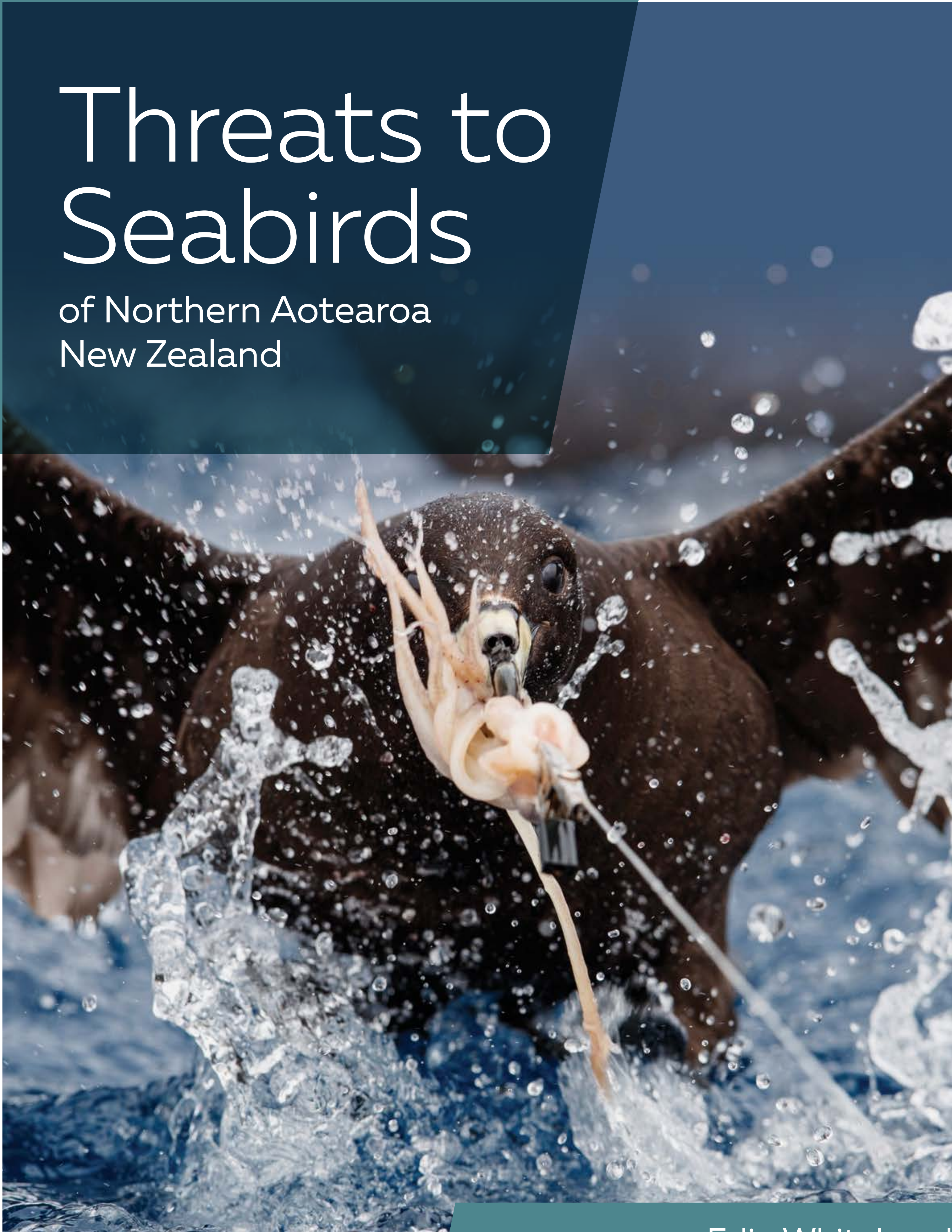
# Threats to Seabirds

## of Northern Aotearoa New Zealand

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NORTHERN NZ SEABIRD TRUST

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**Front cover: Black petrel caught on hookless line during experiments on petrel and shearwater behaviour around fishing vessels.** Photo: Richard Robinson (Depth NZ)/NNZST/DOC

**Endpapers:** Photo: Edin Whitehead

**Facing page: Australasian gannet** Photo: Edin Whitehead

**Following page: Fluttering shearwaters with Te Hauturu-o-Toi/Little Barrier Island in background.** Photo: Edin Whitehead

**Back cover: Northern diving petrel** Photo: Edin Whitehead

# Threats to Seabirds

## of Northern Aotearoa New Zealand

Kei ha ra te pirīnga mo nga
mānu tipi one

Kā tere, kā tere, kā tere…

Where are the sanctuaries
for our birds?

Slipping away, slipping away,
slipping away…

*Saana Waitai*

# Contents

# Foreword

Graeme Taylor, New Zealand Department of Conservation

The long isolation of the Aotearoa New Zealand land mass on the submerged continent of Zealandia created an evolutionary pathway different to all other continental land masses where terrestrial mammals dominated these ecosystems. In the absence of non-flighted mammals, birds became a major driver of the terrestrial ecosystems in New Zealand. While large flightless bird species such as moa influenced plant communities through trampling and grazing, the role of seabirds in mainland terrestrial ecosystems is still poorly recognised and understood. That this special feature of New Zealand's natural history remains unknown to most people is because seabird populations were devastated on the mainland after the arrival of humans and their mammal introductions. Many species survived only on the safe refuges of offshore and outlying islands. Few people realise that in the past seabirds bred across all the mountain ranges and inland hilltops of New Zealand, along all the coastal slopes, on braided riverbeds and on most offshore islands and rock stacks. While these seabirds had to cope with some predation from native rails, raptors, skuas and marine mammals, as well as trampling of the ground by heavy moa, they had coevolved ways to limit the impacts from these native species (e.g. nocturnal activity; nesting under tree bases, logs and rocks; on tussock-clad bluffs and alpine valley heads; on river braids, shell banks and coastal cliff ledges). The mainland breeding colonies of seabirds created a pathway for the transport of vast quantities of marine nutrients from the sea to the highest inland reaches. These nutrients enriched terrestrial ecosystems through a top-dressing of phosphates and nitrogen compounds that fertilised native plants. Seabird burrows provided dark and humid subterranean habitats for a diverse array of endemic invertebrates and reptiles.

While there is good public awareness of our unique and unusual land bird species (kiwi, kākāpō, takahē etc.) very few people appreciate how remarkable is the seabird component of our avifauna. The general public mainly encounter only a small part of our seabird community – gulls, terns, gannets and shags, and occasionally penguins. Yet New Zealand is the world breeding centre for seabirds with more endemic species than all the remaining countries combined and 88 species in total. Those seabird species that still remain on the mainland have to cope with a burden of threats, especially from introduced pests, coastal development, and interactions with people and their pets. For the species that nest in safer locations away from human activity and mammalian predators, these birds still have to contend with fisheries interactions, plastic ingestion, oil spills, and the spectre of climate change with increasing intensity of rainfall events, landslips, coastal erosion, sea level rise, rising summer land and sea temperatures, changes in ocean currents and ocean productivity, and acidification of the seas.

Edin Whitehead has done a remarkable job in collating the wide range of threats affecting New Zealand's seabirds and provides a document of hope in that there are things we can do to address some of these threats. She, and a team of seabird experts working on northern New Zealand seabirds, rightly identify that knowledge gaps in our understanding of the distribution, population sizes and trends of seabird species and populations limits our ability to protect and advocate for these remarkable birds. This document covers the northern part of New Zealand, a biologically rich and special area for seabirds, and sets up a template that could be adopted by groups elsewhere in New Zealand and overseas for protecting and enhancing seabird populations.


**Graeme holding a Chatham petrel.**
Photo: Art Polkanov

# 1. Introduction

**Fluttering shearwater and fairy prions.**
Photo: Edin Whitehead

## 1.1 Seabirds

Seabirds are the most threatened group of birds globally (Rodríguez et al, 2019, Croxall et al., 2012). Aotearoa New Zealand has both the greatest number of resident seabird species in the world (88 of a global total of ~370), and the greatest number of endemic seabird species (37) of any country (Forest & Bird, 2014). In addition, a third of all seabird species are regularly found within our Exclusive Economic Zone (EEZ) during their non-breeding periods. Despite this abundance, and the number of native seabird species surpassing the number of all native land, shore and freshwater birds combined (73), seabirds as a group remain on the fringes of public consciousness in Aotearoa New Zealand.

Here, we define seabirds as those species that spend some part of their lifecycle at sea, feeding in inshore or offshore waters. This group includes petrels, albatrosses, shearwaters, penguins, gannets, boobies, tropicbirds, frigatebirds, shags (or cormorants), skuas, gulls, terns and noddies. Many of these species are truly pelagic, returning to land only to breed, spending the rest of their lives in the marine environment. Their transboundary lifestyles in both marine and terrestrial environments means that, as a group, seabirds are subject to a large array of threats (Gaskin & Rayner, 2013; Provencher et al., 2019). Differences in their ecology and behaviour means that some may be more vulnerble to fishing practices such as long-lining (Anderson et al., 2011) or set-netting (Žydelis, Small, & French, 2013), while others may suffer more from disturbance at colony sites (Pulham & Wilson, 2015), plastic ingestion while foraging (Hutton, Carlile, & Priddel, 2008; Roman et al., 2019) or disorientation by artificial light at night (Montevecchi, 2013).

Top predatory seabirds are often used as indicators, or barometers, for the condition of the marine environment (Cairns, 1987). However, knowing the cause of changes in the productivity of seabird colonies is vital for this strategy to be used effectively, and there are many factors which can influence seabird productivity (Parsons et al., 2008). Understanding the factors that influence a population, including potential threats to specific species and how these may fluctuate over time is important in securing their long-term stability, particularly for at-risk species. Adult survival of long-lived species is crucial to population stability, and threats to this life stage of many seabirds are of particular concern (Croxall et al., 1990). As many seabirds are slow to mature and breed, the long-term population impacts of successive poor breeding seasons can only emerge years after the event (Jenouvrier et al., 2018).

# Seabird biology

*from Gaskin & Rayner 2013*

Seabirds have biological characteristics that differ dramatically to 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 (Schreiber & Burger, 2002). The life-history characteristics of seabirds are often referred to as 'extreme', including long lifespans (20-60 years), delayed maturity (up to 15 years), small clutch sizes (often a single egg with no replacement), and long chick development periods (Warham, 1990). By comparison, many terrestrial birds, such as passerines, have shorter lives, lay larger clutches of eggs and have chicks that mature more rapidly.

The feeding habits of seabirds vary. Some species regularly feed over land (gulls) or in freshwater (cormorants), others feed in tidal harbours and inshore waters (gulls, terns, cormorants, gannets), and the rest feed on the continental shelf and beyond in deep oceanic waters (albatrosses, petrels, shearwaters and gannets). However, all seabirds spend some part of their life cycle on the open sea, an environment to which they are supremely adapted. Flight for many species (i.e. albatrosses, petrels and shearwaters) is extremely efficient, with momentum gained via dynamic soaring, where birds take advantage of reduced wind speeds near the ocean's surface to gain speed to be used on the next ascent (Pennycuick, 1982). Other species, such as penguins, cormorants, diving petrels and shearwaters, fly underwater using their wings.

Seabirds can find their food over large distances. Excellent vision keeps them alert to the activities of other seabirds, fishes and cetaceans (Au & Pitman, 1986), and a strong sense of smell is enhanced by large olfactory bulbs (Hutchinson & Wenzel, 1980). Seabirds have water resistant feathering (from preen gland oils), webbed feet for swimming and bills with hooks, points, serrations and/or filters. These modified bills enable seabirds to exploit prey such as fish, crustaceans (krill) often in association with fish schools, cephalopods (squid), phytoplankton and zooplankton from the surface to depths of 60 metres or more (Brooke, 2004; Rayner et al., 2008, 2011; Taylor, 2008). Unlike terrestrial species, the gut of some seabirds is modified to allow birds to store large meals that are converted to a low weight, rich oil perfect for transporting large amounts of energy over long distances during breeding and migration.

Many seabirds are colonial, with a large number of species aggregating in loose or dense colonies, where they find protection from predators through sheer numbers (Warham, 1996).

**Fairy prion feeding.**
Photo: Edin Whitehead

**White-fronted terns, Tawharanui Open Sanctuary.** Photo: Chris Gaskin

**Pair of Buller's shearwaters at burrow entrance, Poor Knights Islands.** Photo: Edin Whitehead

Species nest either on the surface, or in vegetation (terns, gulls, gannets, cormorants, albatrosses), in rock crevices, or underground in excavated burrows (petrels, shearwaters) (Warham, 1990). Birds return to their colony at the beginning of the breeding season to clean and defend the nesting site and re-establish pair bonds. Albatrosses, petrels and shearwaters have particularly long incubation and chick-rearing phases. For most species, once the chick is large enough to thermoregulate independently it is left unattended whilst its parents forage at sea (Warham 1990; Brooke 2004).

