not cause stress to the species you are studying. Also bear in mind that there may be community sensitivities to the use of drones, particularly in residential areas or beaches – please respect local communities and discuss your operations with them prior to launching your drone.

### 2.2.8 SHORE-BASED SEA WATCH SURVEYS

Sea-watching is a type of birdwatching where participants observe seabirds from a fixed point on the mainland. While many birders will do this as a leisure activity related to their hobby, sea-watching can provide important information relevant to seabird research. Ideal locations to carry out this method are coastal areas where there is an open view of the sea, particularly somewhere that allows birds to pass close by such as a headland with deep water immediately offshore. As many of the birds can be passing far offshore, sea watches are typically carried out using spotting scopes.

To carry out repeat surveys (which are important for seasonal and inter-annual comparisons) ensure that the location is clearly identified and easy to revisit. For comparative purposes, undertake surveys at the same start time for a set amount of time and be meticulous about data collection. If there are large-scale weather events (such as sudden squalls or storms) or offshore fishing vessels (with attendant seabirds) that may impact your count, take detailed notes. Seabird behaviours can also be recorded, such as whether birds are feeding or transiting or being counted singularly or in active groups. Through repeat observations it is possible to build up a list of species that frequent a particular section of coast.

In areas where there are active birdwatching clubs or people are using apps like eBird, see whether there are historical or long-term data available for sea watches in the area. Birders can be a very important and useful resource in this manner, although you need to be careful as some people are better at identifying species than others! Lastly, it is also possible to use sea watches as a method to observe bird activity that may lead to identifying places where birds fly to nesting places inland or help guide capture attempts for the same purpose (see the following case study).

#### CASE STUDY - Beck's Petrel, Silur Bay, southern New Ireland, Papua New Guinea

During an expedition to New Ireland, Papua New Guinea to catch and track Beck's Petrels and try and locate breeding sites, a sea-watch component was included in this multi-faceted expedition at Silur Bay. This was undertaken to assess whether birds were gathering off shore and transiting to locations inland – data which would then be used to coordinate an attempt to use floodlights to try and capture and attach tags to transiting birds[13].

**Figure 86. Beach front survey location at Silur Bay, with helpers. Photo: Bill Morris.**

A scope (Swarovski with 20-60mm zoom) was set up on the shore, and the bay scanned for Beck's Petrels. They were counted whenever they were seen. The method used was to do a slow scan every 15 minutes from one side of Silur Bay to the other from 15:00-18:00. Beck's Petrels were only counted if they were seen below the horizon (i.e., coming closer into the bay). On each afternoon many seabirds were counted on the horizon, but they were too far away for positive identification and were discounted. Total counts by 15 minutes were then tallied (see Figure x). It was found that there was a steady build-up of birds coming closer into the bay as the survey period progressed, with birds milling about in restless flight until the point of darkness. No birds were ever seen flying inland or flying over the camp during daylight hours, however, two to three birds were seen flying overhead in the lights after dark. The results of these surveys were then used to guide the subsequent capture and tracking methods (both at sea and on land) throughout the rest of the expedition.

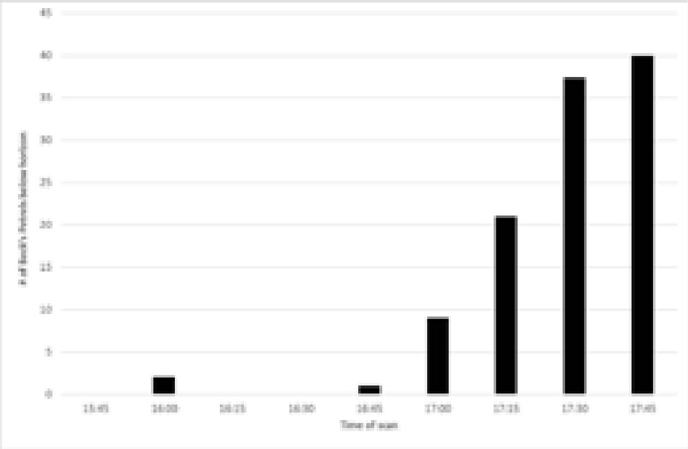


Figure 87. Total counts of Beck's Petrels by 15 minutes. Source: Beck's Petrel Expedition 2017 report.

### 2.2.9 AT-SEA SURVEYS

**Close to islands**

Boats are excellent platforms from which to observe and count seabirds, particularly for birds that are flying further offshore (where they may be harder to count by land-based sea watches), colonies of birds breeding on remote coastlines, aggregations of seabirds foraging at sea, or for seabird surveys in the waters off inaccessible islands. In the latter case, sea-based surveys may be the only way to get counts of seabirds breeding in those areas.

**Method**

If you want to undertake repeat at-sea surveys, make sure that your method is clearly identified and repeatable. Repeat surveys are extremely useful as they allow for an assessment of seasonal or inter-annual changes in seabird populations in your study area. For example the method adopted for surveys of the coast of Tutuila, American Samoa[68], is that all seabirds seen from the boat travelling along the coast are counted if they fit into the following categories:

- Any seabirds in flight or resting between the boat and the shoreline,
- Birds occurring inland,
- Birds flying or perching along the shoreline,
- Birds within 100 m seaward of the boat.

Figure 88. Surveying off the coast of Tutuila, American Samoa. Photo: André Raine

All birds were identified by eye or with the aid of binoculars (Swarovski 8.5x40). For each record, data were collected on an app designed by the project team. Data included time, species, number of individuals, behaviour, and GPS points. GPS points were particularly important to allow the distribution of each species to be plotted and mapped after each survey, along with the location of any breeding colonies. Surveys were undertaken at least twice a year – in May and November – annually. This allowed surveyors to cover the breeding seasons of most seabird species breeding on Tutuila. Doing multiple surveys was particularly important as species such as Bridled Tern, which are a winter-breeding species, were only recorded during November surveys and were absent in May. The methods used above were an abridged version of methods used in earlier surveys in 2000 and 2003 and were carried out in such a way that results could be roughly compared with these historical surveys[69].

While standardised surveys are undoubtedly the best way to go for repeat survey efforts, other shoreline or coastal surveys can be more opportunistic. For example, when passing islands on your way to a study site (or even when on holiday), it's a good opportunity to observe what birds might be visible, and to check what stage they are at with their breeding.

Tree-nesting birds such as Red-footed Boobies can be very visible, while others such as noddies may be more hidden in the trees or in the case of Black Noddies in cliffs and sea caves. In the latter case however, they will be visible flying in and out of their nesting places. This is also true for any birds that breed in burrows or tucked away in crevices or on rock ledges like shearwaters and petrels, although in these cases they typically only come in at night and so will rarely be seen around breeding islands during the day (although some species such as Christmas Shearwaters can be seen during the day). Observations from boats passing between islands, or longer oceanic voyages can be used to collect important data on many of these harder-to-see nocturnal seabird species including identifying key foraging areas (see next chapter).

Figure 89. Christmas Shearwaters over one of the stacks at Morotiri, French Polynesia. Photo: Hiroyuki Tanoi.

Figure 88. Frigatebirds and boobies, Phoenix Island, Kiribati. Photo: Hiroyuki Tanoi

Figure 89. Polynesian Storm-petrel, Morotiri, French Polynesia. Photo: Hiroyuki Tanoi

**Offshore surveys – boat-based**
These include trips made in the vicinity of major islands both inside and outside reefs, sometimes into very deep waters, or searching out seamounts, circumnavigations, day trips and multi-day trips (live aboard). They can be undertaken as dedicated seabird surveys, or as part of multi-taxa marine surveys.

**Method 1**
Every opportunity for conducting boat-based seabird surveys in the Pacific should be seized upon as so few are carried out in the region, and chartering boats can be expensive. The method outlined here requires one or two people with keen eyes, knowledge of species identification (with a focus on identifying seabirds at sea), binoculars, a GPS, a notebook and pen/pencil, and a camera if one is available.

The survey route needs to be logged by GPS from start to finish. Continuous counts of seabirds and seabird activity are made. GPS waypoints are taken every 10 minutes; and species counts collated within each of those periods. Additional waypoints should be taken for any special seabird sightings as well as other pertinent marine activity (e.g., fish and bird work ups, cetaceans, turtles, large fish). Any off-effort periods (when no one is observing and taking notes) also need to be logged.

Sightings should be made looking forward across the bow, either side and out to a distance of 300m. Every bird seen should be recorded and if possible, identified to species. Seabirds seen at sea in the tropics can be very scattered and occasional, but there will be places where the numbers increase, and in some cases grow to very large numbers of highly active birds, especially when foraging over fish schools (e.g., tuna, mackerel). If a camera is available photographs are extremely valuable for confirming identification of species and recording notable activity. This is particularly important for obtaining records of rare species, or species that are inherently hard to identify.

Data collected during the survey is best (or easiest) written into notebooks, or datasheets then transferred to digital spreadsheets while at anchor at night, or after the trip finishes. The data can then be mapped in GIS, with density mapping to highlight hotspots. Conducting repeat surveys at different times of the year is recommended.

The sightings and the route can then be uploaded into an online platform such as eBird - https://ebird.org/about/resources/sharing-your-sightings-on-ebird

Figure 90. Samoa seabird survey, Upolu circumnavigation, November 2022. Photo: Chris Gaskin

### Method 2

Seabird surveys are an integral part of the California Current Ecosystem - Long-term Ecological Research project[70]. These are seasonal surveys (winter, spring, summer) primarily in the Southern California Bight. The method outlined below is a much more structured, formal approach which is repeated for every survey and uses a dedicated application for entering observations.

Observations of seabirds are made continuously during daylight ship transits between oceanographic/ plankton sampling stations. The observer, located on the bridge approximately 15 meters above sea level, uses hand-held binoculars and occasionally also a digital camera to assist in the identification and enumeration of birds. The observer records all birds seen within a 300-meter strip transect to one side and front of the vessel while the ship is underway at > 5 knots. Observations are entered into a computer using the dedicated application "DLog"; the ship's position is automatically recorded from an external GPS every 20 seconds. Each observation includes the species, the number of individuals observed, and their behaviour (mostly "flying" or "sitting on the water"). Observation data are post-processed using standardised species codes, validation of positioning data, and binning of observations into along-track sections of 3 km in length. The data are then integrated into a survey database that contains data from 1988 to the present. These data are used to derive summary statistics.

### Attracting seabirds at sea

The method of attracting seabirds to a boat for viewing is to use a combination of scent, fish oil slick, and food items to lay a trail that draws birds and channels them towards the boat. This can be done as a chum-and-drift setup. Chum is made up of minced fish and fish oil, which is frozen into manageable blocks. Using chum has the advantage of drawing in birds that may not be visible when you start, and a chance to find out the range of species in a particular area. Petrels and shearwaters (Procellariforms) have a highly developed sense of smell, as well as good vision, and they will be attracted upwind towards the source of the scent trail you have made. As birds gather, their activity can attract other birds that see them. For seabirds, finding food at sea is not easy, and they will be curious if they see other birds' activity. When it comes to collating the data into spreadsheets, the data collected while chumming should be kept separate from the natural occurrence data collected while travelling from place to place.

### The value of opportunistic sightings

We know so little about at-sea distribution of many species across much of Oceania. Therefore, all sorts of observations can be extremely useful. These include observations made from ferries, during birdwatching or fishing trips, or on the way to other recreational marine activities such as diving and snorkelling. Identifying species accurately is very important, but even if an exact identification is not possible, a good description of a bird or birds seen can be very useful. Photographs are even better as they can be more closely examined once you are back on land and not bouncing around at sea. If you see birds you do not recognise and have a good camera with a decent zoom lens, take as many photographs as possible obtaining different views of the bird (head on, side, above, below etc). Once you have a sighting, or sightings, you should report or share them to build up a picture of where different species occur. That can be done through online platforms such as eBird - https://ebird.org/about/resources/sharing-your-sightings-on-ebird and iNaturalist https://www.inaturalist.org/

Figure 91. Tropical and Wedge-tailed Shearwaters off Savai'i, Samoa, photographed during a cetacean survey. Photo: Juney Ward

## 2.2.10 AERIAL SURVEYS OVER SEA

Scientific investigations in offshore areas are logistically challenging and expensive; therefore, the available knowledge on seabird at-sea distribution and abundance, as well as their seasonal variations, remains limited. While tracking studies have provided valuable information on seabird ecology and distribution, that technology still excludes a large proportion of seabird populations (such as non-breeding or non-accessible birds, small or shy species) that cannot easily be equipped with data loggers.

At-sea visual surveys allow whole seabird populations to be considered and offer valuable information on their distribution at various scales and different times. Boat-based surveys can be more frequent and allow for closer views of birds thus increasing chances of identification and study of behaviours, but aerial surveys have advantages for broad-scale investigation of seabirds' ecological preferences or distribution, covering greater areas at a faster speed. They are thus comparatively more economical, and the high speed of the aircraft allows the selection of the best weather conditions for observation, while ensuring a faster coverage of the sampled region than a boat would achieve. Aerial surveys generally aim to assess the distribution of all seabird taxa present in the area (particularly familial groupings, as smaller or similar species can be hard to identify to species level from airplane surveys). They can also investigate their seasonal variations, estimate their densities and abundances, and finally highlight areas of importance for seabird conservation at sea, especially offshore. The next case study highlights how these surveys are undertaken, how the results are used, and what the strengths and limitations of this methodology are.

### CASE STUDY - Who lives in the open sea? Distribution and densities of surfacing marine megafauna, including seabirds through Remmoa aerial surveys in the South Pacific

**Sophie Laran, Observatoire PELAGIS, La Rochelle Université – CNRS, France**

The large dedicated aerial survey programme, Remmoa, was conducted in three different subregions of the South Pacific: New Caledonia (2014), Wallis and Futuna EEZ (2015), and French Polynesia (2010)[71]. The aim of these campaigns is to monitor marine megafauna (marine mammals, seabirds, turtles, rays, sharks, large fish, as well as marine litter and boats) in French overseas territories and adjacent waters, to identify their habitats and hotspots of density and diversity and reveal areas of ecological interest for marine megafauna. Following the West Indies and French Guiana and the Southwest Indian Ocean, these surveys were conducted using a standard line-transect methodology, and the same standardised multi-taxon protocol. Three high-winged aircraft (Britten Norman Islander) flew at 90 knots with a target altitude of 600 feet (183 m). Each flight typically consisted of two observers scanning the sea surface on either side of the aircraft with the naked eye to survey close to the track line through both bubble windows. Seabird sightings were collected in strip transect within 200m band each side. Observers attended a training course (including flights) to apply the standardised protocol, collect data using SAMMOA application, and identify taxa to the lowest taxonomic level possible.

**Figure 92. Aircraft interior with some of the survey team, viewing through observation bubbles either side. Photo: Thomas Auger.**

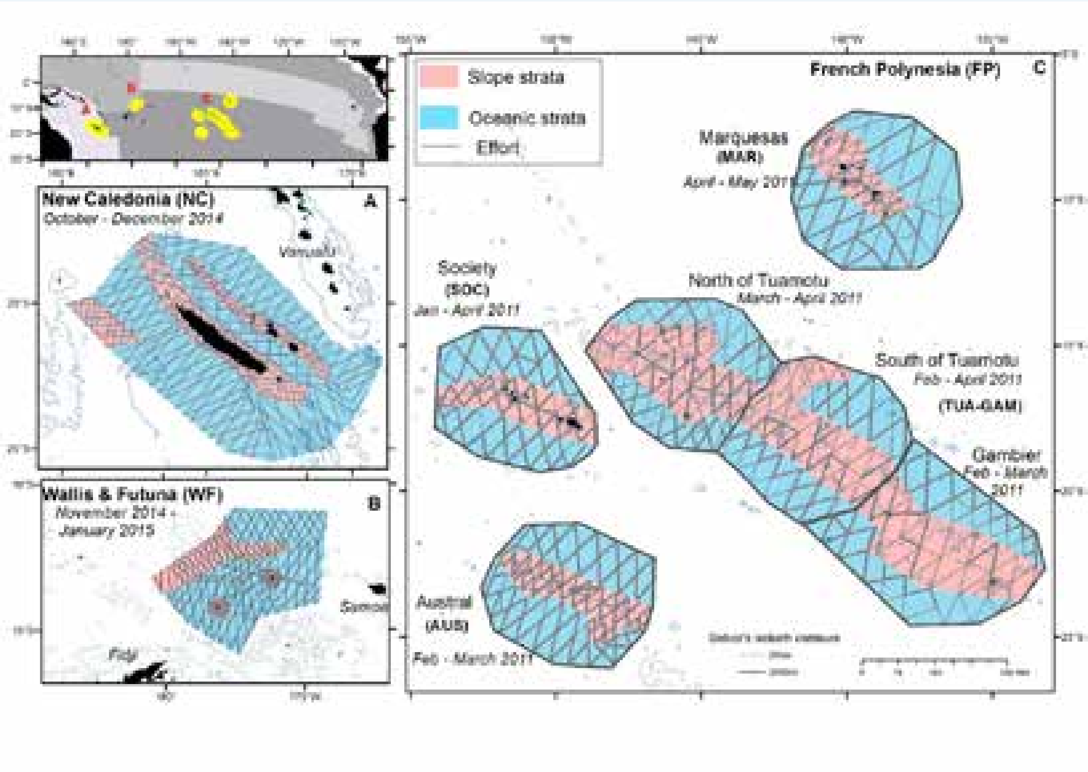


Figure 93. Survey effort for the REMMOA aerial surveys in the Tropical Pacific Ocean. (a) New Caledonia 2014, (b) Wallis and Futuna EEZ 2015, and (c) French Polynesia 2010.

In the South Pacific more than 122,000 km of transects were analysed (2.5 million square kilometres). Of the 25,842 seabird sightings, 4,094 could be assigned to single species and 16,011 were identified at the genus level. For consistency, sightings were pooled into 11 different taxonomic groups as species identification could be difficult for terns: 'brown' terns, 'grey' terns, White terns, noddies, Hydrobatidae, 'grey' petrels, 'brown' petrels, shearwaters, Sulidae (boobies), Phaethontidae (tropicbirds), Fregatidae (frigatebirds).