Long-term monitoring studies are important in untangling the relationships between seabirds and their ecosystems, and the influence of environmental and human factors upon them.

Historically, seabirds have played a critical role as ecosystem engineers by providing marine-derived nutrients to terrestrial ecosystems and physically altering the habitats they breed in by nest burrowing (Smith, Mulder, & Ellis, 2011). The loss of these species, such as from the introduction of predatory mammals, has resulted in depauperate ecosystems lacking in associated invertebrate fauna and plant species (Bellingham et al., 2010; Croll, et al., 2005; Maron et al., 2006). By eradicating mammalian predators from islands, the benefits of seabird recolonization have been well demonstrated (Jones et al., 2010, Jones et al., 2016), both in the terrestrial and surrounding nearshore marine systems (Bellingham et al., 2010; Roberts et al., 2007; Brooke et al., 2017). Nearshore reef and seaweed ecosystems benefit from nutrient runoff, while on land the plants, invertebrate, reptile and terrestrial bird faunas benefit from marine-derived nutrients (Rankin & Jones, 2017).

Seabirds are thus important both for their own sake, and also the crucial role they play in the foundation of their ecosystems. We require a greater understanding of their lives and the threats that they face to make decisions regarding their conservation, as while there is ample global literature on these topics, there is very little at the local scale for the Northern New Zealand region.

## 1.2 Region covered

The Northern New Zealand region this report covers comprises coastal land and marine areas from East Cape to the Manawatāwhi (Three Kings Islands) and the Waikato west coast (Map 1). This area includes the Hauraki Gulf (Map 1), which hosts a diversity of seabird life and has been recognized as an international 'Important Bird Area' for the diversity and endemism of its resident seabird fauna (Forest & Bird, 2014; Gaskin & Rayner, 2013). Twenty-eight seabird species breed within the Northern New Zealand region (Table 1). Of these, five species breed nowhere else in the world (black petrel (*Procellaria parkinsoni*), Pycroft's petrel (*Pterodroma pycrofti*), Buller's shearwater (*Ardenna (Puffinus) bulleri*), New Zealand storm petrel (*Fregetta maoriana*) and New Zealand fairy tern (*Sternula nereis davisae*)). The region also includes significant populations of a number of other species (grey-faced petrel (*Pterodroma gouldi*), Cook's petrel (*Pterodorma cookii*), fluttering shearwater (*Puffinus gavia*), Australasian gannet (*Morus serrator)* and flesh-footed shearwater (*Ardenna (Puffinus) carneipes*)) (Table 2). At the New Zealand scale, seabird diversity of Northern New Zealand, particularly the wider Hauraki Gulf region, ranks highly compared to similar sites of international seabird importance in terms of species diversity and endemicity (e.g. Kermadec Islands, Chatham Islands, Snares Islands) (Gaskin & Rayner, 2013).

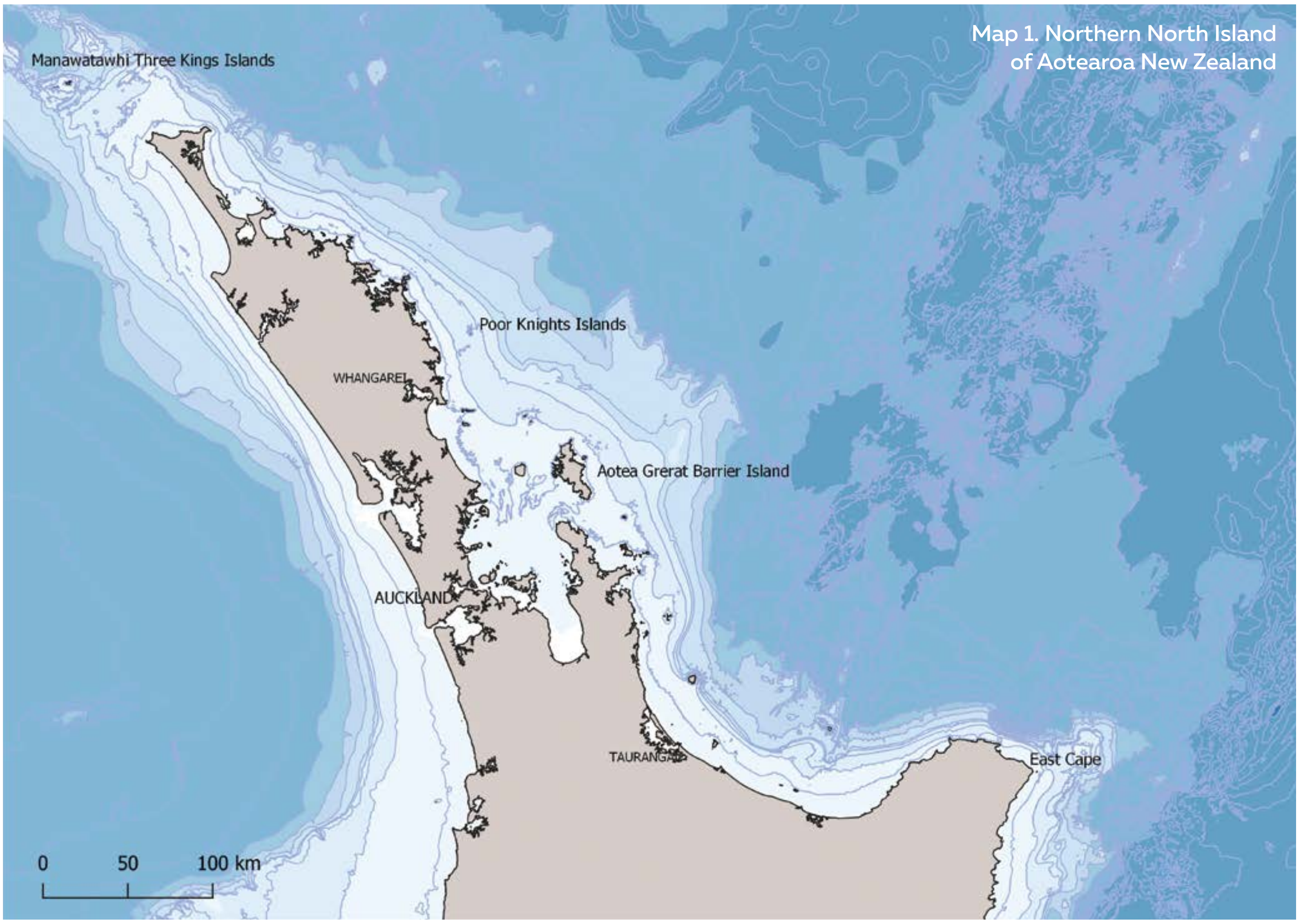
Despite the proximity of these seabird colonies to New Zealand's largest city, many species in Northern New Zealand remain poorly studied. The New Zealand storm petrel was thought extinct until 2003. Its sole breeding site on Te Hauturu-o-Toi (Little Barrier Island) was then only discovered in 2013 (Rayner et al., 2015). For some species, such as Buller's and little shear-waters, we lack reliable population estimates despite their colonies being within easy access from the mainland. It is important we gain such estimates so that we can assess population vulnerability to current and future threats. In doing so, the establishment of long-term monitoring studies of these seabird species will provide an ongoing measure of how they fare over time, help to assess where urgent conservation efforts are required, and may allow certain species to be used as indicator species for the health of the marine environment of the region.

**NZ storm petrel on forest floor, Hauturu.** Photo: Edin Whitehead

**Black petrel.** Photo: Edin Whitehead

**Pycroft's petrel.** Photo: Edin Whitehead

**Cook's petrel.** Photo: Edin Whitehead


Map 1. Northern North Island
of Aotearoa New Zealand
Manawatawhi Three Kings Islands
Poor Knights Islands
WHANGAREI
Aotea Grerat Barrier Island
AUCKLAND
TAURANGA
East Cape
0
50
100 km

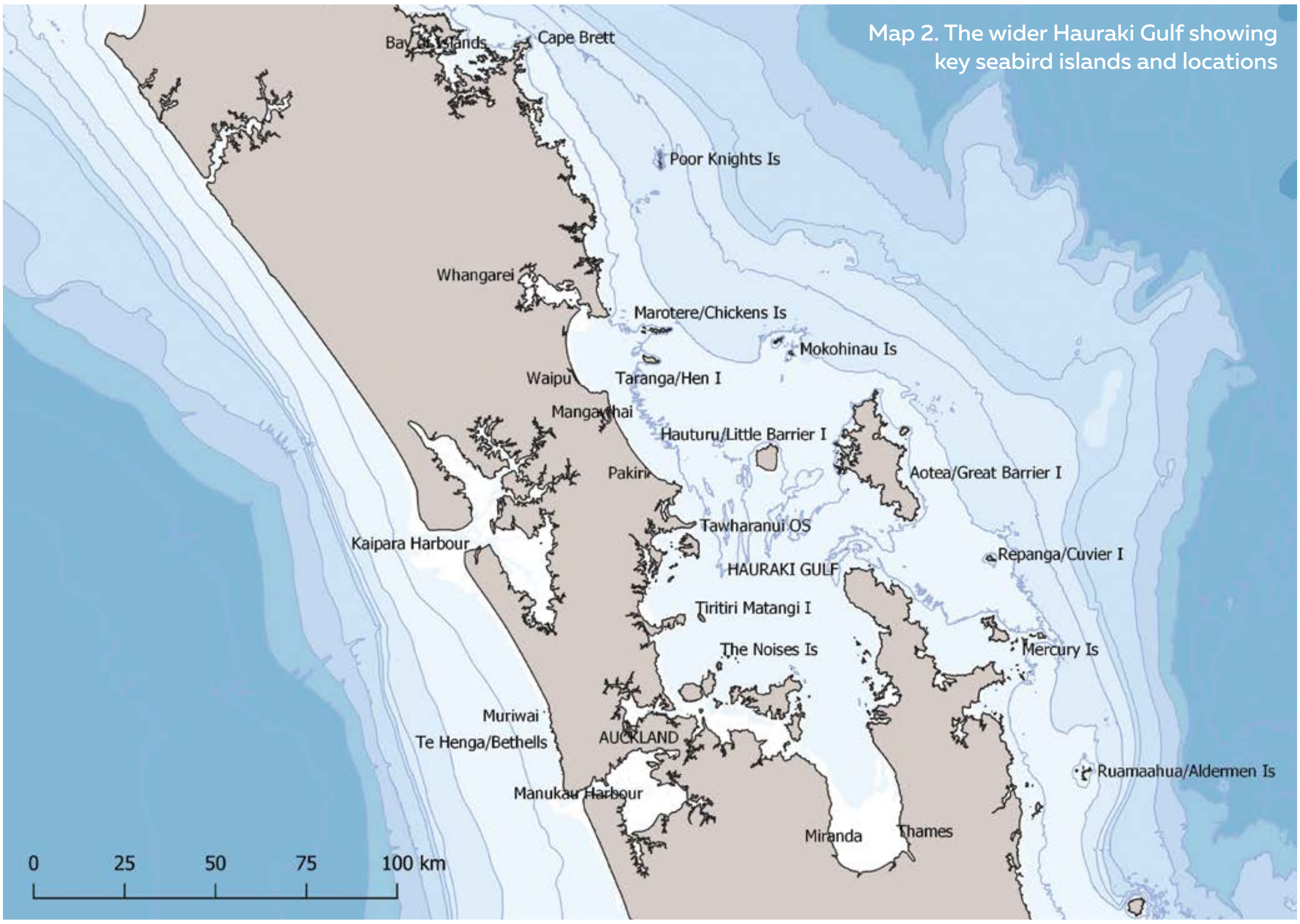

Map 2. The wider Hauraki Gulf showing
key seabird islands and locations
Bay of Islands
Cape Brett
Poor Knights Is
Whangarei
Marotere/Chickens Is
Mokohinau Is
Waipu
Taranga/Hen I
Mangawhai
Hauturu/Little Barrier I
Pakiri
Aotea/Great Barrier I
Tawharanui OS
Kaipara Harbour
Repanga/Cuvier I
HAURAKI GULF
Tiritiri Matangi I
The Noises Is
Mercury Is
Muriwai
Te Henga/Bethells
AUCKLAND
Ruamaahua/Aldermen Is
Manukau Harbour
Miranda
Thames
0
25
50
75
100 km

Table 1: The seabirds breeding within the Northern New Zealand region.