Taxonomic diversity appeared to be broadly similar across subregions, while seabirds encounter rates showed contrasting patterns. Cumulative density of seabirds peaked in the north of French Polynesia and New Caledonia. The latter hosted the highest densities of shearwaters and 'grey' petrels. Conversely, noddies, White Terns, boobies and frigatebirds were most abundant in French Polynesia and tropicbirds stood out as the only stable group in all three subregions.

The analysis provided density estimates for a total of 22 different marine megafauna taxa including marine mammals, sea turtles, and elasmobranchs (sharks, rays and skates). For seabird data collected via strip transect methods, in the absence of an available and accepted methodology, we did not attempt a correction (as was carried out for marine mammals) and therefore our results should be considered as conservative estimates.

Identification from plane can be a bit limited as some species are difficult to identify. Storm-petrel species for example can't be identified at species level but their fluttering flight is characteristic. Tropicbirds are easier to identify to species, with the white tail being easier to detect than the red one. Difficult groups remain the petrels and shearwaters, with only a few sightings identifying species available.

Nevertheless, this study provides the first comparison of marine species assemblages across the three oceanic subregions and establishes a regional baseline for the biogeography of marine megafauna in the region. The taxonomic and spatial extent of the results opens new perspectives for the development of local conservation measures, especially for taxa with already documented population declines.

**Drone use at sea**
Drones can provide a useful tool for surveying seabirds nesting and roosting along coastlines and on islands, especially where access is difficult, or birds would be greatly disturbed by ground parties. This is essentially the same method as flying a drone survey from land, just that the platform for operating is from a boat deck (see Section 2.2.7).

UAV (or drones) are also used to survey marine megafauna behaviours including seabirds, cetaceans, and fish schools, as well as covering more localised marine areas. As always, make sure you are fully aware of the legal requirements for undertaking surveys with drones in your area, and ensure you operate in an ethical way that does not cause stress to the species you are studying.

### 2.2.11 SHORELINE AND OTHER OPPORTUNISTIC SURVEYING

Many of us enjoy the coast and walking along the high tide line of a beach can sometimes yield unexpected finds, such as seabirds that have been washed ashore. Exposed beaches often yield more results than do estuarine coastlines. In some countries (e.g., Aotearoa New Zealand and Australia) there are regular beach patrols with organised groups, in some places monthly. This would not be feasible on most Pacific islands, but opportunistic findings can yield important information. These dead or dying seabirds can provide an important additional way to collect data on seabirds. Opportunistic discoveries such as these can be used in several ways, including (i) discovering new species records or extending known breeding distributions, (ii) helping chart migration routes and wintering grounds, or (iii) identifying conservation threats such as oil spills, entanglement (or direct capture) in fishing gear or disease outbreaks. In this section we will consider what to do if you find a dead or dying seabird on the shoreline.

**Health and Safety**
Firstly, it is important to stress that dead birds, like anything dead on the shore, should be considered a health hazard. These birds could indicate a disease outbreak (such as avian flu, H5N1) and so every caution should be used to protect yourself. If there are many dead birds, then assume the worst, do not touch them, take as many photographs as possible, and contact your local health authority. If it is a single carcass, then it is safer to proceed as outlined below, but pay attention to personal health and hygiene, use disposable gloves if you have them, limit the amount of contact to the body, and wash your hands thoroughly afterwards.

**Identification**
Accurate identification of birds is essential but is not always easy. It depends on the state of the bird, and whether it is a common species for that area, or not. Certain seabird groups can be notoriously tricky to tell apart (e.g., petrels, shearwaters, or storm-petrels), with the added complication of different colour morphs between species or different plumages depending on age (e.g. boobies). Getting a good record of any seabird found on beaches is extremely important, as our knowledge of their distribution in the tropical Pacific is poorly known. These could be birds that are migrating into and through Oceania or breeding within the region.

To ensure the best chance of identification, it is vitally important to take photographs. A wide range of photographs are needed:

1. Overview photo of the whole bird – both upper and lower surfaces
2. The upper and undersides of the wings
3. Close ups of head and bill
4. Close ups of feet and legs
5. The upper and undersides of the tail.

When taking these photographs also provide scale – anything on you can be used, such as a match box, lighter, camera lens cap, or even a sandal (be sure to note the size), or your hand.

Taking this one step further, if you have a way of safely collecting the carcass (such as a plastic bag), collecting the body is extremely useful. If you cannot collect the carcass then collecting a couple of feathers and putting them in a bag would be another useful step. Once the carcass has been collected, it should be either taken to an organisation in your country that works with seabirds or stored in a freezer (but NOT one you keep your food in!) until you wish to look at it further. These carcasses are useful for obtaining key measurements to resolve identification issues – and this is best done with measuring instruments like a ruler (items that you will unlikely have at hand while walking along the shoreline).

Send the details with photographs to the Pacific Seabird Advisory Group contact for expert advice on what you have found (see Section 5.2).

**Live birds**
If the bird you find on the shore is still alive, carefully collect the bird using the steps outlined in Section 3.2. Contact whatever local organisation deals with rescue and rehabilitation, or if there are none, consider consulting a veterinarian. Do not attempt to feed the bird or give it water as if done improperly, this has the potential to cause immediate death. Put in a cardboard box with adequate ventilation, to reduce stress, birds need quiet and dark.

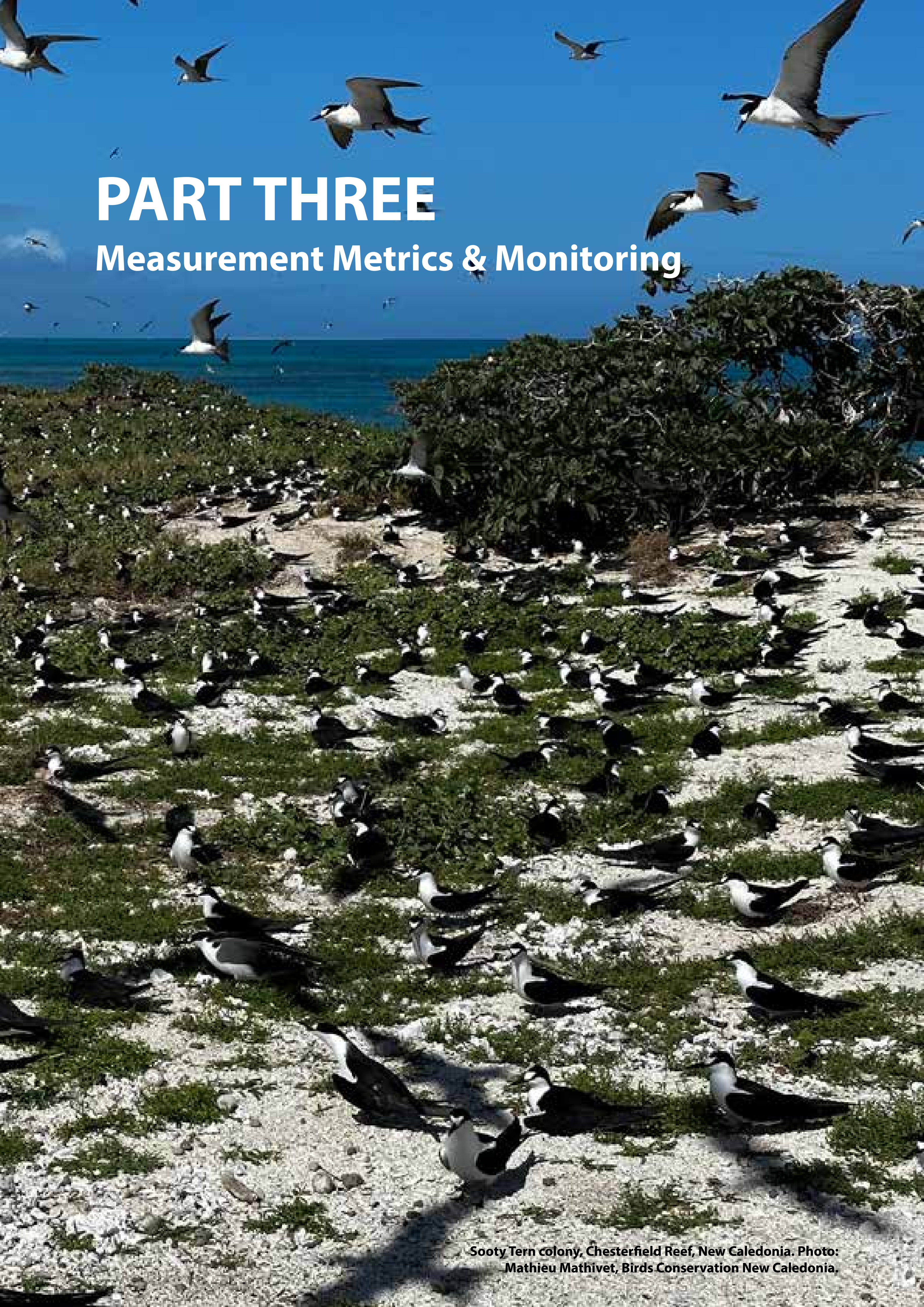
### 2.2.12 FINDING BREEDING SITES AS A KEY PRECURSOR TO CONSERVATION ACTION

There are at least five species of seabirds in Oceania for which breeding sites are either entirely unknown or not confirmed, and other presumed extinct species that may still be clinging to existence somewhere. It is also possible that there are more, undiscovered species or subspecies waiting to be found. Locating the breeding grounds of these species should be considered a critical seabird conservation priority. With each project of this nature the broad goals would be to:

1. Find the breeding site,
2. Once located, assess immediate threats and feasibility of critical management actions (such as predator control or eradication),
3. Develop local conservation management capacity.

The first of these may seem particularly daunting for such rare and cryptic species and several of the methods described in this manual will be required to achieve this goal. However, there are several recent examples where this has been successfully undertaken. Examples include discovering a breeding location (including burrows!) of a previously thought-to-be extinct seabird (see section 2.1.12 CASE STUDY – New Zealand Storm-petrel) and narrowing down the probable breeding grounds of the Beck’s Petrel by tracking a bird captured at sea (see section 2.1.12 CASE STUDY – Beck’s Petrel).

**Figures 94-98. Five species for which breeding sites are unknown. Top left: Beck's Petrel (PNG), Top right: Fiji Petrel, Middle left: Heinroth's Shearwater (PNG, Solomon Islands), Middle right: New Caledonian Storm-petrel, and Bottom: Pincoya Storm-petrel (Chile). Photos: Hadoram Shirihai (3), Peter Harrison (2).**



# PART THREE

## Measurement Metrics & Monitoring

Sooty Tern colony, Chesterfield Reef, New Caledonia. Photo: Mathieu Mathivet, Birds Conservation New Caledonia.

# 3.0 MEASUREMENT METRICS & MONITORING

This section presents the methods required to gather data from the seabirds themselves, starting with burrow monitoring, then bird handling, taking measurements, banding, and samples, and checking breeding status. These hands-on methods can lead to a variety of research studies; mark recapture, measuring reproductive (or breeding) success, diet , monitoring stress, investigating for plastics ingestion and contaminants. The section rounds off with monitoring cyclone impacts on seabird populations and measuring the success (or otherwise) of predator control measures. Once again, choosing the appropriate method will depend on what your research project and monitoring programme is aiming to achieve.

The methods outlined in this section require research projects to have the necessary permitting in place, and that the participants handling birds have been trained for the tasks to be undertaken.

## 3.1 NEST MONITORING

For surface and tree nesters, refer to Section 2.2.7 (Monitoring tropical seabirds using drones) as this offers the least invasive and potentially most accurate monitoring method. Although ground truthing is required in every case to ensure accurate identification of species.

**Burrow nesters**

For seabird species that nest in burrows (e.g. storm-petrels, petrels, shearwaters), monitoring presents a number of challenges. Burrow entrances can be very narrow and small or deep and convoluted. Burrows can be arrayed in very high density (making it difficult to safely access individual burrows without collapsing others) or very low density (making them very hard to even find). Burrows of some species can be found on very steep slopes or within cliff walls, making access difficult and dangerous. Burrow monitoring takes considerable time. Where there are dense large colonies, more than 50% of burrows in a colony may not be used for breeding in any one season, but still will need to be checked to look for signs of breeding. Lastly, burrows can often be fragile, increasing the risk that monitoring work could cause damage to the burrow itself. Because it may not be possible to easily access the burrow chamber, understanding what is happening inside a burrow during the breeding season can also be extremely difficult. In this section we consider the finer points of burrow monitoring.

**Figure 99. High density burrows, Rako/Buller's Shearwater, Tawhiti Rahi, Aotearoa New Zealand. Photo: Edin Whitehead.**

**Method**
After locating burrows, it is important to individually mark them to allow you to track their activity over time. Burrows can be marked in several ways. Attaching metal or plastic tags with unique numbers or combinations of numbers and colours is a good and unobtrusive marking technique. Burrows can also be marked with PVC poles and night reflectors placed near the burrow entrance, making it easier to locate them from afar. Alternatively, in rocky areas numbers can be spray painted on rocks next to the burrow itself. Care needs to be taken in marking burrows – depending on the prevalence of seabird predators in the area and the types of predators, obvious markings can increase predation risk (particularly if those predators are avian predators that use visual cues (like corvids or rails)). Furthermore, repeated monitoring can increase predation risk through the creation of trails and human scent, both of which can allow mammalian predators to cue directly in to the burrow itself. For this reason, it is not recommended to do regular burrow monitoring in areas where predators are prevalent unless some form of predator control is in place.

The number of visits to a burrow is an important consideration for burrow monitoring. How many times you visit a site may depend on a number of factors, including availability of staff, funding, ease of access, cost of access (e.g. by boat or helicopter vs by foot), data collection needs etc. For assessing reproductive success (see Section 3.6), you will need to monitor each burrow enough times to assess whether breeding was initiated, and a chick fledged. This requires a firm understanding of the phenology of the species, so that you can check the burrow at key times (arrival, incubation, chick rearing, fledging). The more visits you do, the more accurate your reproductive success calculations will be, but this will be tempered by the previous conditions listed and potential disturbance to the birds.

Assessing burrow contents presents the main challenge in burrow monitoring. In many cases, you may not be able to easily assess the burrow chamber by simply looking into the entrance and seeing the back of the burrow. In these scenarios, handheld cameras are a useful tool. By simply reaching as far into the burrow as you can and taking photographs with the handheld, this can increase your capabilities of assessing burrow contents. However be careful when you do this – you have no idea what is inside the burrow, and even if it is not an angry biting bird there could be something more dangerous like a rat, spider, centipede or snake (depending on where you are doing your research).

Examples of handheld cameras used for this purpose include Olympus Tough Stylus TG series, Panasonic Lumix DMC-TS series and the Fujifilm Finepix XP series. Taking this one step further, there are multiple burrow scope options. These include endoscopes specifically designed for the purpose or off-the-shelf store-bought models (such as those used by plumbers to access the interior of drain pipes!). Burrow scopes can allow you to get much deeper into a burrow or allow you to access narrow burrows where you can't get your arm into. They can however be tricky and time consuming to use and in wet environments the end of the scope can quickly get muddy requiring repeated cleanings during each check attempt.

**Figure 100. Using a burrowscope to check for Tahiti Petrel occupancy, Nemou Island, New Caledonia. Photo: Mathieu Mathivet.**

During each burrow check, data should be collected to record any signs of activity within or around the nest. This includes the presence of adult(s), egg, or chick for burrows where it is possible to see the chamber. If it is not possible to access the burrow at all, then you should carefully assess the burrow entrance for any sign that there is activity within the burrow. Key seabird signs to look for includes guano, footprints, digging, trampling, feathers, eggshell, scent, fresh vegetation in the burrow chamber and down during fledging. Cobwebs inside the burrow are a sign of limited or no activity. Collecting data on seabird signs throughout the season will help you assess the overall levels of breeding activity and success. Many people place a small row of 3-5 vertical thin sticks in front of the burrow entrance to detect movements in and out of the burrow. These sticks need to be pushed in sufficiently, so they don't blow over in wind but are easily knocked down by a bird walking through the entrance. Brush them with your hand to test. Toothpicks can be useful in areas lacking trees and shrubs. Remember other animals can knock down a stick fence (terrestrial birds, reptiles, predators etc) but a burrow with sticks intact all season is clearly inactive.

At all times when checking seabird burrows, care should be taken to minimise disturbance to the birds inside, surrounding vegetation and burrow structure. Extra care should be taken with burrows containing new pairs, or during incubation, when birds may be more prone to abandonment and nest failure. Any signs of depredation (such as a dead adult or chick in front of/ inside a burrow, chewed feathers or egg, etc.) or the presence of scat/droppings/prints that indicate predator activity in the vicinity of the nest, should also be recorded as this can be beneficial for guiding management actions.

At the end of the season, a final status should be assigned to each burrow. The following categories can be used:

- **Active breeding confirmed:** Breeding was confirmed as having been initiated during the season through the presence of (i) an adult during the day during the incubation period, apparently incubating (sitting tightly in the nest bowl), (ii) an egg, (iii) down or (iv) chick. For this category, the outcome is noted as either:

  a. **Success:** Nest successfully fledged a chick. As you are unlikely to witness the fledging event unless you are using a camera, a successful fledging can be considered in the following scenario: A chick was confirmed in the burrow up until typical fledging month and on the following check the presence of small amounts of down outside the nest site indicate that the chick was active outside the burrow and subsequently fledged. No signs of depredation or predator presence were noted. Burrows with cameras provide information on exact fledging date and time.

  b. **Failure:** Nest did not fledge a chick. The failure stage (egg or chick) and cause of failure (depredation of chick or egg, abandonment, depredation of breeding adult, etc.) should be recorded where known. Burrows with cameras can provide information on depredation events and predator visitations pertinent to nest failure.

  c. **Outcome Unknown:** Breeding was confirmed at the site; however, no subsequent visits were made, no visits were made late enough in the season to confirm fledging, or signs were inconclusive.

- **Active, unknown:** The presence of an adult bird, or signs of an adult bird (guano, feathers, trampling, etc.) indicate that a bird was present during the breeding season, but it was not possible to confirm whether breeding occurred but failed or breeding was never initiated. Either way, no chick fledged. Situations like this arise in instances where (i) it was not possible to examine the back of the nesting chamber due to the structure of the burrow or (ii) the burrow is discovered late in the breeding season and, as it was not therefore monitored during the egg-laying period, it is not clear if breeding had been initiated that season. Note that some burrows will be occupied by former breeding pairs that have chosen to take the season off or used by a single bird trying to attract a new partner.

- **Prospector:** Bird(s) recorded visiting nest, but signs are indicative that these are prospecting and not breeding birds. Examples would be new excavations within a previously inactive burrow, a single visit during the breeding season to a previously inactive burrow, a visit to a burrow where both adults had been confirmed killed the year before, or the preliminary excavation of a burrow-like structure combined with the confirmed presence of a seabird (feathers, guano, etc).

- **Inactive:** No sign that the burrow has been visited in that breeding season.

- **Status Unknown:** Burrows where there was no way to assess what had happened in the burrow during the year (i.e., burrow found at the end of the season with seabird sign but no indication of what actually happened, or burrow monitored at points during the season but breeding status and outcome unknown).

These outcomes are then used in the creation of reproductive success rates.

## Seabird burrows can be very varied in shape and size

Figure 101.  New Zealand Storm-petrel burrow in a crevice between rocks. Photo: Chris Gaskin.

Figure 102. Shallow holes such as this Wedge-tailed Shearwater burrow. Photo: André Raine.

Figure 103. Deep convoluted burrows such as this Tahiti Petrel burrow. Photo: André Raine.

**Figure 104. Large caves such as the entrance to a Hawaiian Petrel burrow. The variation shown above presents monitoring challenges. Photo: André Raine.**

## 3.2 HANDLING BIRDS FOR RESEARCH OR MANAGEMENT ACTIONS

In the section below, we outline several ways in which birds can be handled for research or management actions. For capture methods, see the previous section where we discuss options for different species and situations. Handling birds should never be taken lightly, as it inevitably causes stress to the bird and in the worst case could even cause an injury. It should never be undertaken by someone who has not been trained, as this could result in injury to either the bird or the handler. Training should involve the correct capture and handling techniques specific to the species in question, as there are many differences between handling say a storm-petrel and a shearwater, or a petrel and a booby. Therefore, before considering capturing seabirds, assess whether it really is necessary to achieve your goals; it may be that you don't need to handle the birds at all.

If you decide that bird capture is a vital component of your work, then there are several things to consider.

- **Time of day** – In tropical environments in particular it is best to capture and handle birds at night or during the morning or late afternoon, when temperatures are not so hot. Heat stress is a serious issue for birds and handling them (especially extended handling for tagging work) could cause the bird to overheat. Conversely, during the chick rearing period if you handle an adult bird returning with food for its young, you may inadvertently cause regurgitation thus denying the chick its meal at a critical growth period.

- **Time of season** – During the breeding season, birds are particularly vulnerable to handling immediately prior to egg laying and during incubation. If you handle birds just prior to egg laying, some species may even lay their egg in the weighing bag due to stress. During incubation, you may cause abandonment of the egg.

- **Species-specific considerations** – Some species are more robust than others, or more tolerant of handling. Furthermore, some species may be more prone to wing or leg strain. Consult the literature and experts in the field to see whether they have any pointers or warnings about your study species.

- **Contamination on your hands** – make sure you do not have anything on your hands that could contaminate the bird and potential compromise its waterproofing, such as sunscreen, oils from a previously handled bird which regurgitated, etc. Clean your hands thoroughly before handling a bird.

Figure 105. Holding a small seabird, a storm-petrel, Rangitāhua/Kermadec Islands. Photo: Chris Gaskin.

With all the above incorporated into your research planning, and the bird now in hand, it's also important to understand how to properly handle it. Some species are docile in the hand while others are notoriously feisty (as anyone who has handled a Wedge-tailed Shearwater can tell you!). Appropriate handling techniques will minimise stress, help calm the birds and – critically - mitigate against the risk of injury both to the bird and the handler(s). In all cases, it is important to immobilize the bird as quickly as possible, keeping the wings against the sides of the body – wildly flapping wings are a common cause of injury for the bird. Likewise, make sure the bird's head is not darting about. Remember the beak is a formidable weapon and seabirds have extremely fast reflexes. Keep your eyes well away from the business end of the bird, or any other tender parts of the body. Be aware that their claws can be very sharp. Wearing safety glasses or prescription glasses will protect the eyes.

Figure 106. Restraining a Hawaiian Petrel to attach a satellite tag. The bird's head is covered by a bird bag. Photo: André Raine.

If the bird does manage to bite you with its beak, don't jerk away as this can cause the beak to further tear open your flesh and can damage the bird's beak as well. Have a second person gently open the beak and then remove the bitten body part. Understanding how tightly to hold a bird is also important; too tight and you could hurt the bird, too loose and the bird could get a wing (or even body) free. For the novice, this is a steep learning curve, so make sure you train with an experienced bird handler until you are confident that you can do it on your own.

As a side note, you may not even be intending to handle birds in your project but may find you have to if you find an injured bird at your management site, or a fledgling seabird that has been grounded by fallout. These handling techniques are therefore useful skills to learn regardless so you are ready to deal with unexpected incidents.

Once captured, smaller seabirds (storm-petrels, shearwaters, petrels) can also be put in bird bags (for weighing) or boxes (to calm them down, or while you are removing additional birds from a mist net, for example). Bird bags can be made specially with a draw chord at the opening, or alternatively an easy option is to use pillowcases. When using bird bags, make sure the bag is big enough for the species you are working with, that it is made from a light enough fabric that it is not too hot, and do not leave the bird in the bag for an extended period (really it should just be used to weigh the bird and then extract the bird for whatever else you need to do). If it has a draw string, make sure that does not inadvertently get wrapped around a leg, and make sure there are not loose bits of thread that could do the same. Bring multiple bags with you; best practice is to not reuse a bag on a new bird as you can transfer disease or parasites between individuals. Bags need to be thoroughly washed following use.

Bird boxes should be big enough for the species you are working with. It is not good practice to put multiple birds in a box (unless there is a divider that keeps them fully separated), as in their panic they could injure each other. Boxes should have sufficient air holes and be placed in shade where they will not overheat.

Some projects use tubes or wraps to restrain birds. The aim of these devices is to keep the wings tight against the birds body and immobilise it, thus preventing injury. With your bird now looking like a burrito, you can more easily take certain measurements (particularly head measurements).

**Figure 107. Holding a Masked Booby for banding, measuring and sampling. Photo: Karen Baird.**

Figure 108. Restraining a Red-tailed Tropicbird for banding, measuring and sampling. Photo: Chris Gaskin.

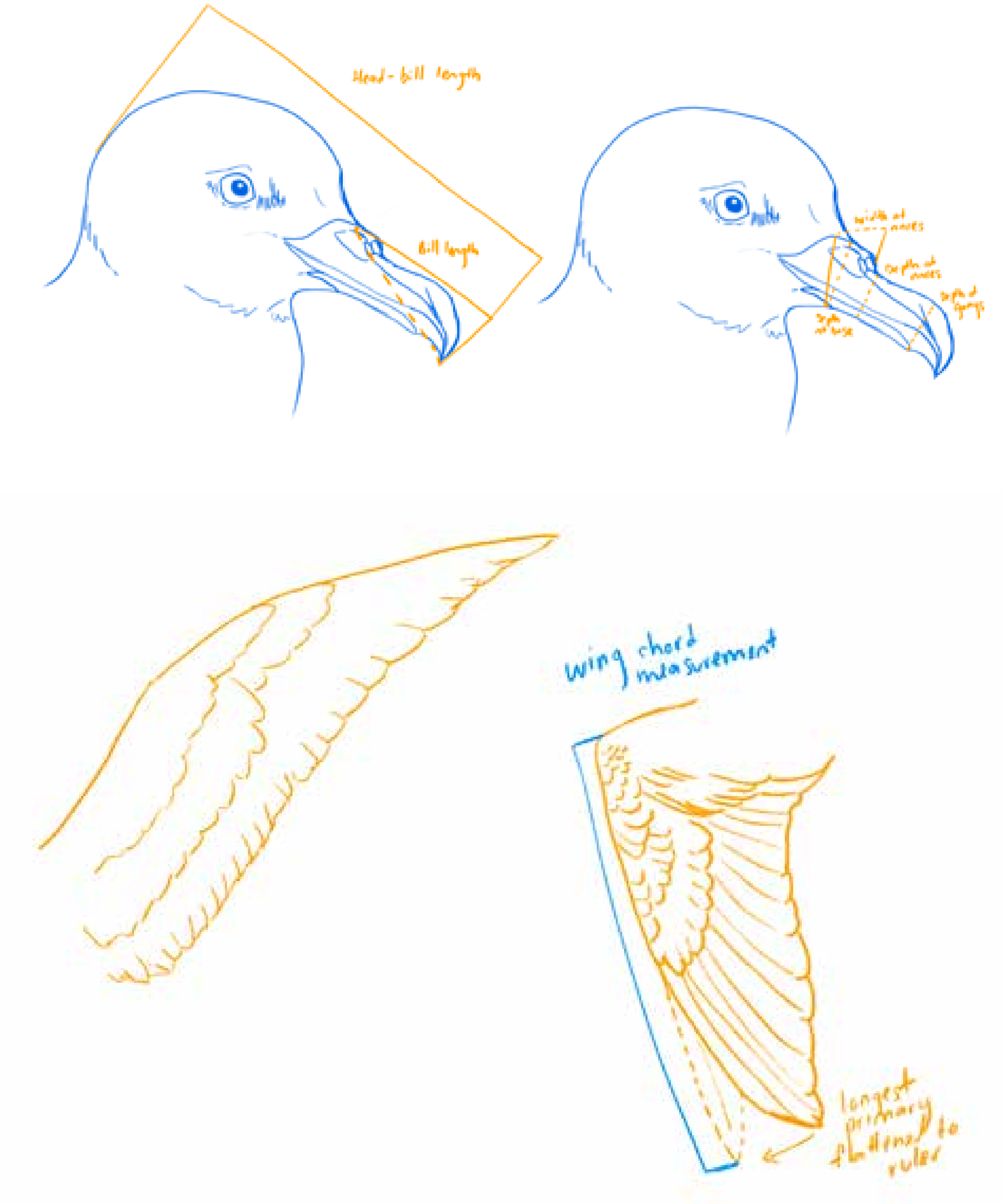
Lastly, in the case of larger birds (such as boobies and albatrosses) remember these birds are big and strong. The same rules for immobilising the bird as outlined above hold true for these larger species. Keep the wings against the bird's body, don't hold it too tightly or too loosely, keep an eye out for heat stress, and keep that beak away from your face. With these larger birds you need two people on the team: one restraining the bird and the other banding. Indeed, as a rule of thumb handling and restraining is best done with multiple people.

### Reasons for handling birds

There are a number of reasons why a project may involve handling birds (under the appropriate permits of course!). These include attaching tracking tags, leg banding for site fidelity or longevity assessments, dietary studies, rescue and rehabilitation campaigns etc. In these cases, it is often useful to collect a series of morphometric measurements while the bird is in hand which can aid in differentiating between sexes, identification of subspecies (or even the discovery of cryptic species), body condition and considerations of variation between subpopulations and within-populations. Standard measurements include.

- Weight (remember to subtract the weight of the bird bag if you are using one)
- Head-bill length
- Head length
- Bill length (length of bill from tip of beak to base of feathers)
- Nalospi length (bill length to nostrils)
- Bill depth at end of nostril
- Bill width at end of nostril
- Gonys depth
- Gonys width
- Wing (can be either flattened or un-flattened, make sure you standardise throughout your study and specify which you used)
- Tail length
- Tail fork length (if the species has a tail fork)
- Tarsus
- Length of middle toe

Measurements are important for identifying and separating rare species, and with many species can be used to identify sexes. For common species you may only need to take a few different measurements such as weight, wing length and bill length. If the species you are studying has never been studied at your location before then taking more measurements is important in case there are differences between locations where the species is breeding.



Figures 109-110. standard measurements. Graphics by Edin Whitehead.

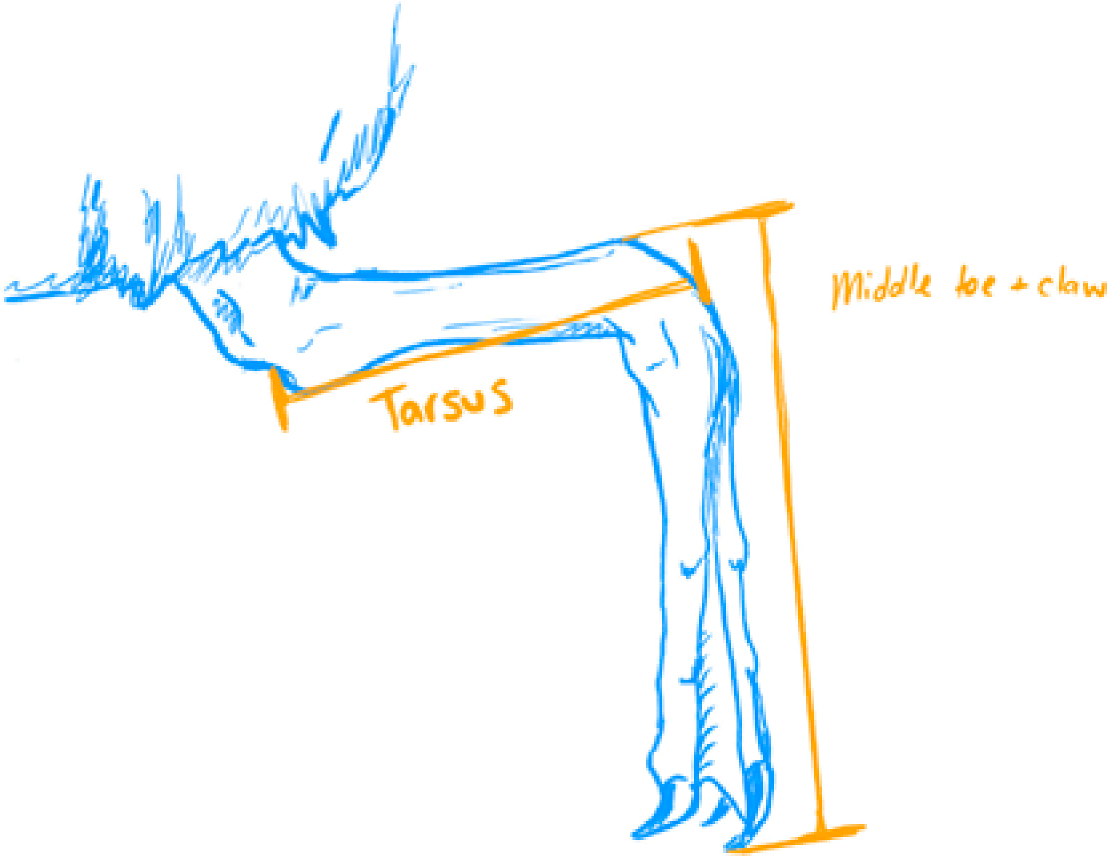


Figure 111. Standard measurements. Graphic by Edin Whitehead.

Additional measurements that can be taken to consider body condition include fat scores, feather moult patterns, feather stress bars and parasite load. Breeding condition can be assessed (at the right time of year) by looking for a brood patch and scoring it according to how developed it is (there are established brood patch scores that can be used to identify the stage the brood patch is in, see Section 3.4). During the fledging season, newly fledged birds can often be differentiated from adults by the presence of down (although note that this may be hard to find depending on how recently the bird fledged, so look carefully – the underwing feather tips are often the last place to shed down, also the flanks above the legs and around the neck). Look at the 'perfection' of the feathers (i.e. no wearing on the wing tips, no evidence of sun damage on exposed parts of the feather, etc), or the presence of drawn tips on ends of flight and secondary feathers, where the downy feather has dislodged from the flight feather. Birds with clean new feathers all over the body will most likely be a fledgling as adult birds will have older feathers mixed with new feathers in their plumage.

There are multiple considerations that should be borne in mind when conducting measurements, as these measurements rely on the highest levels of data quality to be useful. For measurement comparisons where the differences may be slight, every millimetre counts!

1. Having the right equipment is key. Having good quality, precision wing rulers, tail rulers, callipers and scales leads to good quality data collection. Make sure your equipment is kept in good condition and cleaned and sterilised after every foray into the field.
2. When different people are measuring birds in a study, you may inadvertently introduce individual measurement biases. One person may tend to overestimate certain measurements for example. To ensure this does not happen, either have the same person always carry out the measurements throughout the study, or if there are multiple people conducting the work have each person measure the same series of birds and look at the data to see if there are any obvious differences. Always record who took the measurements.

Figure 112. Equipment for taking measurements: Wing rulers, tail rulers, callipers and Pesola scales (different weight ranges). Photo: Edin Whitehead.

Figure 113. Explaining taking measurements and samples for Grey-faced Petrels, Taranga Island, Aotearoa New Zealand. Photo: Chris Gaskin.