| Species name (English/Māori) | Taxonomic name | Threat Status (**DOC**/IUCN Redlist) | Endemism Status |
|---|---|---|---|
| Northern little (blue) penguin<br>kororā | *Eudyptula minor iredalei* | **Declining**<br>Least Concern | NZ Endemic Subspecies |
| Northern Buller's (Pacific) albatross<br>toroa | *Thalassarche bulleri platei* | **Naturally Uncommon**<br>Near Threatened | NZ Endemic |
| Black petrel<br>takoketai | *Procellaria parkinsoni* | **Nationally Vulnerable**<br>Vulnerable | Region Endemic |
| Cook's petrel<br>tītī | *Pterodroma cookii* | **Relict**<br>Vulnerable | NZ Endemic |
| Pycroft's petrel<br>tītī | *Pterodroma pycrofti* | **Recovering**<br>Vulnerable | Region Endemic |
| Black-winged petrel<br>tītī | *Pterodroma nigripennis* | **Not Threatened**<br>Least Concern | NZ Native |
| Grey-faced petrel<br>ōi | *Pterodroma gouldi* | **Not Threatened**<br>Least Concern | NZ Endemic |
| Buller's shearwater<br>rako | *Ardenna (Puffinus) bulleri* | **Naturally Uncommon**<br>Vulnerable | Region Endemic |
| Flesh-footed shearwater<br>toanui | *Ardenna (Puffinus) carneipes* | **Nationally Vulnerable**<br>Near Threatened | NZ Native |
| Fluttering shearwater<br>pakahā | *Puffinus gavia* | **Relict**<br>Least Concern | NZ Endemic |
| Little shearwater | *Puffinus assimilis haurakiensis* | **Recovering**<br>Least Concern | NZ Endemic (Endemic Subspecies) |
| Sooty shearwater<br>tītī | *Adrenna (Puffinus) grisea* | **Declining**<br>Near Threatened | NZ Native |
| Fairy prion<br>tītī wainui | *Pachyptila turtur* | **Relict**<br>Least Concern | NZ Native |
| Northern common diving petrel<br>kuaka | *Pelecanoides urinatrix urinatrix* | **Relict**<br>Least Concern | NZ Native |

| Species name (English/Māori) | Taxonomic name | Threat Status (DOC/IUCN Redlist) | Endemism Status |
|---|---|---|---|
| White-faced storm petrel takahikare | *Pelagodroma marina maoriana* | **Relict** Least Concern | NZ Endemic Subspecies |
| New Zealand storm petrel | *Fregetta maoriana* | **Nationally Vulnerable** Critically Endangered | Region Endemic |
| Australasian gannet tākapu | *Morus serrator* | **Not Threatened** Least Concern | NZ Native |
| Pied shag kāruhiruhi | *Phalacrocorax varius varius* | **Recovering** Least Concern | NZ Endemic Subspecies |
| Little shag kawau paka | *Phalacrocorax melanoleucos brevirostris* | **Not Threatened** Least Concern | NZ Native |
| Black shag kawau | *Phalacrocorax carbo novaehollandiae* | **Naturally Uncommon** Least Concern | NZ Native |
| Little black shag kawau tūī | *Phalacrocorax sulcirostris* | **Naturally Uncommon** Least Concern | NZ Native |
| Spotted shag kawau tikitiki | *Stictocarbo punctatus punctatus* | **Not Threatened** Least Concern | NZ Endemic |
| Southern black-backed gull karoro | *Larus dominicanus dominicanus* | **Not Threatened** Least Concern | NZ Native |
| Red-billed gull tarapunga | *Chroicocephalus (Larus) scopulinus* | **Declining** Least Concern | NZ Endemic |
| Black-billed gull tarapūka | *Chroicocephalus (Larus) bulleri* | **Nationally Critical** Endangered | NZ Endemic |
| White-fronted tern tara | *Sterna striata* | **Declining** Least Concern | NZ Native |
| Caspian tern taranui | *Hydroprogne caspia* | **Nationally Vulnerable** Least Concern | NZ Native |
| New Zealand fairy tern tara iti | *Sterna nereis davisae* | **Nationally Critical** Vulnerable | NZ and Region Endemic Sub-species |

# 1.3 This Report

## Aims

This report aims to assess current and emerging threats to seabirds in Northern New Zealand, particularly the wider Hauraki Gulf region, and to identify knowledge gaps. In doing so, both research and conservation action can be prioritized to best mitigate threats to seabirds in the region. Consequently, the report aims to answer three basic questions:

1. What are current threats to seabirds in Northern New Zealand?
2. What are the knowledge gaps regarding seabird species in Northern New Zealand?
3. What are the knowledge gaps regarding threats to seabirds in Northern New Zealand?

## Threat categories

Threats are grouped under the following categories:

1. Invasive Alien Species (includes biosecurity)
2. Fisheries
3. Pollution
4. Disease
5. Climate Change
6. Direct Human Impacts

Although threats have been separated into categories for ease of reference, it is important to remember that none of these threats work in isolation. Species may face multiple threats, and the combination of multiple threats to a population can be vastly more damaging than any one would alone (Sydeman, Thompson, & Kitaysky, 2012).

## Individual threat entries

Each entry describing individual threats will be presented as follows:

1. General information from literature
2. Examples within Northern New Zealand, where possible
3. Key measures to reduce threat

# 2. Threats
## to Seabirds in Northern New Zealand

Marsden Point Oil Refinery from Taranga/Hen Island, fluttering shearwaters in flight.
Photo: Edin Whitehead

## 2.1 Invasive Alien Species and Island Biosecurity

### 2.1.1 Mammalian predators

Seabirds are at their most vulnerable on land. Most are not well adapted to moving in a terrestrial environment, placing them at risk of predation, a threat in a form that was not common prior to the introduction of mammalian species. Given their low reproductive rates, ground-nesting tendencies and long chick-rearing periods, seabirds are poorly adapted to withstand introduced predators, which represent the most significant onshore threat to many seabird populations worldwide (Mulder et al., 2011). The presence of even a single predator can be catastrophic for seabird populations – a single stoat incursion on tidal islands at Te Henga (Bethells Beach) resulted in the death of around 70 Northern common diving petrels (G. Taylor, pers. comm. 2018). In the Northern New Zealand region, introduced species that have an impact on seabird populations include dogs (*Canis familiaris*), cats (*Felis cattus*), rats (*Rattus spp.*), pigs (*Sus scrofa*), mustelids (*Mustela spp.*) and hedgehogs (*Erinaceus europaeus*).

Cats were introduced to many Hauraki Gulf islands, often in association with lighthouse settlements, and remain present on the mainland and inhabited islands in both domestic and feral populations. Cats have contributed to the decline or loss of seabird populations through the predation of both adults and chicks (e.g., Cook's petrel and black petrel population declines) on islands such as Te Hauturu-o-Toi (Little Barrier Island) (Imber, 1987) and Aotea (Great Barrier Island) (Bell & Sim, 2005).

Norway rats (*Rattus norvegicus*), ship rats, (*R. rattus*) and Pacific rats (kiore) (*R. exulans*) have reached the region's mainland and offshore islands. Given its large size (150 – 500 g), the Norway rat is considered most damaging to seabird populations, preying upon adults, eggs and chicks (Atkinson, 1985) of species such as the white-faced storm petrel on Ruapuke (Maria Island, Noises group) (Moors, 1985; Towns & Broome, 2003). Ship rats (50 – 250 g) can kill the adults of smaller seabirds and prey upon their eggs and chicks (Atkinson, 1985). Ship rat presence on many Gulf islands is associated with low numbers of seabirds and other fauna and flora (Towns, Atkinson, & Daugherty, 2006), and has been implicated in seabird declines and local extinction (G. Taylor, pers comm., 2019). More-over, the role of ship rats as a seabird predator is well established: a classic New Zealand example being the ecological catastrophe that followed their invasion to Taukihepa (Big South Cape Island) in 1962 (Bell et al., 2016). This invasion was followed by severe declines in seabird populations, the local extinction of six forest birds, and total extinction of two endemic birds and a bat species (Bell et al., 2016; Miskelly, 2012; Towns et al., 2006).

Fortunately, as a result of eradication programs or historic absence, many islands in northern New Zealand are free from invasive mammalian predators (Russell et al., 2015). As such, seabird populations at these sites are recovering and some are thriving (Borrelle et al., 2016; Brooke et al., 2018; Ismar et al., 2014), which promotes whole-ecosystem recovery (Jones, 2010). However, it is imperative that these islands remain free of predators and other pests, as predator incursions can have rapid and significantly detrimental effects on seabird populations (Hilton & Cuthbert, 2010). Maintaining strict biosecurity measures, efficient surveillance strategies and immediate incursion response plans are crucial in safeguarding these populations (Bassett et al., 2016).

Larger inhabited islands in the region are occupied by cats and rats which are impacting on seabird breeding success (Bassett et al., 2016). Aotea (Great Barrier Island) has the world's largest population of black petrels, one of only two remaining breeding sites for this formerly widespread species. Both cat and rat predation impact the breeding success of black petrels (Bell et al., 2016). With an active breeding population of only ~2,700 pairs and a heavy impact of fisheries on adult birds (Richard & Abraham, 2013), reducing egg and chick mortality is important in safeguarding this relict population. Predator eradication on Aotea would also benefit terrestrial flora and fauna.

Eradicating introduced species from inhabited islands involves more complex social issues than uninhabited islands, and the full support and involvement of residents is crucial to successful operations (Glen et al., 2013). Island communities within the Hauraki Gulf vary in their attitudes towards environmental issues, making social research a key component of eradication planning (Russell et al., 2018). Opposition to the use of poisons (McEntee & Johnson, 2015) from hunters who value pest species such as pigs, and the complication of some predators considered as both pests and pets (cats) must be negotiated (Bassett et al., 2016). However, Rakino Island is an example of an inhabited island in the inner Hauraki Gulf where predators were eradicated with the support of residents (Bassett et al., 2016), and the island is rat-free and now home to an establishing colony of grey-faced petrels (J. McKenzie, pers. comm., 2018).

Mainland seabird populations are under threat from introduced mammals, both pest and pet species. Urban development (see Coastal Development section) around coastal areas brings humans and seabirds into contact, and injury and predation by domestic dogs is a common concern for penguin populations throughout New Zealand (Hocken, 2000, 2005). Surface nesting New Zealand fairy terns, the most endangered bird sub-species in New Zealand, are killed by stoats, cats, dogs and hedgehogs (Pulham & Wilson, 2015). Constant trapping efforts during the breeding season are necessary for these birds to breed successfully at all. Mainland colonies of burrow-nesting grey-faced petrels on Auckland's west coast are at risk

**Cat-killed black petrel.**
Photo: John Kendrick

**Pig damage to petrel burrows.**
Photo: Edin Whitehead

from predator species, and may also encounter roaming pets as many of these colonies are near to residential areas (Landers, 2017). Mainland islands (areas of land, often peninsulas, protected by predator-proof fences), such as Tāwharanui Open Sanctuary, highlight the potential for seabirds to repopulate mainland sites if mammalian predators are eradicated or controlled.

Maintaining areas of low mammalian predator density on the mainland is beneficial not only for the resident seabirds, but also reduces source populations of invading mammals for tidal and nearshore islands, thereby reducing the risk of incursion. Nearshore islands such as Te Hāwere-a-maki (Goat Island) are difficult to keep predator-free post-eradication (MacKay & Russell, 2005; Russell et al., 2009), as the swimming abilities of rats and mustelids allow for continuous re-invasion. The tidal islands of Ihumoana and Kauwahaia are constantly at risk of reinvasion, and the presence of rats and mustelids there has contributed to poor breeding success of a number of seabird species (G Taylor, pers. comm., 2018).

Increasing awareness of the impacts of introduced predators (and uncontrolled pets) on native fauna and the nationwide push for "Predator Free 2050" may help to reduce the impacts of these predators on seabirds in coastal areas, as community efforts increase the area of effective predator control throughout the region. Communities taking ownership to protect 'their' ecosystems and species by increasing local trapping efforts (and controlling pets) must be sustained to have long-term benefits and help populations to recover. Establishing safe mainland spaces for seabirds requires succession planning for the management of these areas, as they need to be protected in perpetuity.