3. Make sure everyone understands exactly what the measurements that are being taken are, as there are differences in the ways that people learn to take certain measurements. The best way to do this is to have a clear diagram available for everyone to consult, like the one in this manual.
4. Consider which measurements will be the most useful. Bill length and tarsus, for example, are both measurements where there is little room for error as the body part is so clearly defined. Wing lengths are often a key measurement, but flattening a wing for measurement can lead to significant variation in the same measurement (i.e. how flat and straight was the wing exactly? Did the bird keep moving around?). Unflattened wing measurements may be more accurate but may not allow comparison with other studies or museum skins. Also check that the wing are not in the process of moulting. The outer primary is normally the longest wing feather, but it varies by species.
5. Unless you are specifically measuring growth rates, avoid measurements on developing chicks. Because they are growing constantly until fledging, lengths and widths change over the time the bird is in its nest/burrow and this temporal effect will create issues for you between individual comparisons.
6. The mass (weight) of a bird can vary depending on whether a bird is carrying a food load or not. An adult caught on its way to a burrow to feed its chick will be significantly heavier than a bird on its way back out after the food has been delivered. In those scenarios, waiting for the bird to feed its chick and re-emerge will standardise the measurement as well as reducing the possibility that the bird will regurgitate a critical meal for its chick while being handled.
7. Be very careful with any birds that might be carrying an egg. An egg will feel like a hard round shape in the lower abdomen. Rough handling could cause the bird to stress lay in the bag. Consider timing of breeding when you are capturing birds.
8. Take detailed notes on exactly how you defined each of your measurements. Clearly state how each measurement was taken and specify which units are being used (i.e. mm versus inches). The more detailed you are, the easier it will be to replicate your study to allow for direct comparisons with future work.

Lastly, a reminder that when handling birds, hygiene is critically important. There are multiple communicable diseases and parasites that can be inadvertently passed from bird to bird (and bird to human) when handling them. Ensure you use best practice hygiene standards during any study that involves a hands-on approach. If possible use different clean bird bags for each bird. Wash and sterilise all holding bags between trips to different colonies. Use hand sanitiser to clean your hands between birds and at the end of a session. This will also take care of any cuts or nicks you may have obtained during bird-handling.

Keep an eye out for signs of disease (e.g. pox lesions) or high parasite load (e.g. feather mites) in your study species during your work, and if you see any signs that your study species may be afflicted by them re-evaluate your study protocols further. Do you need to continue the work in these conditions? And if so, what additional measures do you need to put in place to prevent disease or parasite spread?

## 3.3 SAMPLING FROM SEABIRDS

By taking certain samples there is the potential for gathering detailed insight into the health of seabirds at both the individual and population level, and/or to obtain the sex of the bird. Depending on the question and the desired monitoring outcome, samples can vary from completely non-invasive (e.g. collected dropped feathers or faecal samples under roosts/in colonies), or more targeted (e.g. collecting blood or feather samples from birds). These samples can have a variety of uses, some of which are discussed below, and there are many different methods that can be used to obtain and process these samples. Adequate training from an expert is prerequisite to utilising some sampling methods, as well as the relevant permitting. Appropriate containers for samples to be gathered are needed from small plastic Ziplock bags to vials with 70% ethanol or buffer solution added depending on the sample.

**Feather samples:** Feather samples are useful for dietary studies (using stable isotope analyses) and in the monitoring of stress hormones and contaminants like heavy metals. They can also be used to obtain the sex of the bird. Due to regular moulting, feathers can provide a time-integrated signal of conditions experienced during the period of feather growth – this is usually during the non-breeding season for adults (when considering flight feathers), and while in the nest for chicks/fledgelings.

Feathers can also be plucked from the bird, but this should be done after suitable training, and only the number of feathers needed for the research should be removed. For DNA sexing only the quill tip is used so feathers must be plucked from the skin and avoid touching the tip. Store in a secure labelled bag. Normally 3-4 feathers are plucked per bird.

**Faecal samples:** Faecal samples can assist in gathering dietary data via DNA sequencing, and hormonal assessments to better understand stress and breeding status.

**Blood samples:** These are perhaps the most versatile of samples, but more invasive to obtain, and require specialist training. Blood samples can offer insight into multiple measures of health and energetics, nutrition, stress and reproductive hormones, immunological activity, diet, and the presence of contaminants as well as assessing the sex of the bird. For petrels, an option now available is to gather a sample of blood on a range of individuals in the breeding population[73]. From this, the age range of birds can be relatively accurately determined, allowing targeted management depending on the outcome. For example, a population of mostly older birds would suggest that reproductive output is compromised, such as post-fledging survival.

**Swab samples:** Preen gland, choanal, and cloacal samples can all be obtained by swabbing. They can be used in a variety of investigations, including pathogen risk (e.g. avian influenza monitoring).

**Ectoparasites:** Seabirds play host to a variety of ectoparasites, some of which are species-specific. These can be easily sampled for a better understanding of parasite loads and potential risk factors (e.g. disease). The feather lice species often live on different parts of the body so check on wings, around the head and on the lower belly.

**Regurgitates:** A direct method of studying diet can be from collecting regurgitations. Some species readily regurgitate as a self defence mechanism, which can facilitate sample collection. Depending on the state of these samples, species can be identified visually or via DNA methods, and, if the samples of prey are frozen soon after collection, they can be further analysed for energetic and nutritional content. Two-level sampling can sometimes be achieved where the stomach contents of seabird prey can be investigated for their own prey items, highlighting food-web interactions between seabirds and lower trophic levels. Other items may also be noted such as presence of plastic.

**Figure 114. Collecting blood samples from a New Zealand Storm-petrel captured at sea for a genomics study. Photo: Jochen Zaeschmar.**

## 3.4 DETERMINING BREEDING STATUS (BROOD PATCH)

During the breeding season many birds develop a brood patch, which is an area of bare, featherless skin on the underbody, in preparation for incubation and brooding. A network of blood vessels in the skin of the brood patch raises the temperature locally, perfect for keeping the egg warm.

The examination of brood patch condition of seabirds is a useful technique for ascertaining breeding status and timing for species such as petrels and shearwaters[40]. Analysis of patterns of down loss from captured birds provides an indication of the timing of incubation, as down is lost over the brood patch just before incubation, and subsequent chick rearing, during which the brood patch is re-feathered. Birds that brood chicks for a while have longer-lasting brood patches than those than leave them alone a few days after hatching. For example, unlike passerines, petrels and shearwaters share incubation of a single egg, meaning brood patch status is an indicator of breeding condition in both male and female birds. By assessing temporal patterns of brood patch formation of captured birds can provide an indication of the likely breeding timetable for the species.

Brood patches can be scored to provide more information. An example of a scoring system for brood patch status is as follows:

0 – No down shed (or completely downy)

1 – Traces of down lost

2 – Half patch covered in down, half bare

3 – Traces of down remain (e.g., centre line, around edges)

4 – Patch free of down (vascularization should be noted if seen)

R – Re-feathering present, however, re-feathering could be scored as follows:

R3 – patch with a few developing feather shafts

R2 – patch with substantial coverage of burst shafts

R1- patch completely covered with regrowing down not yet full length.

**Figure 115. Bare brood patch on a New Zaland Storm-petrel, showing some refeathering. Photo: Edin Whitehead.**

Note that while a brood patch is a good indicator of a breeding bird, in some seabird species non-breeders may also develop a partial (or even full) brood patch. Bare brood patches are controlled by hormonal processes in breeding age birds and not by rubbing off down on an egg. They do define the incubation period in a species as most of the year the brood patch is covered in down.

## 3.5 MARK-RECAPTURE STUDIES

Marking birds and then recapturing or resighting them later is a common method of estimating population size, as well as being a primary tool used to estimate survival and age structure in the population (See Section 5.4 Banding Schemes). Multiple visits are required to recapture birds and for survival studies these will be undertaken over multiple years (as many seabird species are long-lived, be prepared to be doing this for a long, long time!).

Mark recapture surveys require that large numbers of birds are 'marked', usually banded (or ringed) on the leg with metal identification bands; some larger species such as frigatebirds and boobies can be marked with wing tags. For shearwaters and petrels, a sub-set of monitored burrows can be utilised for mark-recapture studies. Both individuals of the pair are initially banded, and then the burrows visited annually (if possible) to recapture the birds. In this way longevity and survival rates can be calculated. For all of these studies, it is also valuable to obtain data on the sex of the species (for those that can't be visually identified to sex, take feather or blood samples).

**Figure 116. Banded New Zealand Storm-petrel, Hauraki Gulf. Captured and banded on Hauturu Little Barrier Island. Photo: Edin Whitehead.**

**Figure 117. The same New Zealand Storm-petrel as above could be identified by colour metal band combination and numbers on the metal band. Photo: Edin Whitehead.**

## 3.6 REPRODUCTIVE SUCCESS

Reproductive success (RS) is one of the most important variables to measure as it lets you know how well your study species is faring. Changes in reproductive success can be used to assess how species are reacting to management actions or how environmental variables (such as climate change) are impacting them. Over the long term this calculation can be used to help understand overall population trends.

Put simply, RS is calculated as the number of chicks that fledged from the number of nests where breeding was confirmed (i.e., egg seen or bird sitting tight on nest incubating). Note nests used in these calculations should all be confirmed breeders, not prospectors, which would negatively skew the calculation.

> **RS = number fledged / total number of monitored nests with confirmed breeding & outcome known**

While this calculation is relatively easy for surface nesting species where breeding can be directly observed, it can be much harder for burrow nesting species where it may not always be possible to access the burrow chamber itself. In these scenarios, sign around the burrow entrance can be used to help you sleuth out the outcome of a burrow, particularly if you have a good understanding of the breeding phenology of your seabird species. For example, guano, feathers and footprints outside the burrow throughout the season, followed by bits of down attached to the burrow entrance at the end of the season, could be used to infer a successful breeding attempt. Conversely, regular sign outside a burrow that ceases halfway through the season could be used to infer a failure (but beware prospecting birds and non-breeding pairs). Burrow cameras can also be used to gain a greater understanding of whether or not a burrow was successful.

In the case of burrow nesting seabirds, the above calculation of reproductive success is likely to be an overestimate of true reproductive success. This is because each year there will be a certain number of monitored burrows where breeding did in fact occur and the burrow failed, but these were not considered in the reproductive success calculations as it was not possible to actually confirm breeding (mainly because the burrow was too deep to assess whether an egg was ever laid). Therefore, another more conservative measure could also be considered as follows:

> **Number fledged / total number of monitored burrows that were confirmed active (not including prospectors) & outcome known**

In studies of burrow nesting species, both calculations could be considered to assess the true reproductive success, with the assumption being that the true figure lies somewhere between the two.

Another thing to consider is sample size. If you have calculated your RS with only three burrows then this clearly would be less indicative of the true RS of the colony than if you had sampled 60. As a general rule of thumb, the more burrows you monitor the more robust your estimate will be, within the confines of burrow availability, budget and logistics. A couple of other considerations should be taken into account. If your colony is scattered across a large area with multiple terrain features, make sure you are monitoring burrows across the colony in its entirety – predation can be very location specific, and birds doing well in one part of the colony may have fare differently from another area where the birds are being eaten by a localised predator.

## 3.7 DIET STUDIES

The prey that seabirds eat and what they feed their chicks can tell us a great deal about their feeding ecology, marine food webs, and ocean variability. As bottom-up processes (e.g. prey availability, distribution, energetic content) can have a large influence on seabird life histories, understanding what prey they rely on, especially during breeding, is key to interpreting how fluctuations in the marine environment relate to changes in their physical health. Knowledge of prey and trophic relationships is also useful in assessing the threats posed to seabirds by fishing activities. Fishing can either directly impact seabirds through bycatch, or by indirect competition for food resources through largescale biomass extraction, and the flow-on effects that impact the availability of shared prey resources such as zooplankton via multispecies foraging aggregations.

The ability of seabirds to adapt to climate change will also vary depending on their foraging strategies as the distribution and availability of their prey changes. A better understanding of these potential changes is needed for forecasting climate impacts on seabird species. Minimally invasive techniques of assessing dietary niche, and dietary change over time (e.g., stable isotope analysis) are an important tool for seabird research and conservation.

Many methods are used to study seabird diet. Some are based on opportunism whereby samples are collected ad hoc, e.g. from watching food uptake directly, taking photographs, or by collecting dropped fish, regurgitated food, or faeces. Others take a more systematic approach through regular collections or sightings made within a specified time. Techniques vary greatly and range from inducing regurgitations to totally non-invasive and repeatable observations of fish-carrying birds. Indirect methods include observations of feeding flocks, analyses of faeces or regurgitated food remains, or blood, feather and tissue collection for stable isotope or fatty-acid analyses.

**Figure 118. Opportunistic diet sample from a Brown Booby, a regurgitation made just before it took off from a low branch of a tree on the shoreline, Nukutolu Islets, Lau Group, Fiji. Photo: Chris Gaskin.**

Figure 119. White Tern with a bill full of fish, Honolulu, Hawaii. Photographer unknown, but image use with publisher's permission.

As with all the monitoring methods described in this manual, the choice will come down to what your monitoring programme is aiming to achieve; the need to clearly establish WHAT you want to survey and monitor and WHY (See Section 1.7). The bottom line will be a case of choosing according to your needs, budget, and the skills and capacity available to you.

## 3.8 MONITORING STRESS – AN INTRODUCTION TO ECOPHYSIOLOGY

A useful tool in the conservation biology toolbox is the ability to measure stress in wild populations. Understanding how a population is faring in response to changing environmental conditions can take time when using demographic measures such as breeding success and population trend data, which require several years to collect. Ecophysiology (how internal physiology relates to the ecology of an animal in response to their environment) can offer more rapid insights into the stress experienced by seabirds. It is commonly used to understand how environmental conditions impact the ability of birds to breed successfully, or how food shortages can impact chick growth and development. Paired with behavioural and dietary data, ecophysiological techniques can assist with routine monitoring of seabird populations[74].

Ecophysiological tools are varied. In this chapter we provide an overview of some commonly used methods, using either blood, feather, or faecal samples from seabirds. A consideration for using these methods is having good baseline data from 'healthy' individuals and populations for comparison, and some of these data do already exist from studies of Pacific seabird species.

### Method

Haematology and blood nutrients: Small blood samples can be used to gather data on the health status of birds (energetic expenditure, hydration, nutritional status, white cell ratios). Red-cell parameters of haematocrit (proportion of red cells to plasma), haemoglobin, and cell counts can be used to calculate further parameters of cell size and haemoglobin content to assess physiological condition. As red blood cells have a turnover rate of around 35-45 days, they form an integrated measure of body condition over several weeks, although short-term acute stressors (like dehydration) can impact this. Blood nutrient analyses can be done with electronic point-of-care devices such as blood glucose metres, and there are some devices that measure a whole suite of blood parameters which have also been validated for use on birds.

Endocrinology: Assessments of stress in wild populations commonly use the avian 'stress' hormone corticosterone as a measure of how seabirds are responding to environmental stressors such as food shortages, or human-related ones such as tourism impacts. Corticosterone can be measured from:

- Blood samples (provided these are taken within 3 minutes of first disturbance, to capture 'baseline' circulating levels) to capture short-term changes,
- Faecal samples provide a more time-integrated measure, or
- Feather samples allow assessing relative amounts of circulating hormone during the feather growth period. Feather samples are particularly useful from chicks, as they capture the development period in the nest, while for adults they will represent the period following the previous moult.

### When to use

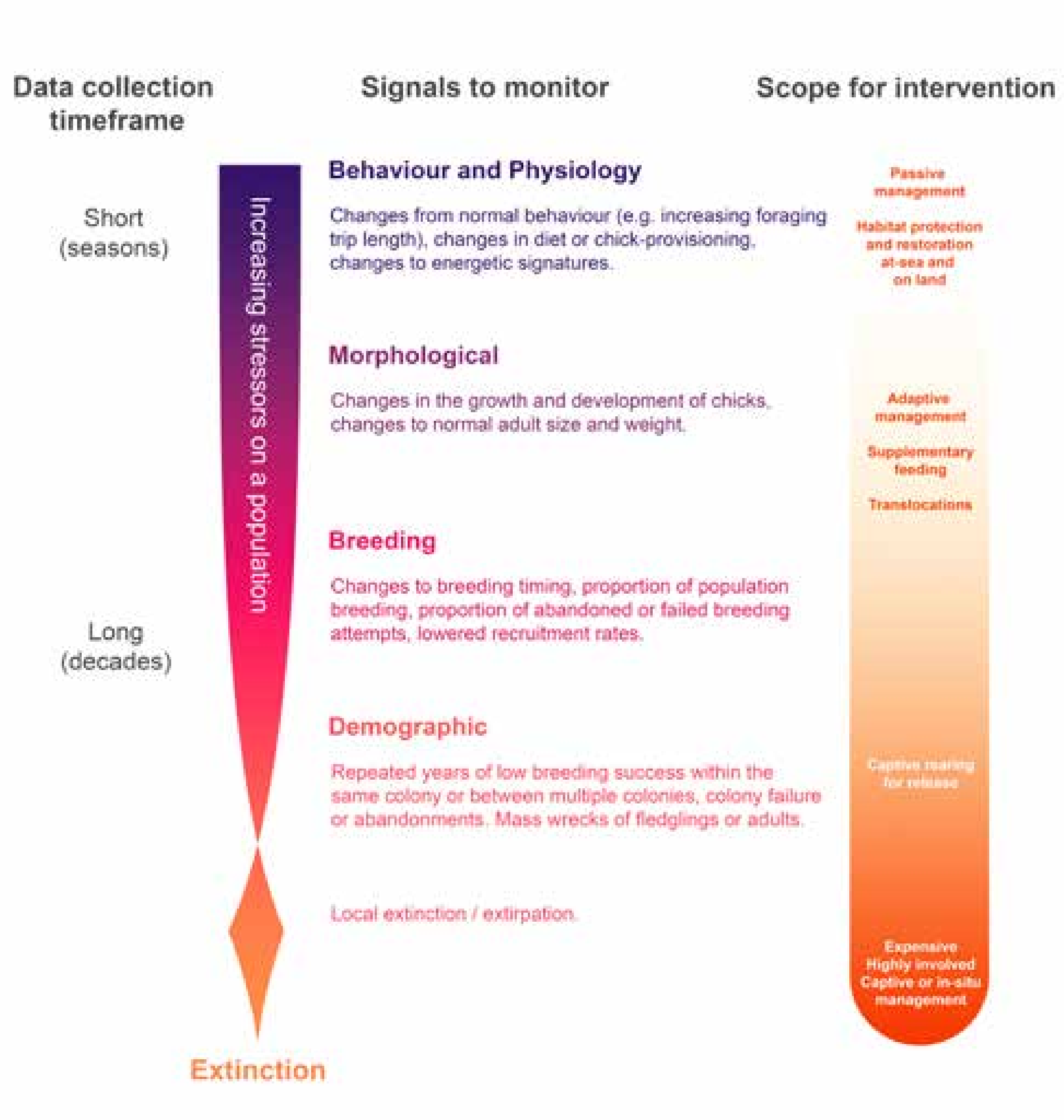
Ecophysiological data can be used to assess population condition over time (between years), or to compare between colonies. The expertise required for the analysis of some types of samples in laboratories can preclude this as being too expensive, however in some cases, samples like feathers can be archived as they are stable over time and could contribute to long-term studies of seabird health in response to climate change.

### Data management and analysis

Once baseline values and reference ranges are gathered, it is straightforward to plot the distribution of values annually to assess shifts in the variance and mean value of ecophysiological parameters. Formal statistical testing is recommended for determining relevant shifts at the population level, and other data should also be incorporated where possible (bird mass, diet data, behavioural data) to better understand how seabirds respond to change.

### Related use of data gathered

The power of ecophysiological data is realised when used in combination with studies of behaviour and diet to gain a holistic view of the status of seabird populations. By undertaking these integrative studies, it is possible to gain a better understanding of how seabirds respond to changes in their environment. Incorporating these tools into routine monitoring will help provide information of seabird condition within a timeframe that allows for adaptive responses to help conserve at-risk populations (Fig. 120).



**Behaviour and Physiology**

Changes from normal behaviour (e.g. increasing foraging trip length), changes in diet or chick-provisioning, changes to energetic signatures.

**Morphological**

Changes in the growth and development of chicks, changes to normal adult size and weight.

**Breeding**

Changes to breeding timing, proportion of population breeding, proportion of abandoned or failed breeding attempts, lowered recruitment rates.

**Demographic**

Repeated years of low breeding success within the same colony or between multiple colonies, colony failure or abandonments. Mass wrecks of fledglings or adults.

Local extinction / extirpation.

**Figure 120. Monitoring populations under stress. An outline of the sequence of signals to assess in seabird population monitoring, the timeframe of data collection, and examples of the scope for intervention when looking for signals of stress at each stage[75].**

For a thorough review of accessible ecophysiological tools see [74] (References).

## 3.9 MEASURING PLASTICS ACCUMULATION

**Stephanie B. Borrelle, BirdLife Pacific, Suva, Fiji**

Seabirds feed at or near the ocean surface, along convergence zones and eddies that are rich in prey species. These zones are also where marine plastics occur in high densities, making seabirds particularly vulnerable to plastics ingestion. Reports of plastic ingestion in seabirds started in the early 1960s, and a relatively comprehensive body of work documenting the number and type of plastic ingestion for over 200 seabird species now exists[76]. Although these studies help to demonstrate the magnitude of plastic ingestion in marine species, until recently, a lack of standardised methods for collecting, analysing, and reporting data for multiple taxa have undermined comparisons for populations of the same species[77], and limited population level impact analysis[78]. Standardised approaches to reporting plastic ingestion, or lack thereof, are important to better understand spatial, temporal, and taxonomic trends in plastic ingestion, and shed light on population level effects using correlative studies (e.g. plastic load, types, and demographic parameters).

To assess whether you think there may be a plastic ingestion issue with your target species, it is a good idea to search the area around the nests or burrows. Adults often loose portions of meals they regurgitate to their chicks and the presence of plastics around the nest site is a good first indicator of a potential issue. Collect information on size and colour of plastic.

There are three main techniques used to evaluate the ingestion of plastic in seabirds: necropsies, regurgitations, and pellet analysis. Each of these have advantages and disadvantages to collecting data on plastic ingestion (Table 3). Regardless of the methods, there are key metrics that are recommended to be collected in any plastic ingestion study. These include the species, location of sample collection (including colony if known), age (adult, juvenile, chick at the minimum), sex, body condition metrics (body mass, subcutaneous fat, pectoral muscle size), and the cause of mortality with necropsy studies when possible. It is also important to report zeros as these are important for understanding demographic drivers of plastics ingestion.

**Table 4. Advantages and disadvantages of different methods used in seabirds to assess ingested and accumulated plastics.**

| | Pros | Cons |
|---|---|---|
| **Necropsy—carcass examination (dissection)** | Can determine entire plastic burden<br>Tissues can also be easily taken for plastics-associated contaminants analysis<br>Sex and age, health status, and cause of death can be determined<br>In case of beach-cast birds: non-invasive | Does not always allow for consistent repeated sampling<br>Is usually opportunistic without options for preplanned sampling in relation to season, sex or age<br>In the case of hunting specifically for research samples this technique is invasive |
| **Regurgitations** | Can be repeated on the same individuals to compare plastic load between seasons and years<br>In comparison to hunting birds for research, regurgitations are relatively less invasive | Not all species can be made to regurgitate<br>Does not guarantee a complete sample<br>Low but real possibility of injury occurring to the bird<br>The individual may lose a meal that was costly to acquire |

|  | Pros | Cons |
|---|---|---|
| **Pellet collection** | Easily collected<br>Non-invasive collections<br>Can be repeated between seasons and across years<br>Can be regularly sampled<br>Can be implemented easily and at low cost | Cannot be used to assess microplastics<br>Depending on the species, may be difficult to attribute pellets to individuals<br>Does not guarantee a complete sample<br>Typically only useful during the breeding season when birds are occupying nesting sites on land |

A significant challenge with plastic ingestion studies is that samples and sources of mortality may not represent a true sample of the population for a species and its interactions with plastics. Because sampling is generally opportunistic, e.g., beach cast and bycaught birds, the plastics data may be biased towards certain locations or events that lead to reduced body condition where plastic may have contributed to the death of the animal or not. For some species it is possible to get regurgitations from birds in the field, which can serve to take a more targeted approach to sampling a species, including focusing on specific age classes and annual trends in ingestion.

However, there are limitations as studies have found there are considerable differences in the load of plastics when comparing regurgitation data to necropsy data[79] due to differences in the gastrointestinal tracts among species. For example, the gizzard may not be fully washed out in Procellariforms leading to an underestimate of plastics load. Pellets or boluses are another opportunistic but non-destructive sampling method for seabirds such as shags, terns, and skuas but the key limitation to this approach is collecting data on biometrics (as above) and the consideration of species-specific differences in ejected versus retained plastics. Other species, such as Procellariforms that have been reported with some of the highest loads of plastics generally do not produce pellets (although it is possible to find regurgitates outside of burrow entrances with plastics in them). Albatross chicks do a pellet regurgitation before fledging to offload squid beaks. It is possible adults do the same thing at sea and certainly adults feeding chicks are offloading their plastic loads into their chicks.

Consideration of the species being assessed, sampling opportunities and study question being posed, standardised methods for sampling and reporting are recommended to improve our understanding of the impacts of plastics ingestion on seabirds. Refer to Reference 78 for a comprehensive guide on performing necropsies and data collection for plastic ingestion including separating micro-plastics from macro-plastics.

## 3.10 CONTAMINANTS IN SEABIRDS

Seabirds are considered as biomonitors for the marine environments in which they forage. By consuming marine prey, they effectively sample the marine environment. As some species feed on high trophic level prey, they essentially bioaccumulate any contaminants that are present in the ecosystem. Samples from seabirds can be used to monitor environmental pollution of contaminants such as heavy metals, plastic-associated chemicals and agrichemicals. In the past, seabird feathers have been used to monitor the impacts of large-scale oil spills (such as the Prestige oil spill[80]), by investigating the amount of heavy metal contaminants in chick feathers prior to and for five years after the spill.

Another reason for assessing the contaminants present in seabirds is to assess whether or not they are suitable to eat. Harvesting eggs, chicks, and adult seabirds is a common practice in the Pacific, and as marine foragers they are susceptible to having high levels of certain contaminants that pose a risk to human health. Two harvested species in Aotearoa New Zealand and Australia are Sooty Shearwaters (*Ardenna griseus*) and Short-tailed Shearwaters (*Ardenna tenuirostris*). These species are subject to both traditional cultural and commercial harvests, and the presence of contaminants in muscle tissue has been the focus of multiple studies.

Although contaminants have generally been found to be lower than the national standards for food safety in each respective country, 57% of short-tailed shearwater chicks sampled had levels of copper and lead that exceeded acceptable levels[81]. There may be seasonal fluctuations in the amounts of these contaminants depending on the diets of birds, and routine monitoring should be considered for any seabird species that are regularly consumed.

**Method**

**What samples to take**
The part of the bird (egg, muscle tissue, etc) that is consumed is the best sample to take when considering human health implications. Seabirds have the ability to deposit contaminants into their feathers, which are routinely moulted and can lower the levels of contaminants present in the body. For environmental monitoring, feathers are a less invasive sampling method that may better reflect temporal fluctuations in contaminant presence in the ecosystem.

**When to use**
There have already been numerous studies on heavy metals in easily obtainable samples (e.g., feathers) for Pacific seabirds. This is a good method to establish local baselines, as seabirds forage in different areas at sea.
Testing of harvested seabirds should be done periodically to ensure there have been no changes that may pose a health risk.

**Analysis of data**
Laboratory analyses of samples will be required. This may involve sending samples overseas, so permitting and permissions are of utmost importance and need to be obtained prior to the project. Data can be accumulated into spreadsheets. Good record keeping is essential for interpretation, so make sure to record all relevant details (date, species, sample type, location data, age of individual, origin of sample, status of individual, storage method for samples, etc) of sample collection and laboratory analyses. Formal statistical analyses of these data are recommended, and the methods used will vary depending on the questions that are being asked. These data can be accumulated over time to undertake comparative work across years, so it is important to have good data management and storage practices that allow for successive operators to use the data as necessary.

Related use of data gathered

- Combined with other ecophysiological data on health of seabird populations.
- Monitoring in response to environmental disasters such as oil spills

## 3.11 SEABIRD-TRANSPORTED NUTRIENT MONITORING

**Alex Wegmann, Katie Franklin, Dana Sabine, Nick Holmes (The Nature Conservancy)**

To improve our understanding and protection of the functional roles' seabirds play in island and marine ecosystems, we need to measure the quantity (how much nitrogen (N) and phosphorus (P)) and fate (ecological interactions with N and P) of seabird-transported nutrients accurately and consistently. There are several methods for measuring the quantity and fate of seabird-transported nutrients, and each method has its strengths and limitations.

Combining multiple methods will provide a more comprehensive understanding of a given seabird nutrient transport scenario:

- **Isotopic analysis:** Visit the colonies and collect samples from seabirds, their guano, and from the surrounding environment (such as soil, water, and vegetation). Stable isotopes (e.g., nitrogen-15 and carbon-13) are analysed to trace nutrient sources and pathways. Isotopic composition helps determine whether nutrients in the ecosystem are derived from seabirds. For example, a study on nutrient cycling in montane forests used isotopic analysis to assess seabird impacts.

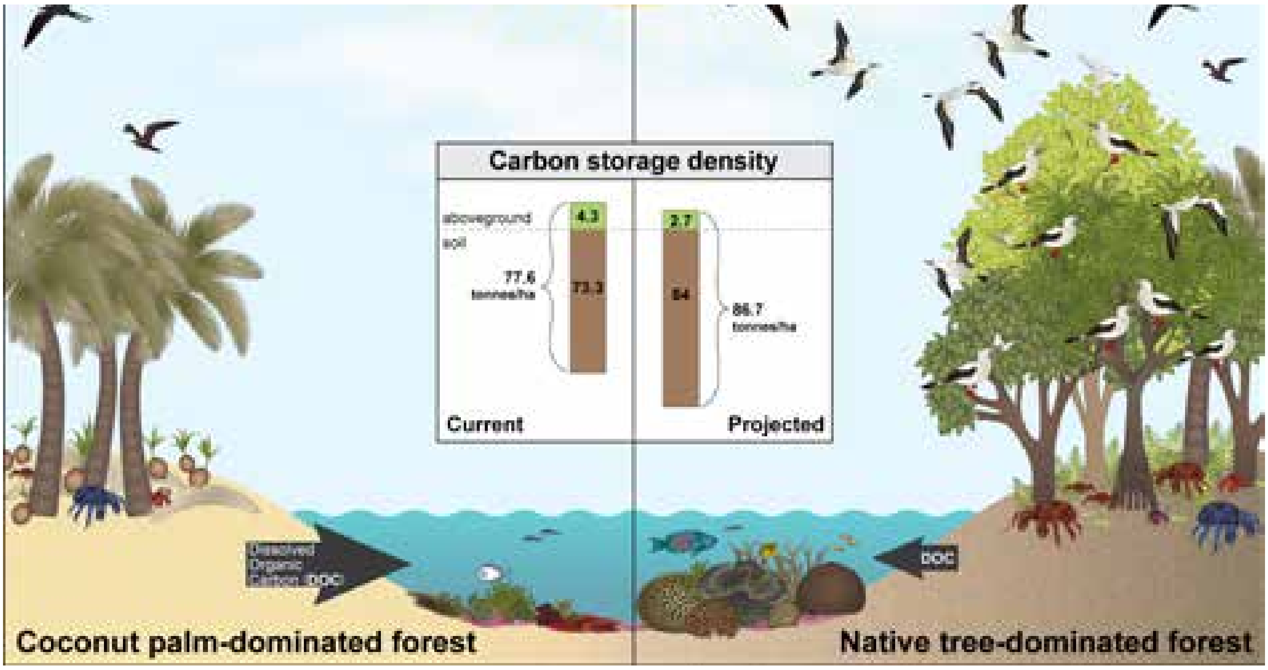


**Figure 121. Conceptual illustration of study results and other anticipated transformation and realignment benefits (bars not to scale). Art: Adi Khan.**

- **Field surveys and sampling:** Visit seabird colonies and collect samples from different habitats (e.g., soil, vegetation, water). Then measure nutrient concentrations (e.g., phosphorus, nitrogen) in these samples. Comparing nutrient levels between areas with and without seabirds provides insights into nutrient transport.

- **Nitrogen and Phosphorus budgets:** Nutrient budgets help estimate the contribution of seabirds to local nutrient availability. Calculate N and P budgets for seabird-influenced ecosystems by measuring inputs (e.g., guano deposition calculated from estimates of seabird biomass (abundance and distribution) and site occupation) and outputs (e.g., nutrient uptake by plants, phytoplankton, and corals). The net effect of seabird nutrient transport is determined by the balance between nutrient inputs and outputs.

- **Experimental manipulations:** Conduct experiments to directly test seabird nutrient effects. For instance, add guano to experimental plots and monitor changes in nutrient availability and plant growth. Control plots without guano provide a baseline for comparison.

- **Isotope tracers:** Isotopically labelled nutrients, e.g., nitrogen-15 (15N) can be used to track nutrient movement through an ecosystem and to identify temporal patterns associated with nutrient inputs[83].

- **Remote sensing and spatial analysis:** Aerial imagery and spatial data analysis can be used to estimate the distribution and abundance of seabird colonies[84], and remote sensing can be used to measure primary productivity (chlorophyll-a) as an indicator of seabird-influenced nutrient distribution across landscapes[85].

- **Long-Term Monitoring:** Regular, continuous monitoring of seabird populations, nutrient levels, and ecosystem dynamics will reveal seasonal patterns, trends, and changes over time, and is needed to continue to build the conservation case for seabirds as key components of island and marine ecosystems.

## 3.12 MONITORING CYCLONE IMPACTS ON SEABIRD POPULATIONS

As we have seen, seabirds are integral to the health of islands and surrounding reef ecosystems (see Sections 1.3.1, 3.11). As ecosystem engineers, the removal of seabirds can lead to significant changes in island habitats and species complexes. The loss or major reduction in seabird colonies through significant storm events, could result in the alteration to ecosystem function or slow island recovery.

This is particularly true after severe or frequent storm events. Given the paucity of basic count and even life-history data for most seabird species across increasingly cyclone-prone tropical regions (thanks to climate change), careful monitoring of seabird demography and recruitment is required to better understand the capacity of these birds to adapt and recover from the rapid changes ahead.
Two major cyclones in recent years highlight the impact of such events on tropical seabirds, Cyclone Winston in Fiji (2016) and Cyclone Ilsa in Western Australia (2023). These affected seabird islands include Namenalala[86] and Vatu-i-Ra (Fiji)[87] and Bedout Island (Australia)[88], all three are Key Biodiversity Area (KBA) sites.

Namenalala and Vatu-i-Ra are situated on either side of Bligh Water, the strait that separates Fiji's two largest islands (Viti Levu and Vanua Levu). Both have volcanic origins and are surrounded by major reef systems. Prior to Cyclone Winston both were covered in forest, which was the main nesting habitat for several species. The cyclone radically transformed both, stripping much of the vegetation, particularly the large trees. This resulted in significant reductions in tree nesting species. For example, the Black Noddy population on Vatu-i-Ra plummeted, from more than 20,000 pairs to less than 1000 nests in 2021 (five years after the cyclone).

Following the cyclone, both islands have started to see vegetative recovery. While tree skeletons remain, the forests are slowly returning although the largely exposed open ground currently favours surface-nesting species (i.e., Crested and Bridled Terns) at least in the short term.

Historical colony count data from Namenalala is patchy, making it difficult to chart the course of recovery of seabird populations (i.e., before and after the storm) on that island. Also, as with Vatu-i-Ra, any estimate of the actual numbers of seabirds lost is impossible without any immediate follow up with on the ground surveys. On a positive note, anecdotal evidence suggests Red-footed Boobies, Lesser Frigatebirds, and White-tailed Tropicbirds are returning to Namenalala and possibly also noddies and terns. Included in the plans for redevelopment of the resort, which was originally located on the island, most of the island's area will be set aside as a bird sanctuary[89]. Both of these examples show how severe storms can cause drastic changes in island seabird populations and also highlight the need for long-term monitoring plans - mapping the recovery of both of these island's seabird population recovery would be an important consideration for future land managers.