**Grey-faced petrel and northern common diving petrels killed by a stoat, Te Henga/ Bethells.** Photo: Graeme Taylor.

## 2.1.2 Avian predation

New Zealand native bird species such as the southern black-backed gull (*Larus dominicanus*), Australasian harrier (*Circus approximans*), pukeko (*Porphyrio porphyrio*) and morepork (*Ninox novaeseelandiae*) (Anderson, 1992) will prey upon the nests, eggs and chicks and/or adult seabirds, including burrow nesting petrels, shearwaters, diving petrels, storm petrels, gulls and terns. While historically this was a normal threat to seabirds, in the case of conserving relict and re-establishing populations it is an issue that needs to be managed. Many of these predatory species have benefited from human land-use change, resulting in their current populations being much larger, and their potential impacts on seabirds much greater than they would have been in pre-human systems (Seaton, Galbraith, & Hyde, 2013). Awareness of the presence of such species is important when designing seabird translocations or protection programmes. For example, southern black-backed gulls have been culled when nesting too close to the breeding sites of the critically endangered New Zealand fairy tern because of the danger to nesting terns and their eggs and chicks (Pulham & Wilson, 2015).

A native avian seabird predator introduced to the Gulf region is weka (*Galliralis australis*). Although a threatened species itself, the danger of weka to seabird populations is well documented (Harper, 2006). Following their introduction to New Zealand seabird islands, such as Whenua Hou (Codfish Island), seabird populations were severely depleted or exterminated (Imber, West, & Cooper, 2003). In the Hauraki Gulf region, this species has been introduced to Rakitu (Arid Island), Kawau, Pakatoa, and Rotoroa Islands where it may have impacted seabird populations. Post rat-eradication on Rakitu, there is potential for the island to be recolonised by seabirds (Borrelle et al., 2016), but only if the threat of weka is managed.

**Pukeko with black-winged petrel, Raoul Island.** Photo: DOC

Weka entering a petrel burrow.
Photo: Chatham Islands Taiko Trust

## 2.1.3 Weeds

Invasive plant species can be detrimental to seabird colonies, in some cases. For example, the sharp spines on vegetation such as boxthorn, (*Lycium ferocissimum*) can spear petrels flying to and from their burrows on Ruapuke (Maria Island, Noises Group) (R. Neureuter pers. comm. 2017). Kikuyu grass (*Pennisetum clandestinum*) in the Te Henga (Bethells Beach) colonies has been found to smother nesting areas, and adult petrels have died after getting their wings tangled in fibrous growth (G. Taylor pers. comm. 2018). Alternatively, on Pokohinu (Burgess Island Mokohinau Islands) buffalo grass (*Stenotaphrum secundatum*) can support several species of burrowing petrels (all authors, pers. obs). Therefore, threat assessment for weed species needs to be on a case by case basis, as some introduced plants may also provide habitat for seabirds.

Transfer of weeds from site to site, a major concern for the integrity of restoring or maintaining native habitats, is largely by humans, wind, and land birds (particularly those that consume fruit and seeds) between islands, or from the mainland to islands. While gulls, terns and shags can have multiple roost sites, burrowing seabirds generally do not move between islands. They feed at sea, breed on land, and return to the same breeding sites year after year (Warham, 1990). Exceptions may be young prospecting birds, which may visit other colonies before settling back with their natal colony (Warham, 1990), or seeds mistaken for prey items and picked up at sea. For example, Tennyson (1995) found kowhai (*Sophora* sp.) seeds in the guts of white-faced storm petrels (*Pelagodroma marina*) on the Chatham Islands. Brush wattle is a weed found on some islands, e.g. Karewa (Bay of Plenty) and Muriwhenua (Marotere Chickens Islands). Tennyson (1995) postulated that floating brush wattle seeds may be ingested and carried to islands by one or more of the petrel species present.

## 2.1.4 Island Biosecurity

The major components of island biosecurity are prevention, detection and response to incursions. Since islands differ in their attributes, such as topography and forest cover, and individual predator species differ in their behaviours, multiple methods need to be used to detect and prevent the invasion of islands, including poisons, traps, passive detection devices and trained dogs. Detecting incursions early is crucial to managing them, as response operations are costly and the potential for damage to sensitive populations by a single individual can be catastrophic, especially in the case of mustelids and cats.

An example of the response required if a rat or rats are detected ashore is as follows: in January 2009, rat prints were recorded in tracking cards set for routine checks on neighbouring rat-free Lady Alice and Whatupuke Islands (Marotere

**Ship (black) rat killed by a Goodnature A24 trap, Hawere/ Goat Island.** Photo: Edin Whitehead

**Stoat killed in DOC 200 trap.** Photo: Edin Whitehead

**Dead ship rat showing feet, and tracking tunnel card showing rat footprints.** Photo: Jamie MacKay

Chickens Islands). One ship rat was subsequently caught in a live trap on Whatupuke Island and another (dead) in a snap trap on Lady Alice Island. Total monitoring response to the incursion involved 26,395 tracking nights and 12,086 trap nights on Lady Alice Island plus 23,506 tracking nights and 16,751 trap nights on Whatupuke Island. The cost of the operation was approximately $100,000 (K. Hawkins, pers. comm. 2018).

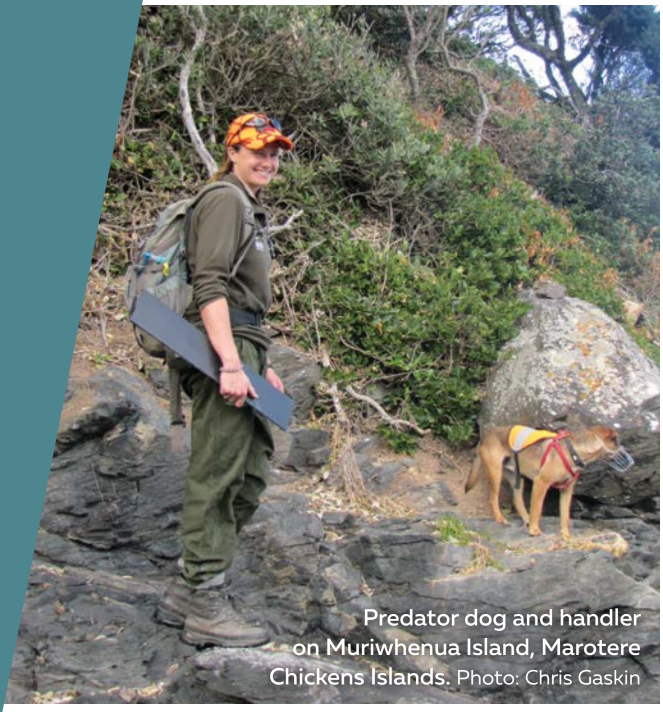
Developing ways to prevent rats and other mammalian predators invading an island in the first place is vitally important given the costs of a response and the potential, in some cases, to undertake the entire eradication process over again. As all vessels are a potential vector for rat invasions, biosecurity measures (permanent predator control devices) should be undertaken on-board all vessels approaching predator-free islands to minimise the risk of transporting mammalian predators. If there are no effective biosecurity procedures to prevent reinvasions or new arrivals undertaken, the investment in the eradication or control of problem species can be wasted.

Currently, only commercial charter boats moving people and cargo to islands in the wider Hauraki Gulf region are required to be checked and have biosecurity measures in place. The benefits of these good conservation measures can be undermined by commercial fishing vessels and the many recreational vessels that anchor overnight close to predator-free island sanctuaries having no such requirements. For example, rats have been observed swimming to anchored vessels close to Aotea (Great Barrier Island), or boarding vessels while tied to jetties at Port Fitzroy and Kaikoura Island (J. Ross, pers. comm. 2018). If any of these vessels made one of the predator-free islands their next port of call, the hitchhiking rats could swim ashore.

Rats are found at most marina, wharf, jetty and slipway areas. Extra measures, such as maintaining traps and poison stations, should be considered around wharves and marinas to minimise the risk of rats embarking, disembarking, and moving between vessels. The approximate cost per annum for boat owners to maintain a rat-free vessel would be: $40 (small boat, one bait station), $55 (medium cruiser, two bait stations) and $140 (larger vessel requiring three). By way of comparison, the cost of initially eradicating pests from Rangitoto and Motutapu islands in 2009 (a single operation) was $4.2 million (or $3.5 million if indirect costs are excluded).

## Key measures to reduce threat

1. Maintaining biosecurity for predator-free island and mainland sites
2. A predator eradication programme for Aotea (Great Barrier Island)
3. Develop an integrated early detection technology system for the region's predator-free offshore islands
4. Predator-free marinas and Predator-free boats – commercial and recreational.
5. Identify sites where weed species are impacting seabird colonies and initiate control/eradication programmes



Predator dog and handler on Muriwhenua Island, Marotere Chickens Islands. Photo: Chris Gaskin

# 2.2 Fisheries

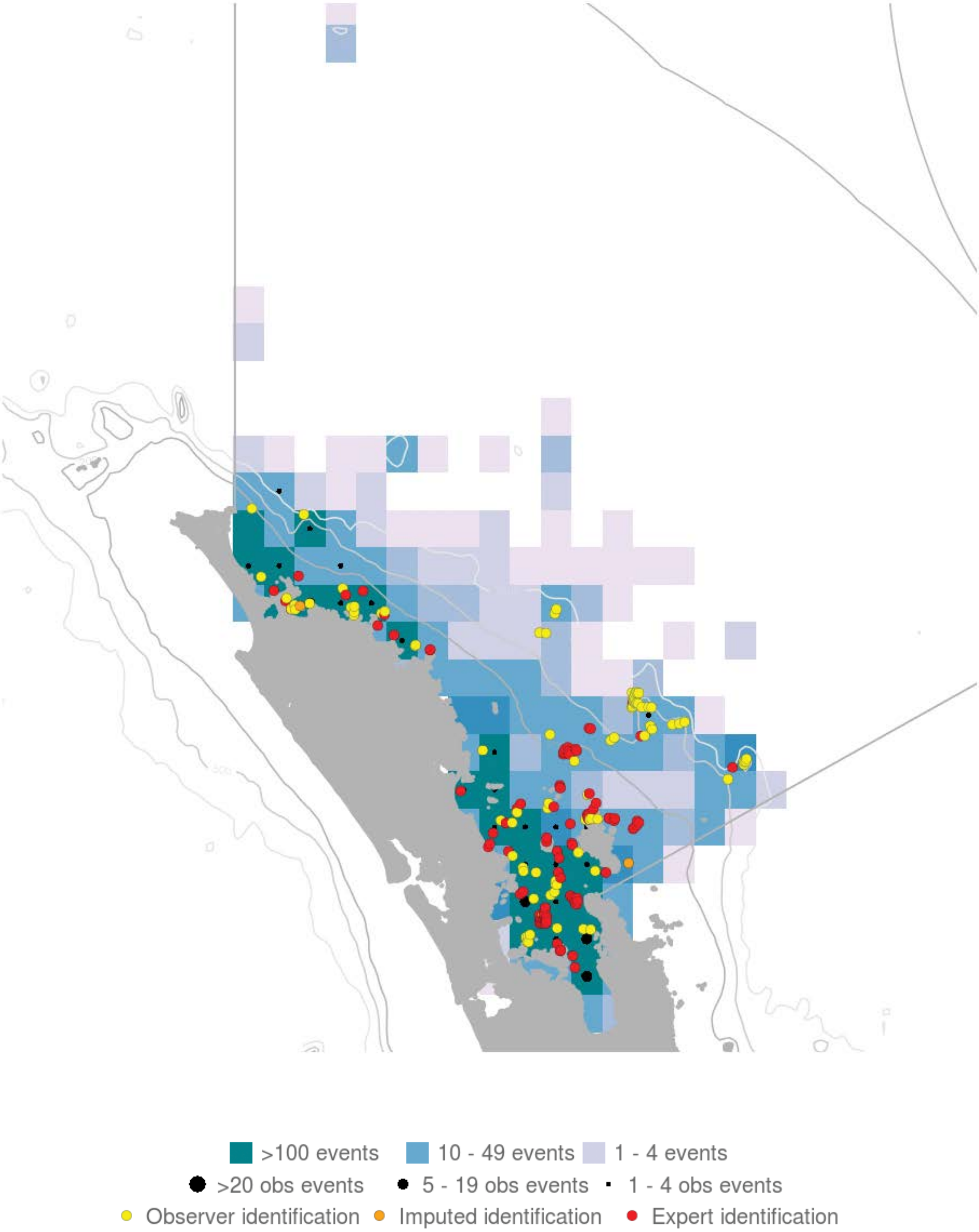
## 2.2.1 Commercial Fisheries

Globally, commercial fisheries have had significant impacts on seabird populations (Grémillet et al., 2018). Long-line (Anderson et al., 2011), gillnet (or setnet) (Uhlmann, Fletcher, & Moller, 2005; Žydelis et al., 2013) and trawl fisheries (Croxall, 2008) have been notorious for pelagic seabird by-catch and exploiting fish stocks. Seabirds are opportunistic foragers, and are often drawn to discards and offal from working fishing vessels (Sullivan, Reid, & Bugoni, 2006; Watkins, Petersen, & Ryan, 2008), and will also attempt to dive after baits, hooking themselves or becoming entangled in the line (Gales, Brothers, & Reid, 1998). Hooked birds are dragged down and drown as the line sinks. Birds can also be hooked during the haul, when attempting to take uneaten bait off hooks. Seabirds may also become entangled in the net as it is being hauled in, or collide with net cables in trawl fisheries (Watkins et al., 2008). Diving species are caught in set or drifting gillnets and drown (Žydelis et al., 2013). By-catch of seabird species, particularly wide-ranging pelagic foragers such as albatrosses and large burrowing petrels has been well-documented.