The situation on Bedout Island, in the Indian Ocean off Western Australia in the first year following the cyclone was also dramatic. All vegetation was stripped off the coral island, and the formerly abundant seabird populations which when the storm hit were at the height of breeding and were almost totally devastated. The surveys found adult and chick carcasses, and abandoned eggs. It was estimated that 80–90% of the populations of three seabird species (Masked Booby, Brown Booby, and Lesser Frigatebird (*Fregata ariel*) were killed in the storm, with only 40 breeding Masked Booby recorded on the island 15 weeks later. Also, unlike many records of tropical cyclones elsewhere there was minimal evidence that adult seabirds fled Bedout Island prior to Cyclone Ilsa's arrival. While some birds may have been at-sea during the surveys, or otherwise absent due to the damage to Bedout Island, the numbers of seabirds appear substantially reduced[88].

Figures122-124. Before and after photos for Vatu-i-Ra. Photos: BirdLife Pacific.

**Survey methods adopted post-cyclone:**

Vatu-i-Ra: The island was visited one month after Cyclone Winston struck, with follow up visits in three and eight years later with teams camped on the island[90].

Namenalala: Limited surveys had been conducted prior to Cyclone Winston, and no monitoring following.

Bedout Island: Three surveys of Bedout Island were completed following Cyclone Ilsa. The first survey was completed four days after the storm passed. A helicopter flew over the island (permission to land was requested, but not approved); it spent approximately 20 min generating aerial imagery. A second, ground-based survey was undertaken ten weeks after Cyclone Ilsa. The island was accessed by boat, and a single person spent 2 h on shore. Deceased seabirds were counted and identified to species level within five transects (60 × 2 m) placed haphazardly across the island with an aim to cover as much of the central seabird breeding habitat as possible. As this survey was limited in duration, a third and final assessment of seabird mortality was completed one month later to provide additional transect data, including from parts of the island not covered in June. During this final survey, the island was accessed by helicopter and a further 10 transects (60 × 2 m) were completed over four hours using a similar approach[88].

## 3.11 MONITORING SUCCESS (OR OTHERWISE) OF PREDATOR/PEST CONTROL MEASURES

**Paula A. Castaño, Paul Jacques, Richard Griffiths, Island Conservation**

For some seabird conservation projects, invasive species eradication is possible but often this is not feasible for technical or socio-political reasons, in which case control may be the only management strategy to prevent further biodiversity loss[91]. Eradication of introduced predators such as rodents, cats, pigs, and mongooses, can result in very positive outcomes in short periods of time with seabirds breeding successfully and expanding their breeding distribution. Additionally, removal of invasive competitors (e.g., rabbits) that outcompete seabirds for breeding burrows can also result in positive outcomes for ground nesting seabirds, with some species returning to islands to breed successfully after several decades.

At Midway Atoll National Wildlife Refuge, United States, for example, Bonin Petrel (*Pterodroma hypoleuca*) populations increased from fewer than 5,000 nesting pairs in the 1980s to over 135,000 pairs in 2008 after the eradication of rats in 1997[92, 93].

On Hawadax Island, Aleutian Islands, United States, 10 years after the removal of rodents Tufted Puffins (*Fratercula cirrhata*), not previously recorded as breeding on the island, were documented. Many other similar examples exist where seabirds have benefited from the removal of invasive predators/pests from islands around the world[94].

In areas where total eradication of invasive species cannot be completed, other invasive predator management systems can be implemented such as pest control using tools such as traps, firearms, toxins or predator fencing to exclude invasive species from an area. Predator control can be implemented to prevent the loss of species until eradication becomes feasible or an alternative such as fencing can be deployed [53, 95]. In contrast to eradication, pest control only supresses the invasive species' population and benefits to the seabird species of concern will only be apparent for the period of time the tool is deployed, . However, in some instances it can be the only management strategy available to prevent a species from completely disappearing. For example, in the Galapagos Islands, the largest breeding population of Galapagos petrel (*Pterodroma phaeopygia*) in the world was successfully sustained on Cerro Pajas, Floreana Island, thanks to an extensive and long-running control program targeting introduced rodents, feral cats, pigs, goats and donkeys. This effort has been led by the Galapagos National Park and undertaken annually since the 1980's[96], with feral pigs successfully eradicated at the end of the 1980's and goats and donkeys successfully eradicated by 2011[97,98,99].

Pest control techniques and tools should be chosen carefully based on best practice for the predator/pest species targeted. Other factors that will play into selection of tools include the size and accessibility of the site, local climate (e.g., rainfall), availability of funding, and logistical limitations (e.g., access, number of available fieldworkers). It is also essential to consider the impact of suppression tools on native non-target species to ensure that tools do not cause unacceptable levels of primary or secondary mortality. For example, if you are considering conducting rodent control using anticoagulant rodenticides, depending on the avifauna of your site there may be a possibility that other species will be negatively impacted (e.g., raptors or other native predators), through secondary exposure. Mitigation actions may be required to ensure that these non-target species are not impacted. Check regulatory requirements when considering the use of tools to make sure you can legally use them in your area. Additionally, ensure that you have conducted extensive outreach efforts to ensure that communities and stakeholders have all of the facts available to them as misinformation can be damaging.

Predator fencing greatly increases the effectiveness of existing animal control efforts, shifting the focus from perpetually attempting to control predator numbers, to eradication and surveillance[100]. Predator fencing makes it feasible to remove all animals from within the fenced unit and focus control efforts on buffer areas around the fence's perimeter. In Aotearoa New Zealand and Hawai'i, predator exclusion fencing has been used to successfully recover seabird populations with extraordinary results[101]. The fencing excludes all species of rodent and other mammalian predators and prevents animals from digging under or climbing over the fence,[102,101,103]. Resource managers in Aotearoa New Zealand have built more than 52 predator fences that protect more than 10,000 hectares. At least eight fences have been built across the Hawai'ian islands. These fenced areas now serve as refuges for endangered seabird species.

To measure the impact of your predator/pest management effort (e.g., eradication, control or predator fencing), a robust monitoring program should be designed and put in place prior to the intervention. Collecting data before an intervention is undertaken is important for establishing baseline conditions against which data collected later can be compared. This is important to determine if the intervention is successful, if any adjustments are required, or if additional interventions are required. Further it can allow you to share stories about the positive impacts of your intervention on the ecosystem and conservation target.

Assessing the effectiveness of pest management will require an initial focus on determining if our control, eradication, or fencing plus eradication efforts have been successful in reducing the threat to the conservation target species. Have they supported increased breeding success and recruitment of individuals into the adult breeding population (e.g., seabirds' burrow occupancy rates, fledging success, breeding distribution, etc.). Monitoring programs should also wherever possible measure other impacts on the environment.

For pest control operations, where the target is not reduction of the invasive species population to zero as in eradication, it is recommended that the aim be to reduce the target pest population to a pre-determined threshold, as measured by standardised monitoring techniques. Prime examples are aerial baiting operations on the Aotearoa New Zealand mainland designed to suppress rats, brush-tailed possums and mustelids, to protect native biodiversity. The success of these operations is determined by assessing the relative abundance of pest predators using techniques such as chew cards (for possums) and tracking tunnels (for rats and mustelids) before, and after, the operation.

Detection methods for determining success of eradication (including within a fenced area) or control will vary by species and can include searching for sign of invasive predator (e.g., footprints in appropriate sites, faeces, gnawed seeds, seabird carcasses, egg or chick predation), spotlight searches, snap traps, live capture traps, chew blocks, wax tags, inked footprint tracking tunnels, dressed timber stakes soaked in peanut oil, candles, lard, chocolate, wax block baits secured in bait stations, wooden boxes providing shelter and wood shavings as nesting material, trail cameras, thermal drones, and trained indicator dogs. Prior to selecting the tools to be deployed for confirmation of success such as snap traps, an assessment of the possible impacts that these can have on other native species (e.g., passerine birds, rails) should be assessed to prevent causing additional harm to these species including our conservation target species.

Figure 125. Left figure shows chew blocks deployed for detecting rodents in Great Sitkin, Aleutian Islands, United States prior to eradication. Right figure shows chew cards with peanut butter deployed across Pinzon Island, Galapagos, Ecuador for confirming rodent eradication.

To confirm the success of any pest/predator eradications in particular you should employ multiple detection tools. The amount of effort required to confirm absence will vary on the size of the site and the target predator/pest species, but as a rough guide at least two reliable methods should be used. It is critical to select methods that have been proven previously in the island to have a high probability of detecting your target predator/pest species. Devices (e.g., traps, tracking tunnels, trail cameras, etc.) can be spaced in a grid-pattern, in transects, or may target specific landscape features where the target species of removal may be more likely to be encountered. This latter spacing is particularly useful for animals like feral cats that are not distributed evenly across space but frequently use defined landscape features (e.g., human and game trails) and will concentrate around seasonal food sources (e.g., colonies of terns and burrow-nesting seabirds).

Timing of monitoring success of eradications will vary depending on the target species. For larger and more detectable species such as feral pigs and feral cats it is typical to search for survivors immediately. For operations targeting these species it is only possible to determine in retrospect when the last individual was removed, and the last months of the operation are spent in continuous detection efforts to build confidence in the absence of the target predator/pest. For rat species a low population of individuals is much harder to detect, therefore success should be confirmed one to two years after the eradication attempt. This allows for at least two breeding cycles in temperate islands and possibly more (three or four) on tropical islands, for these rapidly reproducing animals, and greatly increases the detection probability if rats have survived, conversely reducing the amount of effort required to confirm absence.

Detection tools will support you when determining if additional interventions are required, for example if monitoring reveals that not all invasive predators were removed within a fenced area or from an island, or if you should consider moving from a suppression strategy to a more permanent solution like eradication or an intermediate intervention such as predator-proof fencing. Monitoring may also reveal other threats, e.g. detection of previously undetected predator/pest species that may require further management.

In addition to confirming the success of eradication by not detecting invasive predators in the treated area or by reducing their impact on circumscribed areas, a crucial component that allows for measuring the positive impact of invasive species removal on the island environment and the recovery of impacted seabird populations is monitoring from ridge-to-reef. This monitoring assesses the restoration of the treated island or area and its surrounding ocean ecosystems, as well as the re-establishment of locally extirpated seabird species. A growing body of scientific research suggests that significant loss of native connector species, such as seabirds, leads to nutrient cycle disruptions that can result in reduced marine productivity and poor coral reef health[104]. Measuring ecosystem-scale impacts requires a holistic approach and relies on a carefully considered strategy, beginning with the collection of pre-eradication data to enable measurement of change at pre-determined intervals (e.g. one-, two-, five-, and 10 years) post-eradication.

**Conservation impact monitoring (pre- and post-eradication)**

Here we provide information on methods that could be used to measure the positive impacts on the seabird species of concern. For additional information on standardised methods for terrestrial and marine monitoring we invite you to visit and consider joining the Island Ocean Connection Challenge. This challenge aims to strengthen our understanding of island-ocean connections by completing systematic, standardized and repeatable terrestrial and marine monitoring before and after the eradication of invasive mammals, while supporting the restoration of critical island habitats.

To document change in seabird abundance and diversity post-intervention it is recommended to combine highly effective population monitoring techniques (via acoustic recorders, population counts, and/or sampling plot nest counts) with generalised, island-wide data collection for evaluation of the seabird community. The metrics often used on islands to monitor the impact of invasive predator/pest removal or control on seabird populations are relative abundance, population size/abundance, and diversity. For determining the most appropriate survey method, it is highly recommended as previously indicated within this manual to consider the breeding phenology and synchronicity of the seabird species of interest as well as the nesting habitat.

Acoustic monitoring is ideal for vocal species that may be difficult to detect due to habitat (e.g., forest, inaccessible cliffs), dispersed nesting (i.e., don't have centralised colony), nocturnal behaviour, or rarity. In addition, this tool can be deployed for long periods (e.g. years), allowing for a more reliable comparison between seasons and years, which is especially important for asynchronous breeders or those species that don't have a consistent breeding season.  Unless the site is too small, a minimum of eight devices should be deployed on each island across suspected seabird habitats, at least 200m apart. Devices should have mixed diurnal-nocturnal recording schedules and sufficient battery life and memory card storage to allow for continuous recording for up to one year.

Colony or nest counts are ideal for species with nests/individuals that are highly detectable, the nesting area is accessible and at least somewhat centralized (e.g., observers feel confident they are detecting birds or nests in the habitat). In addition, the total numbers will be most accurate for species that have a synchronous breeding cycle; repeating surveys multiple times throughout the year is best for asynchronous breeders. Nest counts that include a complete count of all individuals and active nests of a species are recommended. Searches can be conducted in-person or using aerial imagery (e.g. drone) and should cover the species' preferred nesting habitat ideally during an early stage in the breeding cycle. Mapping the distribution of nests (e.g. perimeter of colony), marking individual nests, or describing the area searched (e.g. 10m-wide coastline swath) are ways to describe the current distribution of nests.

If a true census or count of all individuals is not possible, because nesting is dispersed across a relatively large landscape or not feasible because of the abundance of nests, sampling plot nest counts may be the best survey option. Plot site selection, size, and number will depend on the species being monitored and the habitat. When possible, a random sampling design is preferred; however, where nests are grouped or there are multiple habitat types that need to be surveyed, stratifying the sampling locations by habitat type is best.

Whether deploying bird point-counts from the coastline or by boat independent of other seabird monitoring methods or in tandem, the point-count methodology offers valuable information for understanding seabird population trends. We recommend the use of boat-based point counts on islands with lots of vegetation while islands with rough ocean conditions or open landscapes may be more conducive to coastal land-based counts. In either case (or a mix of both land and sea), point-counts should be conducted from five to ten established, replicable locations around each island (sites distanced at least 200m apart and ideally paired with remote sensing devices). Morning surveys involve spending five minutes per site (50-150m from shore) recording all birds heard or seen, noting whether birds are on island (roosting or nesting) or flying over land or water.

Once data is collected it should be processed and shared with partners to support future conservation efforts for our conservation target species.

## CASE STUDY - Assessing the effectiveness of Predator Control in Endangered Seabird Management Sites on Kaua'i using acoustic sensors

Acoustic sensors have been deployed in seven management sites on Kaua'i for two endangered seabirds – the 'ua'u (Hawaiian Petrel) and 'a'o (Newell's Shearwater) – for over a decade to assess the efficacy of colony management actions (mainly the control of introduced predators and invasive plants). Each year, acoustic sensors (Wildlife Acoustic SM4 units) are deployed at 10-14 static survey locations within each site. These are spaced 250 meters apart to prevent double counting of birds (the distance is based on how far the species calls typically travel and are deployed in such a way as to provide auditory coverage over the majority of each of the sites). This long-term monitoring approach allows for a colony-wide assessment of inter-annual vocal activity within each colony.

To ensure that units capture the peak vocal period of both species, units are deployed for a five-month period between May and September, capturing critical periods of the species breeding phenology: courtship, incubation and early chick-rearing periods. As the vocal activity patterns of the two species are markedly different, units are set to record every night at the following rate: 1 minute in every five minutes for 5 hours after sunset and 1 minute in every ten minutes for 5 hours before sunrise. Call rates are calculated for 'ua'u based on data collected in the 5 hours after sunset (this species is not vocal after the first few hours after dark) and for 'a'o based on data collected in the 5 hours before sunrise (this species is vocal in both periods, but more vocal in the hours before sunrise).

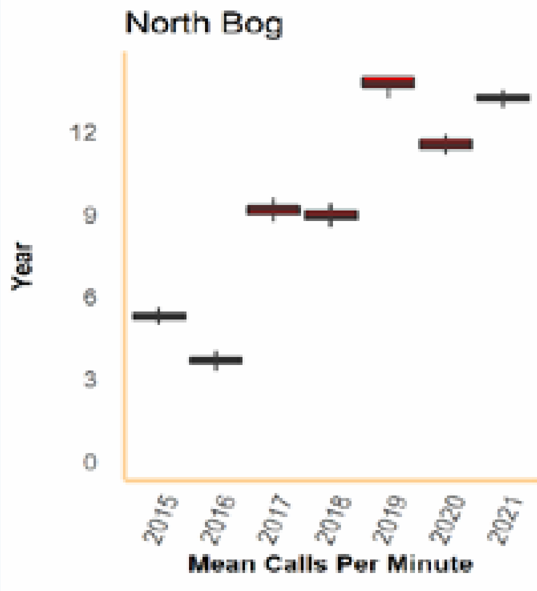


**Figure 126. 'Ua'u and 'a'o call rates recorded by acoustic sensors at two different management site on Kaua'i. Supplied by André Raine.**

As call rates for both species have previously been found to be directly related to the number of burrows present around each acoustic sensor (i.e. higher call rate = more active burrows), call rates are used as a proxy for assessing colony size. Management (predominantly predator control of introduced cats, rats and pigs) at each site began at the time monitoring commenced, was refined over the first few years of monitoring and has remained at the same intensive level since. Results from acoustic sensors have clearly demonstrated the positive impact of these management actions by documenting a steady near annual increase in call rates (as shown in Figure 126). Acoustic monitoring on an annual basis at these sites has provided a standardised long term and cost-effective method that allows land managers and decision makers to easily assess the effectiveness of their actions.

This mirrors results from other monitoring work undertaken at each colony. In tandem with acoustic sensors, all known burrows (over 1,400 burrows across all sites) are visited eight times a year to assess reproductive success rates, and at each site 30 monitoring cameras are deployed on a sub-set of burrows to assess predator visitation rates and predations. These additional methods are in line with the results found from the acoustic sensors, with increased reproductive success coming in tandem with decreased predation rates and predator visitation over the same time period. As these results show, acoustic monitoring is a cost effective and low intervention method of monitoring the success of management interventions such as predator control.

# PART FOUR

## Managing Data To Support Conservation

Surveying Suwarrow Atoll, Cook Islands.
Photo: Te Ipukarea Society.

# 4.0 MANAGING DATA TO SUPPORT CONSERVATION

This part of the manual provides guidelines on how to manage all the data you are collecting and provides examples of databases. It then looks at the important step of adding your data to regional databases such as the Pacific Seabird Colony Database (Section 4.2), introducing seabird restoration through passive or active means (Section 4.4), and if your project involves active predator control or restoration measures, adding your data to the Seabird Restoration Database (Section 4.4.3). Inclusion of the Marine Megafauna Conservation Toolkit (Section 4.3) recognises the importance of seabird surveys and monitoring for informing marine conservation.

# 4.1 GUIDELINES FOR DATA MANAGEMENT

This section covers the best ways to manage all the data you have collected during your survey and monitoring projects. In this section we consider the first steps you will need to take to manage that data, such as digitising data from notebooks to spreadsheets, or directly into dedicated databases set up for your project.

## 4.1.1 MANAGING YOUR OWN DATA

Collecting good quality data is a key element of any seabird project and is a fundamental aspect of research and conservation work. In this manual we have discussed a wide range of methodologies used to collect data on your target seabird populations. It's at this point that you may find yourself staring at your reams of acoustic files, tracking points and survey sheets and thinking, well now what?

It may seem like there is no such thing as too much data, and broadly speaking that's true. However, if you are not managing your data properly you can find yourself quickly swamped, making it difficult to drill down to the data you really need and the analyses you should be focusing on. This becomes even more true if you are using multiple methods – cameras, song meters, drones, auditory surveys, tracking devices etc. – with data in different formats. Below are some considerations for how to manage your data properly, from collection through to the end product. While we cannot provide detailed guidance on how to set up a robust and efficient data management system for every project, there are a few key steps that you should consider.

- **Understand your data collection needs <u>before</u> you start**. Before embarking on a project, step back and consider the core focus of what it is you are trying to achieve. Then assess exactly what data you require to tackle these objectives. This is a key component of study design and ensures that you are collecting all the data you need (there is nothing more frustrating than being a year into your project and then realising you have not collected a key piece of data) and that you aren't wasting valuable time collecting data that you won't actually use.

- **Ensure your data collection methods are clear.** When collecting data in the field, make sure everyone is on the same page about what needs to be collected, and exactly how that data is collected. For example, if you are measuring morphometrics on captured birds, make sure that everyone knows what you mean by 'beak depth' or 'flattened wing chord'. If you are carrying out nocturnal surveys and counting bird calls, make sure your definition of what you are considering a single call is clear (e.g. a call is a single unbroken note or series of notes). If you are mapping distribution and have several types of polygons (i.e. 'hotspot heavy', 'hotspot light', 'hotspot ground calling'), make sure your team has a clear definition of those polygon types. Clear and concise definitions lead to good quality data collection.

- **Don't wait to digitise!** If you use field notebooks, make sure the field data is digitised as soon as possible; don't wait until the end of the season to start digitising. If you can't, then at least make a PDF copy so that data collected earlier will not be easily lost. By that point, you probably won't remember what some of your notes meant (especially cryptically written notes taken at 2am), and your notebooks may be covered in mud or be wet, or they may go missing altogether. Once a field trip is over, digitise! Also, consider collecting data digitally in the field on mobile devices, which can by uploaded when you return to your base of operations. There are multiple apps (both open source and proprietary) that are now available for data collection, and these make the whole step of digitising field notes redundant.

**Digitise only what you will use.** There is often the impulse to digitise and collect everything when it comes to data. This might not actually be necessary. Consider, for example, a project that has 50 burrow cameras, with cameras set to take photos whenever there is movement in front of the burrow. If these cameras are deployed throughout the breeding season, the number of photos being taken will rapidly build up – even more so during the pre-fledging period when a chick may spend hours outside a burrow exercising and thus ramping up the photos. A project such as this will have hundreds of thousands of photos to digitise and this can be truly overwhelming. In this scenario the impulse may be to try to collect data on every single photo, but do you really need to? If you are assessing the impact of predator control on seabird fledging success, you may only need to digitise predator visitations and confirm chick fledging dates, rather than collecting data on every entry and exit of each burrow by an adult bird. Narrowing this down saves time and allows for a more focused analysis. Another option to consider are cloud-based repositories and processing facilities for your camera trapping images (e.g. https://docs.gbif.org/camera-trap-guide/en/).

**Design and use a good database.** Choosing the right database is key. This is where your data will be stored, and where you will be going to ask questions and understand relationships about your data. An unsuitable database will create extra work - making it hard to find the data you are looking for or answer even simple questions. Carefully consider your data needs, and resources available to you. Do you have funds to purchase something proprietary or should you go the open-source route (e.g., Microsoft Access vs. PostgreSQL)? Do you work with a lot of spatial data and want to automate spatial queries and store spatial data (i.e. PostgreSQL with PostGIS or Oracle Spatial)? Does your project have the personnel expertise to implement powerful solutions, or do you need something simple and user-friendly out of the box to just answer questions (e.g. Metabase)? This step is so important that it is worth consulting professionals to assist with the design. Avoid organic solutions of storing data from different years, species, colonies in separate files hoping that they will be interoperable and always remain in the same folder – ideally all of the data should be contained in a single (or very few related) database(s).

**Back up your data!** It may seem obvious, but make sure you back your data up frequently, to multiple sources, one of which includes a cloud-based solution. Don't store everything on a single laptop, as inevitably it will crash, swirling your data away into the ether, never to be seen again. Have an external hard drive (or several) kept somewhere away from your computer or office database or data server. These hard drives can be small and portable, so you can also take them into the field with you if you are on extended field trips with base camps. For larger teams, use an office server with regularly scheduled backups to keep your data safe, while also frequently backing up to a cloud-based storage service. Cloud back-up solutions are not only safe storage places, but they also offer data processing that would be very laborious to do by hand. For example, seabird tracking data can be safely stored on both Movebank (https://www.movebank.org) and the BirdLife Seabird Tracking Database (www.seabirdtracking.org), which facilitates analysing the data via R packages and annotating data with environmental remote-sensing products. Raw sound recordings can be safely stored on ecoSound-web (https://ecosound-web.de/ecosound_web/collection/index/118) where you can also automatically run recognizer algorithms (BirdNet) over your data to extract calls of target species, which can also be done for camera trap data on several online repositories (e.g. https://docs.gbif.org/camera-trap-guide/en/).

**Automatically produce reports and validate.** Most projects will need to report summaries of what they have found to partners, funders, government authorities etc. Creating such reports can be a significant burden, but a well-designed database can facilitate the automated creation of reports at regular (e.g. quarterly, annually) intervals (e.g. https://github.com/steffenoppel/GoughReports). These automated reports are not only useful for external reporting, but also immediately flag up potential errors in the database for data validation. For example, a plot of reproductive success over time that lists a value of >100% for one year will immediately indicate an error in the data, whereas finding the one erroneous entry where somebody accidentally entered an incorrect value will be much harder to detect. Producing and inspecting reports at regular intervals therefore allows you to efficiently assure the quality of your data.

### 4.1.2 SURVEY DATABASES

A variety of databases can be created to store data collected during surveys and monitoring programmes. They can include:

1. Nest monitoring and count data.
2. Camera and trapping data: This is designed mostly for invasive trapping or camera trapping, i.e., for camera, cage or any other kind of trapping data with tables to record effort and captures.
3. Individual marking, recapturing, and tracking data: this is for ringing/ banding, the deployment of tracking devices, recapture and retrieval, as well as codes to process the data and upload it into the database.

Once you have an expectation how much data you will need to manage (and of what type), consult with a professional to get advice on what database architecture would be most efficient for your needs. If you want help to develop your own database contact the Pacific Seabird Advisory Group (see Section 5.2)

You will need to fill in the information below for the first nest in each colony visit!

Figures 127. Example pages from a breeding bird database using MS Access Database software - based on one developed for Gough Island, Atlantic Ocean. Supplied by Steffen Oppel.

## 4.2 PACIFIC SEABIRD COLONY DATABASE

The Pacific seabird colony database is a record of known seabird colonies in the region by species and location. Data has been collected by a variety of researchers over many years including published and unpublished data and contributed to the database. BirdLife International Pacific collated the original database, and it has now been placed on an interactive platform on SPREPs INFORM data portal. Data can be entered and uploaded via an online form which is then curated (checked and verified for accuracy) by a database management team.

The database currently captures information on over 1000 seabird colonies. There are significant gaps in the colony database in terms of distribution of information across the Pacific. More than 20% of the records come from French Polynesia alone and over half of the colonies across Oceania have not been counted since 2000. For identification of Key Biodiversity Areas this is also a significant gap as data should be no more than 10-12 years old.

There are 10 species of globally threatened seabirds which breed in the region, these are Beck's Petrel (CR), Fiji Petrel (CR) and Heinroth's Shearwater (VU) (unknown breeding locations are hampering conservation efforts; Polynesian Storm-petrel (EN), Phoenix Petrel (EN), Henderson Petrel (EN), Fairy Tern (VU), Gould's Petrel (VU), Vanuatu Petrel (VU) and Collared Petrel (VU). Collecting regular information on the populations and trends and impact of conservation actions should be a priority for this group.

The purpose of the database is to provide a shared resource for both managers and scientists. Managers can use the data to enable reporting on biodiversity assets as part of national reporting obligations. It can also be used to prioritise monitoring needs and to support the development of national seabird plans. Scientists and researchers are encouraged to submit data to the database and to consider supporting Pacific countries with technical assistance in monitoring of seabirds.

It is important to remember that even if a species' status is not threatened on a global scale, it may be highly threatened on a national scale, i.e., in individual countries. The loss of a species from a country also represents a contraction in range and a loss of biodiversity from that country with all the associated ecosystem benefits. Furthermore, with the looming threat of climate change, every colony is important to help increase the chances of the long term stability of individual species and ecosystem resilience.

**https://pacific-data.sprep.org/pacific-seabird-colony-database**

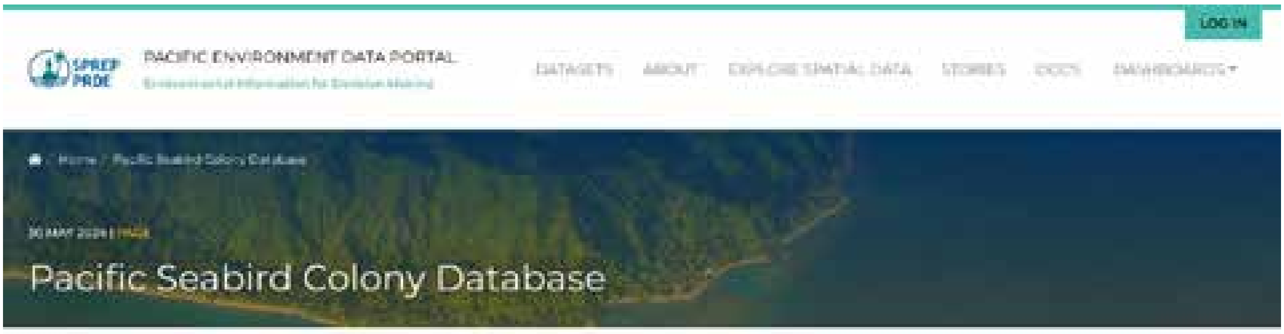


Figure 128. Screenshot of portal open to a data entry. Image supplied by SPREP.

## 4.3 WORKING TOWARDS BETTER MARINE CONSERVATION

### Jonathan Handley, BirdLife International

Figure 129. Banner graphic supplied by BirdLife International

The Marine Megafauna Conservation Toolkit is an open-access online toolkit which facilitates the identification of important sites for marine megafauna and pathways to advocate for their conservation. (https://birdlifeinternational.github.io/Marine-Megafauna-Conservation-Toolkit/)

A primary goal of the toolkit is to facilitate the application of methods to identify sites that meet Key Biodiversity Area (KBA) criteria, including from tracking data, and relevant implementation of conservation actions to support marine megafauna achieve or maintain a favourable conservation status. Key Biodiversity Areas are sites that contribute significantly to the global persistence of biodiversity and are a leading conservation planning tool recognised in multilateral environmental agreements.

Through three main components, the toolkit:

1. Helps users identify critical sites for species, including supporting users to turn complex animal tracking data into outputs useful for decision-makers,

2. Helps users in identifying effective conservation interventions through case studies curated by the global Conservation Evidence Team, and

3. Helps users understand which mechanisms can support decision-makers to act by guiding users through the policy and advocacy opportunities for site-based conservation. For example, where decision-makers require information on important sites for spatial planning, the toolkit will enable this. Additionally, the toolkit enables understanding of what actions are required to conserve important sites within spatial planning exercises. The toolkit therefore facilitates the urgent need to scale solutions for nature conservation.

Whether focused on an individual site or networks of sites from national, regional, to global levels, the toolkit serves to scale solutions for the conservation of marine megafauna.

Ultimately, the toolkit is a key facilitating mechanism that can enable individuals or groups to better deliver outputs and information required for achieving global commitments such as those of the Kunming-Montreal Global Biodiversity Framework, UN Sustainable Development Goals and the Framework for Nature Conservation and Protected Areas in the Pacific Islands Region 2021-2025.

Figure 130. Graphic providing an overview of the Toolkit supplied by BirdLife International

Toolkit in the context of this manual: An essential component for identifying sites that could qualify as Key Biodiversity Areas is having information on species abundance. Therefore, by using the manual to understand how to determine abundance estimates for seabirds, users will be well positioned to take this data and apply methods outlined in the toolkit to progress conservation actions in the Pacific.

## 4.4 SEABIRD RESTORATION PROJECTS – SUMMARISED

Seabird restoration projects may occur for a variety of reasons. These include re-establishing populations to historic breeding sites, encouraging breeding at locations recently cleared of invasive species, establishing multiple breeding colonies, preventing extinction, restoring ecosystem function and resilience or to reinstate a sustainable cultural harvest and proactively preparing for the loss of low-lying colonies due to climate change and subsequent sea level rise. The poor conservation status and great diversity of seabirds can make their conservation a priority. Fortunately, many practical, cost-effective techniques exist for seabird restoration[105].

The role of seabird-driven ecosystem functioning has become better understood over the last fifty years, resulting in a shift from species-specific restoration to a holistic ecosystem-based approach. Seabird restoration can strengthen ecosystem resilience by re-establishing marine-derived nutrient input which is crucial when restoring islands (and often mainland areas as well) to fully functioning ecosystems. The restoration process can take time but ultimately result in long-term ecological benefits for both the seabirds themselves and terrestrial (and adjacent marine) ecosystems. While most restoration projects will have an ecological focus, seabird restoration can present additional cultural, social and economic benefits to communities. Accessible seabird colonies can provide opportunities for education, community engagement and a connection to nature.

Seabird restoration can also benefit communities through ecotourism opportunities, and large active colonies of seabirds (particularly ground nesting seabirds such as albatross, terns and boobies) can provide significant attractions for wildlife tourism. Furthermore, some Pacific communities would like to see seabird populations return to a level whereby sustainable harvest could be reinstated, a practice that creates cultural cohesion and restores cultural traditions.

Seabird restoration projects can also be complex due to social, practical, financial and ecological factors. These complexities need to be considered early in the process when planning a seabird restoration project and will vary depending on (i) what species are being restored, (ii) where, when and how restoration will occur and (iii) who needs to be involved in the partnership. Before any active restoration is carried out, the first steps are to ensure that threats have been removed, the correct permissions have been obtained and that life histories of seabirds have been considered.

Additionally, for successful restoration projects, several factors need to be considered, more than just space and time. These include cultural considerations, species-specific behaviours, habitat requirements and life-history traits, as they influence seabird population recovery and recolonisation of newly available habitat.

Make sure you ask all the pertinent questions, such as "Is it the right breeding habitat and topography? Is there any indication the species bred in the area before? Are there likely to be sufficient food sources available within foraging distance of the species involved? Are there seabirds already breeding in the area that may be active competitors (you don't want to translocate a species to an area where it will be immediately outcompeted by a more aggressive resident seabird species!)? Is there enough breeding space in the area to create a colony?" The answers to these questions could be the difference between success and failure.

Seabird restoration projects also need to be conducted in an ethical manner (especially translocation projects which rely on removing birds, often endangered species, from existing breeding areas) and designed in a way that maximises success. Follow up monitoring is also critical with clear and definable measures of success using appropriate monitoring techniques. Remember, because seabirds are long-lived and often only start breeding at an age of several years, restoration projects are a serious commitment as these kinds of projects can take decades to come to fruition. Plan for the long term in terms of budget, strategy, methodologies and permitting.

**Methods**

There are two approaches to seabird restoration: Passive restoration, and active restoration. Which approach is the most viable depends on a range of factors, including:

- Proximity to source colonies
- Habitat quality at restoration site
- Urgency of action (from a conservation viewpoint)
- Species being targeted for restoration
- Sufficient availability of species being targeted (for translocation projects)
- Permitting requirements
- Funding availability to maintain activities for decades
- Expert availability

### 4.4.1 Passive restoration

Passive restoration involves removing or controlling invasive predators and invasive, habitat altering vegetation to allow seabird populations to recover or recolonise sites naturally. This has been the most common management strategy for seabird restoration in the past but is highly dependent on the proximity of the restoration site to source populations or active transit routes. This technique is the least costly, least risky and least time consuming.

For some species it can be highly successful – for example, passive restoration in Maui Nui, Hawaii through predator control and the creation of predator proof fences, has resulted in significant increases in 'ua'u kani (Wedge-tailed Shearwater) populations within a short time frame. Breeding pairs skyrocketed from zero to several thousand breeding pairs in less than 20 years in three colonies and only slightly less dramatic increases in three other sites[17]. However, passive restoration may have a lower success rate than active restoration in other scenarios.

### 4.4.2 Active restoration

Active restoration techniques manipulate the demography and movement of seabirds, requiring an understanding of species-specific behaviour and population dynamics to be successful. Active restoration projects typically take two forms: some rely on social attraction (using speakers and decoys to attract birds to the protected area) whilst others rely on social attraction coupled with translocation (actively moving birds from one a source colony to the protected area). Both methods can accelerate the recovery or recolonisation process or can be used where passive restoration has failed to regenerate populations. Active restoration for burrow nesting species typically also includes the creation of artificial burrows (which can kickstart breeding by relieving birds from the burden of having to dig their own burrows).