Elevated adult mortality accelerates declines in seabird populations, because adult survivorship year to year is normally high (Croxall et al., 1990). This is because many seabirds have prolonged juvenile periods and many only begin to breed after up to fifteen years at sea, and tube-nosed seabirds in particular are at-risk (Warham, 1990). During breeding seasons, the death of a single adult bird from a pair will also result in the death of their dependent chick, which cannot be adequately provisioned by a lone parent. For some species it can take many years for birds to select a new mate before breeding can recommence.

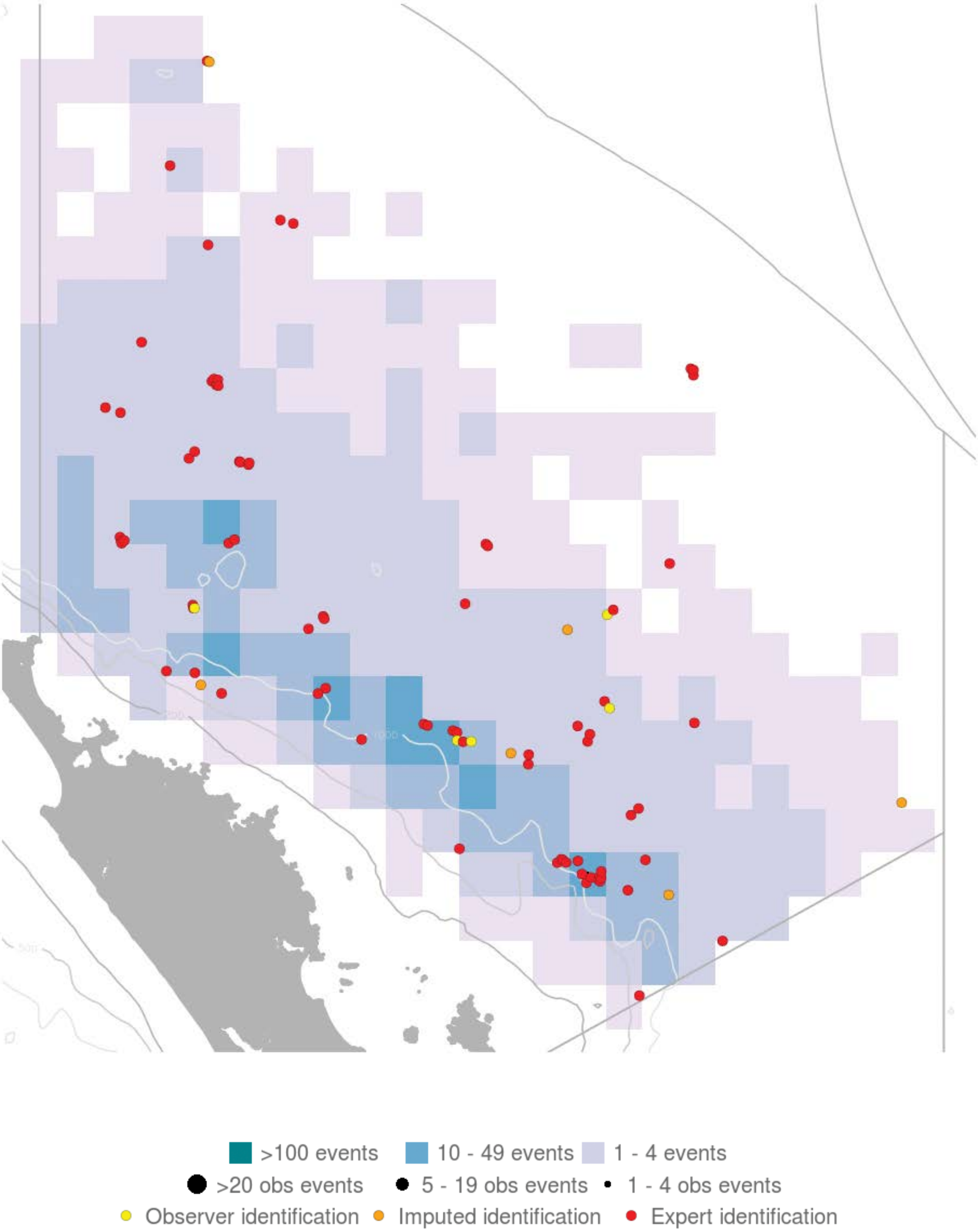
Seabird by-catch can have impacts on demographics beyond simple mortalities (Dillingham & Fletcher, 2011). As some species have either age- or sex-related partitioning in foraging areas, by-catch can unintentionally target certain age or sex classes, resulting in age or sex biased populations (Bartle, 1990; Bugoni, Griffiths, & Furness, 2011; Gianuca et al., 2017). For example, the Antipodean wandering albatross (*Diomedea exulans antipodensis*) has extremely skewed adult survivorship rates, with the female population declining twice as rapidly as the male population since 2004 (Elliott & Walker,

# Bottom longline



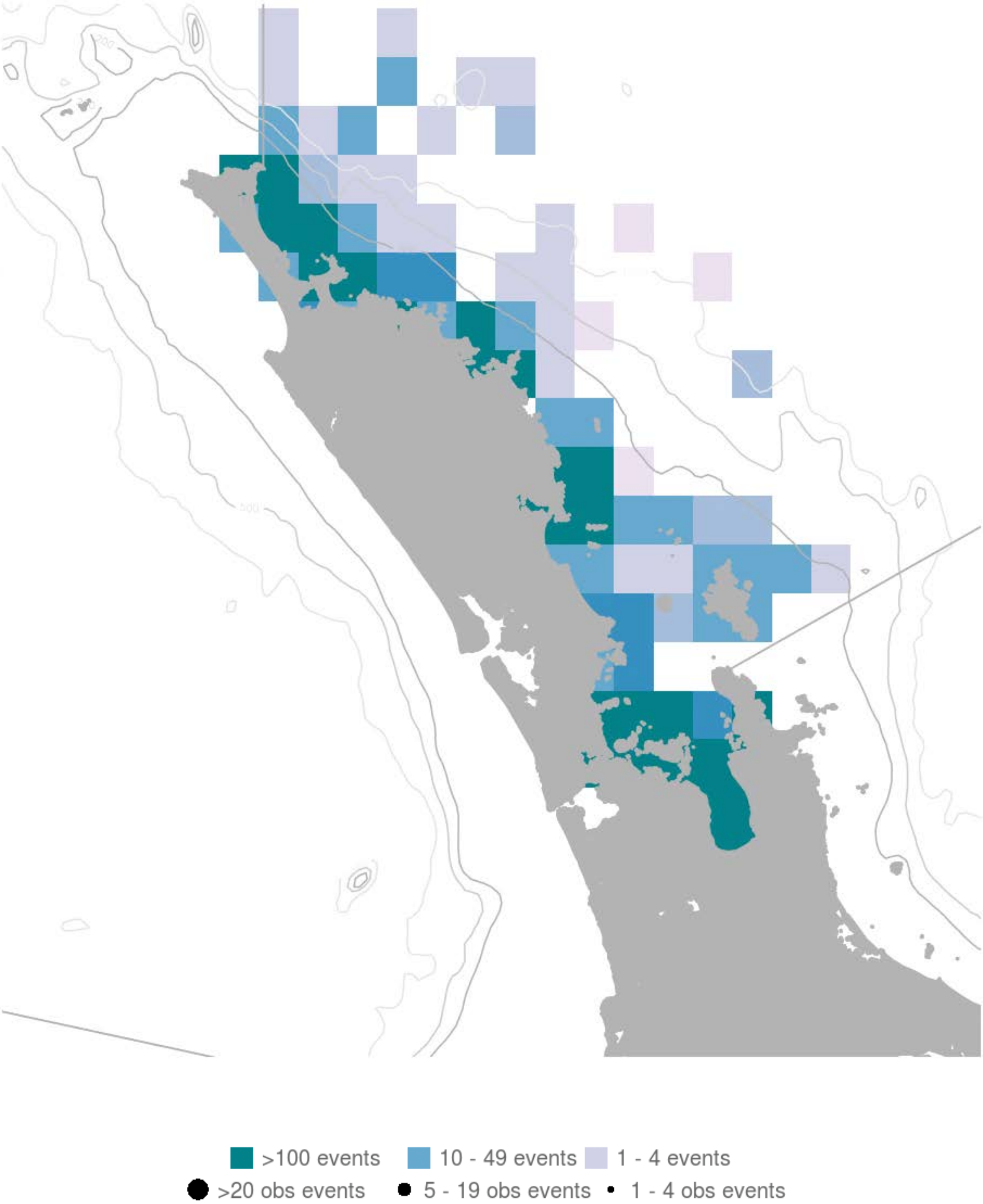

Captures of all birds in bottom longline fisheries. Map of fishing effort and observed captures, 2002-03 to 2016-17, 98.9% of effort displayed (Abraham & Thompson 2015).

# Surface longline



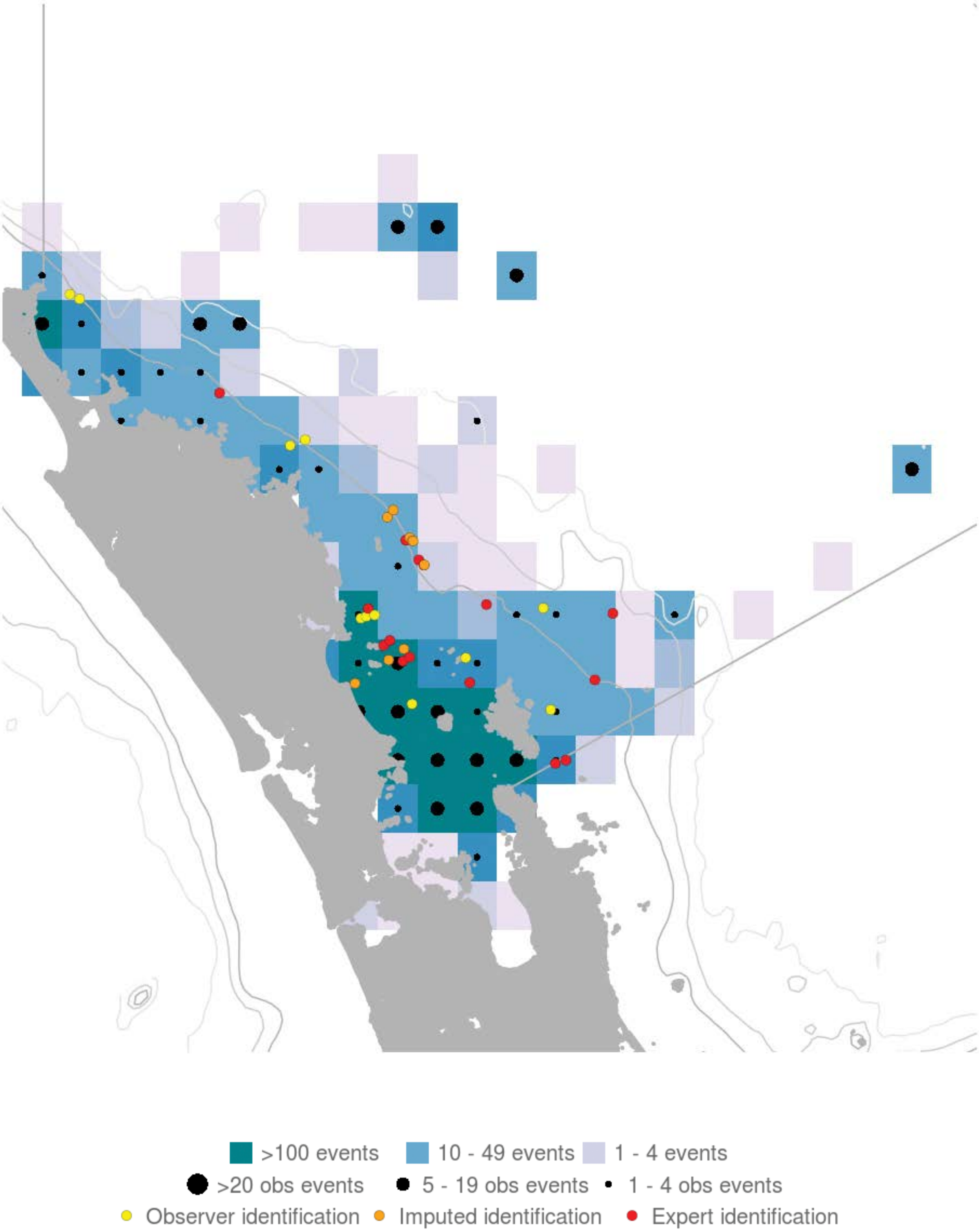

Captures of all birds in surface longline fisheries. Map of fishing effort and observed captures, 2002-03 to 2016-17, 98.4% of effort displayed (Abraham & Thompson 2015).

# Set net




Captures of all birds in setnet fisheries. Map of fishing effort and observed captures, 2002-03 to 2016-17, 91.8% of effort displayed (Abraham & Thompson 2015). NB: there are no data points for observed events because there are no observers on set net fishing vessels.

## Trawl




Captures of all birds in trawl fisheries. Map of fishing effort and observed captures, 2002-03 to 2016-17, 98.7% of effort displayed (Abraham & Thompson 2015).


**Tori lines deployed to deter birds from line sets and hauls, Hauraki Gulf.** Photo: MPI

2017). Female Antipodean albatross forage in different locations from males during the non-breeding season, visiting the coast of Chile, and appear to forage in lower latitudes where large high seas fleets are operating. Band recoveries from fisheries mortality suggest that this could also be a contributing factor in their greater decline (Elliott & Walker, 2017). Autopsy reports from bycaught birds in fisheries within the New Zealand Exclusive Economic Zone (EEZ) show a strong male bias for most species (Bell, 2011, 2012, 2014). This is a potential risk for northern New Zealand species that are susceptible to by-catch, such as black petrels and flesh-footed shearwaters.

Several mitigation techniques have been developed to reduce seabird deaths (Bull, 2007a, 2007b, 2009; Melvin & Parrish, 2001; Melvin et al., 2014). In New Zealand, Section 58 of the Fisheries (Commercial Fishing) Regulations 2001 details the by-catch mitigation strategies that must be undertaken by surface longline vessels fishing for tuna and swordfish within New Zealand's EEZ, requiring only two of three mitigation measures (line-weighting, night-setting, tori lines) (ACAP, 2017). However, this is not consistent with the best practice guidelines set out by the Agreement for Conservation of Albatross and Petrels (ACAP). ACAP best practice requires simultaneous use of all three, or the use of hook shielding devices. In addition, low observer coverage (independent by-catch observers aboard fishing vessels) in all commercial New Zealand fisheries means true compliance is difficult to assess.

Long-line and trawl fisheries are reported to be responsible for most seabird by-catch in New

Photo: Hookpod Ltd

## New technologies

HookPods (www.hookpod.com), a type of hook shielding device, which shields the barb and hook while lines are set, is a new method that is recommended as a stand-alone mitigation measure by ACAP (ACAP, 2017), following successful trials in Australia, South Africa, and Brazil (Sullivan et al., 2018), and HookPod-mini New Zealand (Goad & Sullivan, 2018). Results show lower bycatch rates than long-lining with other mitigation methods while not affecting catch rates of the target species. Recent changes (December 2018) in Pacific regional rules covering fishing for tuna have now supported ACAP best practice recommendations that hookpods can be used as a standalone measure from January 2020. This means that New Zealand fishing vessels can adopt this measure.


Flesh-footed shearwater.
Photo: MPI


Black petrel.
Photo: MPI

Zealand (Richard, Abraham, & Filippi, 2015; Waugh, MacKenzie, & Fletcher, 2008). The high likelihood of overlap between seabird foraging areas and fisheries predicted for New Zealand waters, due to the high density of seabird species (Karpouzi, Watson, & Pauly, 2007), is one explanation for the by-catch in New Zealand fisheries. However, many of our seabird species are trans-oceanic and trans-equatorial migrants, spending their non-breeding seasons in the eastern or northern Pacific (Shaffer et al., 2006), where they are at risk from other fisheries outside our jurisdiction.

There is a large fishing effort within the Northland/Hauraki Region, particularly within the Hauraki Gulf (Hauraki Gulf Forum, 2010). In the region, commercial bottom longline fishing has the greatest reported overall effort, followed by surface longline and trawl fisheries. However, the observed proportion of fishing events is extremely low for all three fisheries, making estimates of by-catch problematic. Since the 2002-03 season, the year with greatest observer coverage of bottom longline vessels was 2009-10 with 6% of hooks observed; on average only 2% of hooks are observed. For surface longlining, 2015-16 saw 11% of hooks observed, with an average since the 2002-03 season of 7%. In regional trawl fisheries, 17.4% of tows were observed in the 2016-17 season. The percentage of observed trawls has increased since 2002-03, but on average only 6% of tows have been observed. There is no observer coverage of set net fisheries in the region.

In 2011, black petrels were identified as the species nationally most at-risk from interactions with commercial fishing vessels throughout New Zealand's EEZ (Richard et al., 2015), a status that has not changed up to the most recent analyses (AEBAR, 2017). This vulnerable population cannot sustain the rate of captures currently estimated from observed incidents, which are potentially an under-estimate of the true impact of fisheries (Hall, Alverson, & Metuzals, 2000). Four birds were observed killed on surface long-line vessels along the north east coast of the North Island in 2016/17, with just 8% of tows observed. All were black petrel. In the bottom long line fishery for the same period 14 birds were observed with just 4.7% observer coverage, 11 were black petrel. Another species of concern in the region is flesh-footed shearwater, also a commonly caught species that is at risk of decline, now the 3rd most at risk from fisheries in New Zealand. While species that breed in the region are at risk of by-catch mortality, many other seabirds from throughout the New Zealand region, including sub-Antarctic albatrosses such as Antipodean albatross are also caught in Northland/Hauraki fisheries, particularly surface longlining (Dragonfly Science **https://psc.dragonfly.co.nz/2018v1/released/summary/**). Small coastal fisheries are rarely well-observed, so estimates of by-catch may not accurately represent their true impact on seabird populations (Hall et al., 2000).

Pied shag hanging in a tree by fishing line, Sandspit.
Photo: Edin Whitehead

## 2.2.2 Recreational Fisheries

Recreational fishing also has the potential to adversely impact seabird species through by-catch. Recreational fishers encounter seabirds diving after baited hooks or becoming entangled in fishing lines or in set nets (Abraham, Berkenbusch, & Richard, 2010). In many cases these incidents are not dealt with adequately by the fishers, which can cause seabird mortality. Shag species have often been observed trailing nylon fishing line (see figure) (all authors, pers. obs), usually in cases where they have swallowed the hook to consume bait, and the line has been cut without an attempt to remove it from the bird. This is extremely hazardous as it can lead to the birds becoming snagged on their tree roosts, entangled by the line and hanged (S. Neureuter pers. comm. 2018), or strangled by the line itself.

The Hauraki Gulf has the highest recreational fishing effort of any area in New Zealand (Hartill, 2014). In the region, petrels and shearwaters (usually black petrels and flesh-footed shearwaters) are most likely to be accidentally caught by recreational fishers from boats as they chase baits underwater, either becoming entangled in the line or hooked (Abraham et al., 2010). This has caused mortalities when birds have become tangled in vegetation upon return to their breeding colony (E. Bell, pers obs). Gulls and shags are frequently hooked and tangled, especially by coastal fishers from rocks and jetties (Abraham et al., 2010). Most tangled birds appear to be released unharmed, though external and internal hooking causes injury, particularly if birds are handled carelessly. Birds occasionally escape before fishing gear can be properly removed from them, but only on rare occasions do they die at the time of the incident, although they may also be killed on purpose. Evidence of deliberate killing of recreationally-caught shearwaters was uncovered after the Rena oil spill in 2011 when necropsies revealed deaths from deliberately inflicted trauma (Tennyson et al., 2012). Survivorship after injury or attached fishing gear is unknown. Beach-wrecked birds are sometimes found with hook and lines still attached, suggesting the cause of mortality is likely in these instances.

Interactions between recreational fishers and seabirds appear to be commonplace, and most incidents appear to be well-managed by fishers. However, responses to surveys suggest that a small number of recreational fishers may be catching large numbers of birds, the impacts of which cannot be accounted for in general estimates (Abraham et al., 2010). Information on how to handle birds safely for both bird and handler needs to be widely disseminated to recreational fishers. Southern Seabirds Solutions Trust and Forest & Bird have online and printable resources available.

Little shag with fishing line. Photo: Edin Whitehead

Holding a petrel safely around the wings. Photo: Chris Gaskin

## 2.2.3 Set nets

Set netting is one of the most non-selective fishing methods available because nets entrap a wide range of non-target species which come into contact with them. Set netting is undertaken by both commercial and recreational fishers. In the Hauraki Gulf, commercial set net fishers often target relatively small local areas and are focused in the mid-Gulf and Firth of Thames. Recreational set netting occurs in river mouths and estuarine areas throughout the Gulf. The main species targeted by recreational set netters include flatfish (*Rhombosolea spp*), grey mullet (*Mugil cephalus*), school shark (*Galeorhinus galeus*), rig (*Mustelus lenticulatus*) and snapper (*Pagrus auratus*) (Hauraki Gulf Forum, 2010).

Set nets are a risk to seabirds because they become entangled and drown in the nets while diving for food (Žydelis et al., 2009). Depending on species and how nets are used, this can occur during deployment (setting and hauling) or soaking (whilst the gear is fishing). Set netting can be particularly damaging if nets come adrift and float unconstrained through the water column (Hauraki Gulf Forum, 2010).

Based on studies on similar species in New Zealand, and internationally (Žydelis et al., 2009, 2013), these fisheries in the Northland/Hauraki region pose a threat to seabirds. Young, inexperienced birds may die in net entanglements more frequently than older birds, which ultimately could lead to low recruitment to the breeding population (Bregnballe & Frederiksen, 2006). Spatial and temporal closures of set net fisheries are the best method for reducing by-catch of seabird species, as mitigation techniques are yet to be developed to adequately reduce seabird (and other species) by-catch (Crawford et al., 2017).

Set nets are known to catch diving seabirds with shearwaters, diving petrels, penguins and shags being the most at-risk species (Abraham et al., 2010). However, the total impact is unknown as there have been no observers of commercial set-net operations, and recreational information is only recorded when a large incident is observed. In the early 1990s there was considerable concern regarding seabird drownings (shags and penguins) in set nets in the Tāmaki Estuary and the Panmure Basin. This concern resulted in a number of press articles and the involvement of different interest groups. Research by the then MAF (Ministry of Agriculture and Fisheries) Set Net Taskforce into by-catch incidents at the locality acknowledged the problem of seabird entanglements and recommended that parts of the area be closed to set netting. However, the different stakeholders, commercial and recreational fishers, and conservation groups could not reach a consensus (Taylor, 1992).

Fluttering shearwaters in set net.
Photo: Auckland Council

Fluttering shearwaters feed in association with shoaling fish or in widespread groups at the surface feeding on crustaceans and, at times, resting in large, dense rafts (Gaskin, 2013). During the post-breeding period, a considerable proportion of the population remain within local waters. As they feed by diving, commonly in flocks, they can be caught in set nets in large numbers (e.g. 166+ in a single incident at Whangaparaoa Peninsula in May 2009, and more recently at Kawakawa Bay) (M. Maitland, pers comm., 2018). Shag species all forage and feed in inshore waters including river, harbour and estuarine areas where set netting often occurs, and are therefore at considerable risk from set netting, particularly spotted shags. Elsewhere in New Zealand, shags are observed caught in set-nets (Dragonfly Science **https://psc.dragonfly.co.nz/2018v1/released/summary/**).

There are some set net restrictions in place in the Hauraki Gulf. Arkles Bay on the Whangaparaoa Peninsula has a specific ban on set nets, introduced by the local community. There are also some areas where commercial, and in some cases recreational, set nets are prohibited – e.g. 0.5 nm off the Mokohinau Islands, Simpson Rock, Te Hauturu-o-Toi (Little Barrier Island), Rakitu (Arid Island), part of Aotea (Great Barrier Island) and in the Tāmaki-Panmure Estuary (Froude & Smith, 2004). The potential impacts to seabirds from set netting, both commercial and recreational, in an area that is of global seabird importance warrants restricting or banning the use of set nets throughout the Hauraki Gulf. Set nets are restricted in other parts of the country to protect Hector's and Maui's dolphins (Dawson & Slooten, 2005).