Due to the factors influencing seabird population recovery and recolonisation of newly available habitat, deciding whether to use social attraction only or coupling it with translocation relies on a consideration of a number of factors, including whether the target species is currently breeding on site but in limited numbers, whether it is breeding somewhere nearby, or whether the site is on a flyway of the target species. These questions will allow project managers to decide whether social attraction on its own has a chance of success or whether translocation from source colonies much farther away is required.

As active restoration has consequences to source populations (these projects are drawing birds in from other breeding colonies), they need to be carefully and meticulously planned. They can also work in tandem with each other. For example, prior to embarking on translocation actions, some projects may rely on several years of social attraction first to see if that works. This is a good approach to try when initiating new projects, as it may be that social attraction is all you actually need to do. Remember that translocation projects require highly skilled and trained staff, significantly more funds and logistics, and involves the active physical removal of chicks from other breeding colonies, with meticulously planned feeding programmes. As these source colonies may already be managed and have high fledging success rates because of this, there needs to be a clearly defined need and a high likelihood of success of the project prior to its initiation – particularly when dealing with endangered seabird species.

Figure 131. A generalised decision-making tree for restoring seabird populations[107].

**Figures 132-135. Examples of seabird restoration methods, decoys, nest boxes with playback, predator-proof fencing. Photos by André Raine**

### 4.4.3 SEABIRD RESTORATION DATABASE

The Seabird Restoration Database is a unique global product providing practitioners with real world examples of active seabird restoration efforts from around the world. Data from the Seabird Restoration Database are open access and can be found at: **https://www.seabirddatabase.org/**

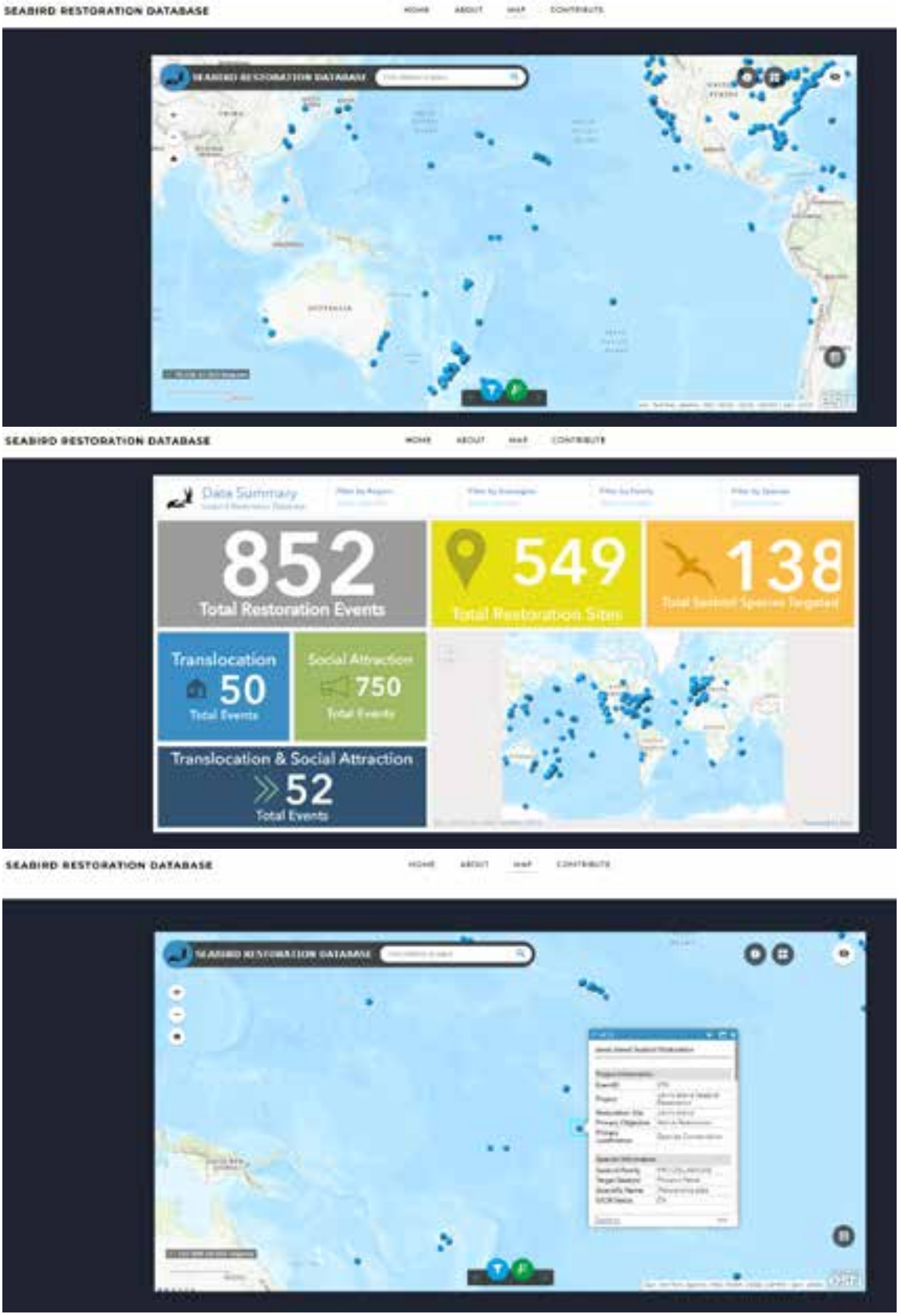


Figure 136-138. Examples from the Seabird Restoration Database showing examples of data for the Central and South Pacific region.

# PART FIVE

## Resources

Restoration team on Tarakoi, Rapa, French Polynesia.
Photo: Tehani Withers, SOP Manu

## 5.1 USING THIS MANUAL

Two versions of the manual are available:

1. The complete manual printed (hard copy) and available through SPREP.
2. An electronic PDF version of the whole manual which can be downloaded from the SPREP website. This version can be used for you to 'go shopping' and build your own manual so that the methods chosen are appropriate to the project or programme you are looking at for your country. Experts from the PSAG can also help you work out which methods to include in your manual.

The electronic manual will be kept up to date to account for changes in technology, new developments in methods, and potentially new case studies. It will be linked closely to the Pacific Seabird Advisory Group (PSAG) (see next Section 5.2), so you can get advice (almost a chat line) as you develop your project or programme.

**https://library.sprep.org/project/term/11108**

## 5.2 PACIFIC SEABIRD ADVISORY GROUP (PSAG)

An expert seabird expert advisory group has been established to help provide advice in developing seabird survey and monitoring projects across Oceania. This is not limited just to researchers but conservation managers, community representatives and others as appropriate. It will allow these groups to reach out to other experts in the wider seabird community to ask questions and explore emerging technology. The PSAG will encourage the transfer of seabird knowledge and expertise between projects through exchange opportunities for conservation workers. Advice will also be sought from the group for checking and verification of data input into the Pacific Seabird Database (see Section 4.2).

Please contact: **sprep@sprep.org**

# 5.3 SEABIRD IDENTIFICATION KEYS

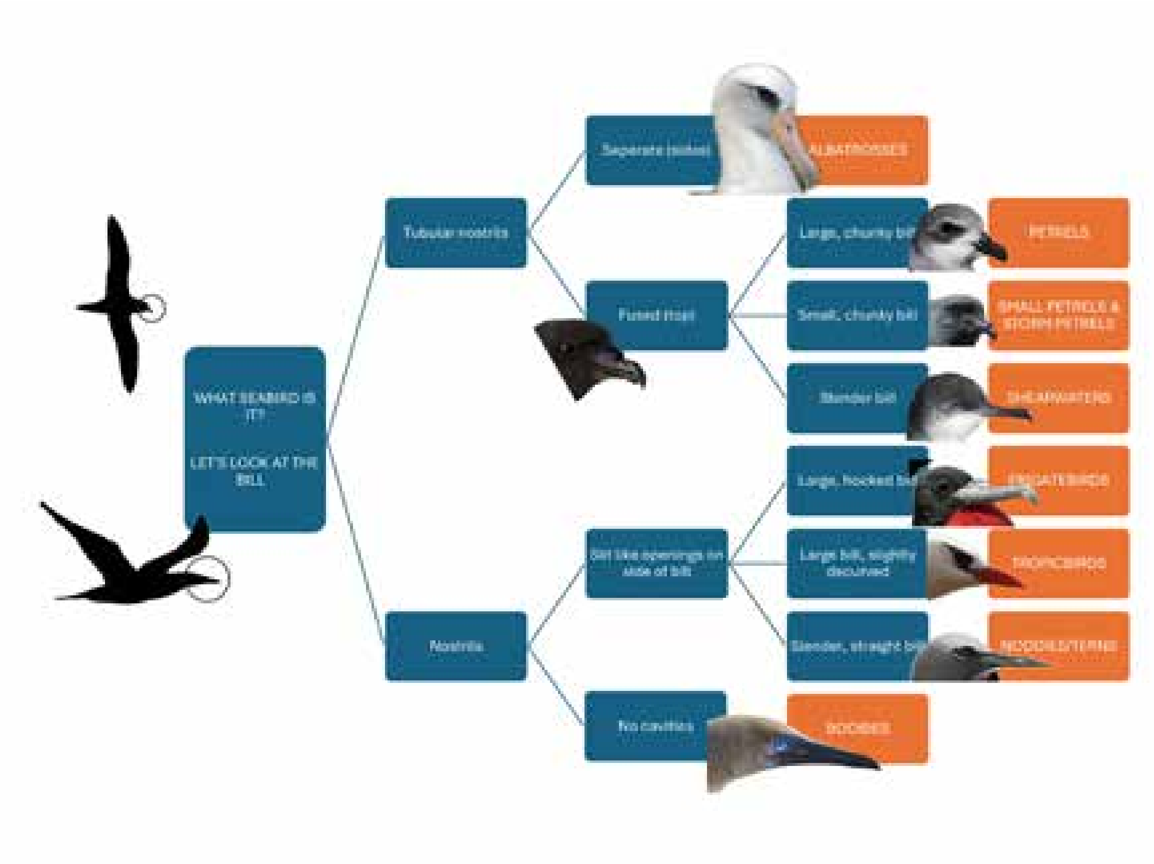


Figure 139. Seabird families identification key using bill shape and type.

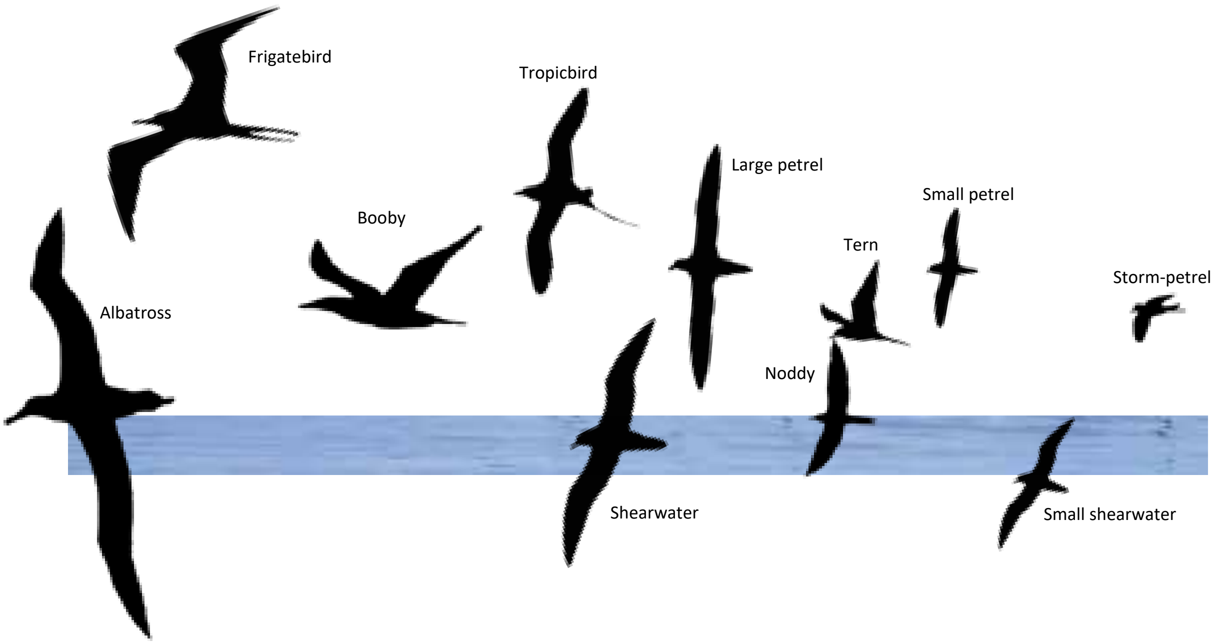


Figure 140. Identification of seabird families by size.

## 5.4 BIRD BANDING SCHEMES

Bird bands (rings) are a permanent marking technique used to identify individual birds. Each metal band carries its own unique prefix and number. Bands allow researchers and conservation managers to study the life cycle (births, deaths, age of breeding), habits such as bird behaviour, breeding activities and what they eat, and also the movements of birds. National bird banding schemes allow for certification for banders and issue banding certificates. They also support the training of banders, manage banding data and supply bands and other equipment to banders.

If your country does not have a national bird banding scheme, it is possible for Pacific projects to request the use of bands issued by recognised national banding schemes (see Section 5.4.1) and utilise an existing banding database.

### 5.4.1 NATIONAL BIRD BANDING SCHEMES

The following are national banding schemes for Pacific rim or territorial countries:

New Zealand National Bird Banding Scheme (NZNBBS), Department of Conservation
https://www.doc.govt.nz/our-work/bird-banding/

Bird Banding Laboratory (BBL), United States Geological Survey
https://www.usgs.gov/labs/bird-banding-laboratory

Australian Bird and Bat Banding Scheme (ABBBS)
https://www.dcceew.gov.au/science-research/bird-bat-banding

France - Museum National D'Histoire Naturelle
https://crbpo.mnhn.fr/

Japan - Yamashina Institute for Ornithology
http://www.yamashina.or.jp/hp/english/banding/birds_rings.html#br07

## 5.5 IMPORTANT RESOURCES

### 5.5.1 Field guides

Harrison, P., Perrow, M.R., Larsson, H. (2021). *Seabirds: The New Identification Guide*. Lynx Edicions, Barcelona, Spain.

Howell, S.N.G & K. Zufelt. (2019). *Oceanic Birds of the World: A Photo Guide*. Princeton University Press, Princeton, United States of America

Howell, S.N.G. (2012). *Petrels, Albatrosses & Storm-Petrels of North America*. Princeton University Press, Princeton, United States of America

Onley, D. & P. Scofield. (2007). *Albatrosses, petrels and shearwaters*. Princeton University Press, Princeton, United States of America

Pratt, H.D., Bruner, P.L., Berret, D.G. (1987). *A Field Guide to the Birds of Hawaii and the Tropical Pacific.* Princeton University Press, Princeton, United States of America.

Raine, A.F. & H.J. Raine (2020). *American Birding Association - A Field Guide to Birds of Hawaii.* Scott & Nix Inc, New York, United States of America.

Van Perlo, B. (2011) *Birds of Hawaii, New Zealand and the Central and West Pacific*. Princeton University Press, Princeton, United States of America.

Watling, D. (2001). *A Guide to the Birds of Fiji & Western Polynesia; including American Samoa, Samoa, Niue, Tokelau, Tonga, Tuvalu and Wallis & Fatuna*. Environmental Consultants (Fiji) Limited, Suva, Fiji.

### 5.5.2 Online field guides and resources

**Birds of the World – Cornell Lab of Ornithology**
https://birdsoftheworld.org/bow/home

Birds of the World is a powerful ornithological research platform that brings together deep, scholarly content from several celebrated works of ornithology with millions of bird observations from eBird and multimedia from the Macaulay Library into a single platform where biologists and birders can explore comprehensive life history information on birds. By subscribing to Birds of the World, you gain access to detailed species accounts, maps, and multimedia; a lot more than is available through free view.

**eBird**
https://ebird.org/

eBird began with a simple idea—that every birdwatcher has unique knowledge and experience. Its goal is to gather this information in the form of checklists of birds, archive it, and freely share it to power new data-driven approaches to science, conservation and education.

eBird data document bird distribution, abundance, habitat use, and trends through checklist data collected within a simple, scientific framework. Birders enter when, where, and how they went birding, and then fill out a checklist of all the birds seen and heard during the outing. eBird's free mobile app allows offline data collection anywhere in the world, and the website provides many ways to explore and summarize your data and other observations from the global eBird community

**New Zealand Birds Online**
https://www.nzbirdsonline.org.nz/

New Zealand Birds Online (NZBO) is a searchable encyclopaedia of New Zealand birds. Although, focussing on birds either breeding, visitors or vagrants to New Zealand, NZBO includes many species from the Pacific. You can find detailed information about all 482 species, including all living, extinct, fossil, vagrant and introduced bird species. The database is searchable by name, conservation status, and geographical distribution. Explore the site to read expert-written texts, listen to sound files of bird calls, and browse more than 13,000 photographs.

**xeno-canto**
https://xeno-canto.org/

xeno-canto is a website dedicated to sharing wildlife sounds from all over the world. Whether you are a research scientist, a birder, or simply curious about a sound that you have heard, you are invited to listen, download, and explore the wildlife sound recordings in the collection. But xeno-canto is more than just a collection of recordings. It is also a collaborative project. You are also invited to share your own recordings; help identify mystery recordings or share your expertise in the forums. There are many recordings of seabirds from the Pacific in the collection.

### 5.5.3 Reports

SPREP (2022). Seabird Action Plan in Pacific Islands Regional Marine Species Programme 2022-2026. The Secretariat of the Pacific Regional Environment Programme, Apia, Samoa.

Becker, P. et al. (2022). White paper - Island ocean connections: exploring land-sea linkages in the context of invasive mammal management. Island Conservation, Scripps Institution of Oceanography, The Nature Conservancy.

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