Records of seabird entanglement in synthetic material indicate that active and discarded fishing gear can cause entanglement mortalities (Ryan, 2018). Discarded fishing gear is a major contributor to marine plastic pollution worldwide (Glagani, Hanke, & Maes, 2015). While not in active use, nets left at sea continue to cause mortalities to a variety of marine life in what is known as 'ghost fishing'. Past practice of discarding broken or leaving hard to retrieve gear at sea can result in long term impacts to populations (Good et al., 2009). This is true of both commercial and recreational fishing operations; however, we have no data for New Zealand and Northland/Hauraki Gulf region.

## 2.2.4 Indirect impacts

Beyond by-catch, fisheries may impact seabird populations by reducing available prey species (Furness, 2003), particularly at crucial periods of the breeding cycle where parents are foraging for both themselves and a dependent chick (or chicks). In addition, the removal of prey species may compound with environmental fluctuations that impact seabird populations, resulting in greater declines than would happen naturally (Duffy, 1983).

Concerns have been raised about the potential impact of the purse-seine fishery on marine systems including seabird foraging (Gaskin, 2015). Although this was first raised in the 1970s, there are new calls for a full investigation into the broader ecosystem impacts and sustainability of this fishery, particularly from environmental and recreation fishery groups (K. Baird, S. Woolford, pers. comm. 2018). Purse-seiners target entire fish schools, encircling them with nets and hauling them aboard. Spotter planes are used to target schools that are obvious from the surface as 'work-ups' or 'boil-ups' as they feed on plankton, often in association with seabirds and cetaceans. Purse seine fisheries in Northern New Zealand often target skipjack tuna (*Katsuwonus pelamis*), blue mackerel (*Scomber australasicus*) and arrow squid (*Nototodarus sloanii*), all species that have either been observed feeding in association with seabirds, or as prey for seabirds (authors, pers. obs., N. Adams, unpublished data). Since the 1990s there has been a substantial increase in pilchard fishing in Northern New Zealand, particularly the Hauraki Gulf (Paul, 2014).

The large-scale removal of schooling fish could reduce food available to seabirds, particularly during their breeding seasons. Anecdotal historical accounts report diminishing fish school size and frequency, particularly of the formerly 'vast' trevally (*Pseudocaranx dentex*) schools from northern waters (R. Walter, W. Doak, R. Grace, pers. comm. 2018). Competition for the same prey between seabirds and fisheries is a known issue in other parts of the world (Furness, 2003), although its extent in our region has not been quantified.

The reliance of some seabird species on subsurface predators (e.g., large fish, cetaceans) to make common prey available – concentrated and on the surface (e.g. euphausiids, small school fish) (Hebshi, Duffy, & Hyrenbach, 2008) is another subject under inquiry at present. Large feeding aggregations of fluttering shearwaters, Buller's shearwaters, fairy prions, Australasian gannets, red-billed gulls and white-fronted terns are often observed over fish schools throughout the Hauraki Gulf (Gaskin, 2017). Long-finned pilot whales (*Globicephala melas*) and false killer whales (*Pseudorca crassidens*) are often found by locating black petrels and flesh-footed shearwaters, which appear to feed in association

**Shearwaters and fairy prions feeding in association with a trevally school, Mokohinau Islands.** Photo: Edin Whitehead with them (J. Zaeschmar, pers. comm. 2017). Gannets and flesh-footed shearwaters have also often been observed foraging alongside common dolphins (*Delphinus delphis*) (Gaskin, 2017).

As well as these inter-species feeding associations, knowledge of food-web interactions and energy flows through marine ecosystems is crucial for our understanding of how these might change if links in the chain are disturbed, as has occurred with human alterations to the marine system through fishing (Pinkerton et al., 2015). The Hauraki Gulf system has been vastly altered from its pre-human state (Pinkerton et al., 2015), and assessing the current condition of the marine environment through multiple avenues is a priority. The large-scale removal of prey fish species will have impacts on predators and prey, but we cannot model these effects without knowledge of the underlying relationships. Profiling the trophic relationships within the Hauraki Gulf system would allow us to determine the extent to which removal of prey species will impact not only seabirds, but other marine organisms as well. The impacts of other threats – such as environmental change – should also be investigated within this framework.

## Key measures to reduce threat

1. Introduce fisheries exclusion zones during breeding seasons of affected seabirds
2. Expand and implement marine protected areas (MPAs) around key breeding sites
3. Investigate the benefit of MPAs for different groups of seabirds including necessary size for protection of key forage resources

**Work-up of fish and seabirds, Te Hauturu-o-Toi/Little Barrier Island in the background.** Photo: Edin Whitehead

**Oiled little (blue) penguin, *Rena* oil spill victim.** Photo: Kim Westerskov

**Oiled petrels and shearwaters, *Rena* oil spill.** Photo: Kim Westerskov

**Oil flowing from the MV *Rena* grounded on the Astrolabe Reef, October 2011.** Photo: Kim Westerskov

# 2.3 Pollution

## 2.3.1 Oil spills

Oil spills are ecological disasters, having wide-ranging effects on the marine environment (Peterson et al., 2003), and the organisms in it (Troisi, Barton, & Bexton, 2016), for years after the event itself (Kingston, 2002; Peterson et al., 2003). In areas of high shipping traffic (container ships, car and log transporters, oil tankers and cruise ships), such as the Hauraki Gulf and the Northland coast, the potential for collisions resulting in petrochemical spills is of concern. Oil spills, beyond directly killing seabirds (Crawford et al., 2000) also have impacts for long term breeding success (Barros, Álvarez, & Velando, 2014), cause persistent sublethal physiological stress (Alonso-Alvarez et al., 2007), and reduce the availability of prey species (Velando, Munilla, & Leyenda, 2005).

The wreck of the *Rena* on Astrolabe Reef (Bay of Plenty) in 2011 resulted in several hundred tonnes of oil discharged into the marine environment (Warne, 2012). It has been considered New Zealand's biggest marine ecological disaster (Schiel, Ross, & Battershill, 2016). Oiling resulted in the death of several thousand seabirds and massive volunteer efforts were undertaken to clean coastal habitats and rehabilitate oiled birds that had the potential to recover. As it occurred during the breeding season for many species, including little penguins, diving petrels and Buller's shearwaters, the loss of these adults also represented the loss of their dependent chicks. If such an event were to occur in the Hauraki Gulf or the Northland coast, particularly during the breeding season (summer) of multiple species, the impacts on seabird populations could be devastating. This could be far greater than the *Rena* given the proximity to many major breeding islands. Rapid response and rehabilitation can be effective in saving some oiled birds, for example penguins and shags (Sievwright, 2014), but Procellariiformes rarely survive oil contamination (Miskelly et al., 2012). The long-term impacts from an oil spill on the environment are largely inescapable. In addition to oil discharge, debris such as plastic beads and packaged food from the containers aboard the *Rena* that broke and washed ashore contributed to fouling of the coastal and marine environment (Schiel et al., 2016).

The potential for oil leakage from an already-present wreck in the Hauraki Gulf, the *RMS*

*Niagara*, has recently been highlighted ('Dire warnings over wreck of the Niagara', Radio New Zealand, 2017). The proximity of this wreck to many seabird islands (Taranga, Marotere Chickens), Poor Knights and Mokohinau Islands), as well as the breeding habitat of New Zealand fairy terns along the mainland coast, is of concern, especially as the quantity of oil still contained in the wreckage is unknown. Significant oil slicks can often be seen while over the site of the wreck (authors, pers. obs., 2018). As the wreck deteriorates further, large quantities of oil could be released into the marine environment in a single catastrophic event.

North Port (Marsden Point, Whangarei Harbour) is moving to accommodate larger vessels and an increase in vessel numbers. In Marsden Point Oil Refinery's Environmental Impact Assessment there was no mention of potential impact on seabirds in the area of a large spill, highlighting a lack of awareness of the global significance of seabird populations in the region. During extension and development of coastal and marine infrastructure there is a need to consider the impact that events such as these could have on the marine life in the region, particularly as the entire Hauraki Gulf region is considered internationally important for seabirds.

## 2.3.2 Plastics

Marine plastic pollution is a pervasive global issue (Andrady, 2015), and is considered to potentially be of the same magnitude of impact to biological systems as climate change. In New Zealand, the first indication that plastics were an issue in our marine environment was in the late 1970s, when Gregory (1978) identified concentrations of virgin plastic pellets on beaches throughout the country, the greatest accumulations being nearby the main centres, exceeding 40,000 pieces per metre of beach. Soon after, Harper and Fowler (1987) documented the increasing incidence of beach-wrecked prions with plastic pellets in their gizzards between 1958 and 1977; birds with greater amounts of plastic being lighter in weight than those with less. The threat of plastic to marine life is not new, but frighteningly little has been done about it.

As many plastics float in the marine environment they are visible and available to seabirds, many of which are opportunistic feeders (Cadée, 2002), although below-surface feeders also show evidence of plastic ingestion (Tavares, de Moura, Merico, & Siciliano, 2017). Plastics in the marine system form a perfect substrate for biofilms (Artham et al., 2009; Lobelle & Cunliffe, 2011). These biofilms are now known to emit a similar chemical odour to that of zooplankton feeding on phytoplankton; di-methyl sulphide (DMS), which contributes to the foraging strategies of some tube-nosed seabirds (Dell'Ariccia et al., 2014). Some species may use DMS to locate food resources across otherwise featureless oceanscapes (Nevitt & Bonadonna, 2005). As these bio-fouled plastics smell like food, these species are at much greater risk of confusing them for food particles and ingesting them (Savoca et al., 2016). However, this is not the case for all seabird species, and others may be more at risk of visually misidentifying plastics as prey, suggested by the selectivity for certain colours of plastic found in seabirds (Lavers & Bond, 2016b).

As well as direct consumption by misdirected feeding behaviours, plastics may also be ingested accidentally while feeding, or consumed by prey species which are in turn eaten by seabirds (Ryan 2016). Ingested plastic may cause internal blockages or perforations (Fry, Fefer, & Sileo, 1987), or result in gradual starvation by filling the digestive tract (Pierce et al., 2004). Consuming plastics and microplastics may also impact the reproduction of prey species (Lee et al., 2013), which has the potential to reduce seabird foraging success.

Not only is the physical harm from plastic concerning for seabirds, there are potential toxicological effects that may be less immediately obvious (Teuten et al., 2009). In their manufacture, plastics are imbued with certain additives, such as PCBs (polychlorinated biphenols), plasticisers and colourants that can have deleterious effects on organisms, such as inhibiting reproductive systems and causing developmental problems (Oehlmann et al., 2009; Ryan et al., 1988).

In addition, while in the environment they are also exposed to contaminants which they may adsorb, increasing the toxicity of the fragment (Ashton et al., 2010; Holmes et al., 2012). Smaller fragments, such as microplastics, have greater surface areas and thus greater potential to pick up chemicals from the environment (Browne et al., 2013). Bioaccumulation may be a risk to seabirds in addition to directly consuming plastics, as they may also take prey which have ingested plastics and microplastics, increasing their exposure to toxic contaminants (Lavers & Bond, 2016a; Tanaka et al., 2013). In addition,

**Plastics collected from northern royal albatross nests, Chatham Islands.** Photo: Edin Whitehead

**Plastic fragments found next to flesh-footed shearwater burrows, Ohinau Island, eastern Coromandel.** Photo: Rachel Buxton

**Plastic found in a dead southern royal albatross, Campbell Island.** Photo: Edin Whitehead

the stomach oils of tube-nosed seabirds appear to act as an organic solvent, leaching flame-retardant chemicals (polybrominated diphenyl ethers/PBDEs) from plastic fragments in the digestive tract much more readily than would occur in water (Tanaka et al., 2015). Such contaminants can reduce survival, impact reproduction (Bouland et al., 2012), and disrupt normal physiological processes (Azzarello & Van Vleet, 1987).

Eighty-one species of seabird have so far been recorded ingesting plastic debris (Wilcox et al., 2015). The type of plastics found in seabirds in some locations has changed over the years, with post-user plastics increasing and virgin feedstock (nurdles) decreasing (Ryan, 2008; Vlietstra & Parga, 2002). The waters around the New Zealand region are predicted to have the highest impacts from plastics on seabirds due to the diversity and abundance of seabird species, both native and migrant, that forage in our waters (Wilcox et al., 2015). In the New Zealand region, plastics have been found in the carcasses of seabirds on one of the most remote islands in our archipelago, Campbell Island (author, pers. obs. 2016). With such a density and diversity of seabirds breeding close to New Zealand's largest city and most heavily populated area, the potential for impacts from plastic pollution are much greater. The semi-enclosed nature of the Hauraki Gulf in which they forage means that plastics may accumulate at greater concentrations here than in more open systems (Barnes, 2009).

A study on marine plastic abundance in the inner Hauraki Gulf (Young & Adams, 2010) indicated that the greatest areas of plastic aggregation were along natural slick lines where currents converge. These often overlap with preferred foraging locations for seabirds, which may benefit from the aggregations of marine algae, zooplankton and larval fish that also accumulate along natural convergences (Kingsford & Choat, 1986). Greater amounts of plastic were found in the Waitematā Harbour than beyond Rangitoto Island towards Tiritiri Matangi Island. Aggregations of plastic are expected closer to input sources, and the type of plastics found are primarily user discards, rather than industrial pellets. This study suggested that the species most at risk of ingesting plastics were smaller surface feeding seabirds such as fluttering shearwaters and white-faced storm petrels (Young & Adams, 2010). An expanded version of this study during the summer breeding season of most of the Gulf's seabird species would contribute to a better estimate of plastic concentrations in the Hauraki Gulf.

In New Zealand, there is growing knowledge as to what extent plastics impact our seabird species. Buxton et al. (2013) found plastic in quantities outside shearwater and petrel burrows on Ohinau Island, eastern Coromandel. Necropsy studies of beach-wrecked and by-caught birds suggest that prions and shearwaters are most at risk of ingesting plastic fragments (Bell, 2012, 2014; Harper & Fowler, 1987). Certain life-history traits such as foraging style and diet predict how likely particular species are to ingest plastic. Further necropsy work has highlighted that storm petrels and prions in Australasian waters may be the most at risk of ingesting plastics due to their foraging styles, which include feeding on the surface by dipping and filtering (Roman et al., 2019). Whether seabirds directly ingest plastic or not, their high trophic position means they may also indirectly consume plastics, or their associated contaminants through their prey. It is likely that even species less at risk of directly ingesting plastic will accumulate fragments and microplastics by consuming contaminated prey (Wright, Thompson, & Galloway, 2013).

Plastic consumption not only impacts the foraging adults, but also their offspring. In feeding their chicks, seabirds will pass on ingested plastics by regurgitation (Skira, 1986). While this decreases the plastic load on the parents, it results in accumulation in chicks that can cause significant distress, as well as blocking or damaging the digestive tract and potentially contributing to mortality (Auman, et al., 1998; Sileo et al., 1990). While some species are able to regurgitate non-digestible items and do so readily (gulls, skuas), many tube-nosed seabirds are constrained by their gut morphology and may not be able to expel some plastic fragments in this manner (Azzarello & Van Vleet, 1987). It is unknown exactly how long seabirds retain plastics in their digestive tracts, and rate of degradation is likely to differ between species (Ryan, 2015).


**Plastics in gannet nests.**
Photo: Nigel Adams

Ingestion is not the only method by which plastics can cause injury and mortality to seabirds. At an individual level, entanglement in marine litter such as discarded or lost fishing nets, monofilament line and nylon rope can seriously endanger marine life (Good et al., 2009; Laist, 1997; Gregory, 1991, 2009). This is particularly a risk for species such as shags that forage in the water column and may come into contact with active or discarded fishing gear (Good et al., 2009; Harrigan, 1991). Seabirds, particularly gannets, may also use plastic debris as nesting material, which puts them and their chicks at risk of entanglement (Votier et al., 2011). Gannet nests in the Northern New Zealand region have been frequently observed to contain plastic – on Horuhoru Rock off Waiheke Island, most gannet nests surveyed contained plastic, usually in the form of nylon rope (N. Adams, unpublished data). Thirty-six percent of seabird species have been recorded entangled in plastic, predominantly from fishing gear (Ryan, 2018). Entanglement is thus further discussed in the Fisheries section.

**Urban coastal development.**
Photo: Edin Whitehead

## 2.3.3 Coastal Development

Sedimentation and runoff as a result of increasing coastal development is of concern for nearshore marine ecosystems. Runoff from coastal development can reduce biodiversity and compromise ecosystem processes in the nearshore environment (Bilkovic & Roggero, 2008; Lerberg et al., 2000). This may reduce the profitability of foraging in these areas for nearshore feeding seabird species. Runoff from areas where earthworks are underway for construction can lead to sedimentation of nearshore areas, unless well managed. The turbid waters associated with this activity could dramatically reduce foraging success of visual nearshore and continental shelf foragers such as fluttering shearwaters, little penguins, terns, especially NZ fairy terns, gulls, and various shag species.

Runoff may also impact nutrient flows from terrestrial to marine environments.

Land uses such as agriculture (particularly cattle/dairy farming) can result in high levels of nitrogen runoff, and without proper riparian management this has flow-on effects for the coastal environment, causing eutrophication and deteriorating aquatic ecosystems (Heggie & Savage, 2009). Stormwater runoff is poorly managed in the Auckland region, resulting in restrictions for beach use due to health concerns ('Dirty water raises health risks at Auckland beaches', Radio New Zealand, 2018; Morton, 2018a).

Sewerage overflow has resulted in high levels of faecal contamination at many beaches on both the east and west coasts, and the public are advised not to swim due to the high probability of contracting illness from contaminated water (see www.safeswim.org.nz). The effects of this contamination on other organisms living in these systems has not been considered, but it has serious implications for biodiversity (Johnston & Roberts, 2009).

Runoff also has the potential to contain heavy metal contaminants. The Auckland region has many coastal areas that are highly urbanised, and the Tāmaki Estuary is known to have high levels of heavy metal contamination due to its industrialised catchment area (Abrahim & Parker, 2002). Urban areas are characterized by impermeable surfaces (roads, pavements, concrete) that do not allow for rainwater to absorb and filter through the soil, rather running directly

**Brightly lit cruise ship off the Poor Knights Islands.**
Photo: Edin Whitehead

**Cook's petrel fledgling freshly departed from Hauturu attracted to lights of Omaha Beach.**
Photo: David Stone

down drains and transporting contaminants into the marine environment (Abrahim & Parker, 2002). In Northern New Zealand, extremely high mercury levels have been recorded in grey-faced petrel feathers, although the cause of this is unknown and may be due to the volcanic origins of much of the environment (Lyver et al., 2017). Increased heavy metals in the marine environment resulting from urban runoff may impact seabirds through their prey, and the potential for biomagnification from prey to predator species (Burger & Gochfeld, 2004).

## 2.3.4 Artificial Light at Night

Both on land and at sea, artificial light at night has the possibility to severely impact seabird behaviour (Montevecchi, 2013; Rodríguez et al., 2017). Disorientation by light is a commonly reported issue, particularly for nocturnal tube-nosed seabirds (Imber, 1975; Rodríguez et al., 2017). These effects are prevalent on nights without natural light sources – during new moon phases, or when skies are obscured by cloud (Miles et al., 2010). Fallout results when artificially light causes confusion, and birds crash-land, rendering them either injured, or vulnerable to predation or further injury and death.

In some species, fledglings appear to be more strongly attracted to lights than adults (Le Corre, et al., 2002), perhaps due to inexperience and their instinctual behaviours to orient towards bioluminescent prey, or use celestial bodies to navigate (Imber, 1975; Telfer et al., 1987). Thus, the impacts of light at night can be seasonal, and the majority of events are associated with fledging dates (Le Corre et al., 2002). In populated areas near seabird colonies intense volunteer efforts have been instrumental in preventing a large number of seabird deaths (Fontaine et al., 2011; Miles et al., 2010).

Lighting through urban areas across the Auckland/North Auckland Isthmus is problematic for species using the North Auckland Flyway from feeding grounds in the Tasman Sea to colony sites in the Hauraki Gulf, primarily Cook's petrels breeding on Te Hauturu-o-Toi (Little Barrier Island) (Gaskin & Rayner, 2013; Forest & Bird, 2015). Transiting birds are known to fly directly across areas of high light illumination, such as central Auckland. However, fledglings departing colonies are most at risk. Misty conditions and low cloud, illuminated by lights at night, compound the problem by causing confusion which


Dead and dying Buller's and flesh-footed shearwaters that had been attracted to cruise ship lights off Northland coast. Photo: DOC

can result in many birds crash landing in residential areas (Telfer et al., 1987). On the ground, they are at risk of predation by introduced pest species and pet animals, as well as the risk of being hit by vehicles (Rodríguez et al., 2017), or simply being unable to take-off again. These are issues that have been addressed elsewhere in New Zealand where seabird populations are close to settlements, such as Punakaiki (Wilson, 2016) and Kaikoura (Deppe et al., 2017). As urbanisation in the region increases, greater intrusion of artificial light at night may cause greater fallouts on nights like these.

Recently, the threat of illuminated ships passing seabird islands has been highlighted by the deaths of 67 Buller's and flesh-footed shearwaters following their crashing aboard a cruise ship which later entered the Port of Auckland (Morton, 2018b). While a proportion of the birds were successfully rehabilitated and released, this incident also demonstrated the need for ship crews to be educated on how to handle seabirds coming aboard. Many of the resultant deaths of birds could have been avoided if the birds had been properly handled and released at sea, rather than kept in cardboard boxes. Cruise ships and major shipping lanes bypass seabird islands in the wider Hauraki Gulf region,

## Reducing risk of vessel lights to seabirds

### Reducing risk

- Minimise light output from vessel using blackout blinds on portholes
- Keep deck lights to only those absolutely necessary for safe operations, use minimum wattage necessary
- Keep deck lights to minimum when nearshore overnight
- Shield external lights so they are directed downwards
- Take particular care during rain and misty nights when bird fallout risk is increased

### Response

- Have someone to coordinate handling and releasing of birds
- Release birds as soon as possible at night, once deck-lights are turned off, or at first light the next morning
- If necessary, keep birds in separate boxes in a cool, dry, dark environment
- Do not release birds when gulls/skuas are present
- Hold bird in open hands over the windward side of the ship, if bird does not take off after a few minutes, gently throw bird up into the air

### Recording:

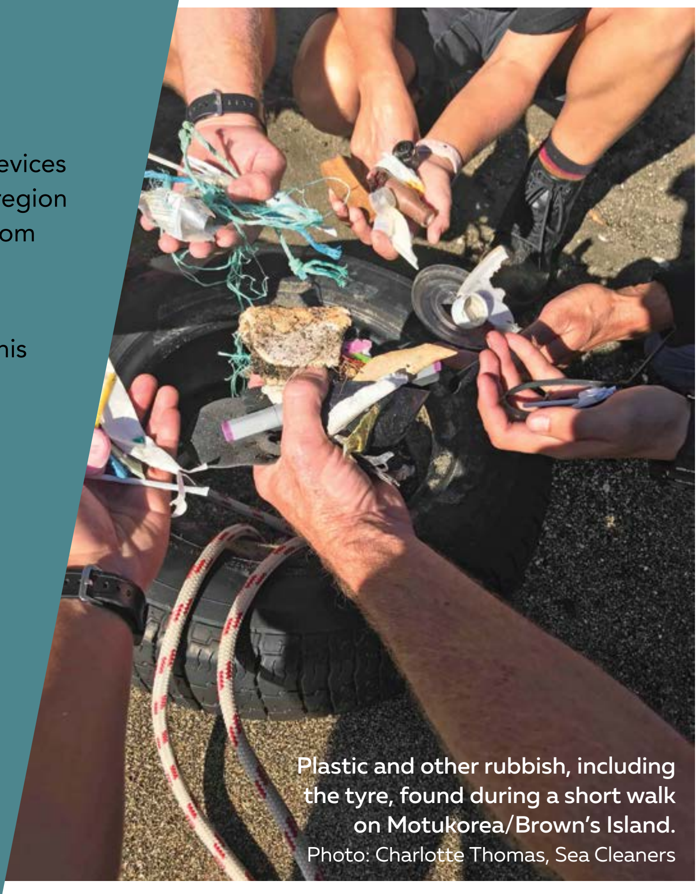
- Record species, number of birds and location
- Take photos to aid identification
- Report to Department of Conservation

and fledglings from these colonies may be particularly at risk. This is a concern for regional endemics such as Buller's shearwaters. Standard protocol used by ships operating in the Antarctic region as described by International Association of Antarctic Tourism Operators (IAATO) should be applied to all vessels passing nearby seabird islands within the Northern New Zealand region. This involves reducing the light spill from vessels and releasing any attracted birds as soon as possible, as outlined on page 37 (modified from IAATO). The Department of Conservation has been working with cruise operators to reduce light-spill from vessels when they are near seabird islands (Cropp, 2019).

Fishing vessels in the Northland/Hauraki region often note birds coming aboard, particularly at night and in adverse weather conditions. These are most often species that do not otherwise interact with fishing vessels, such as white-faced storm petrels, Northern common diving petrels and prions (Dragonfly Science: **https://psc.dragonfly.co.nz/2018v1/released/explore/**). Deck-strike may injure these birds, and they may be unable to take off from the vessel once aboard and suffer the effects of exposure. While lights at night are required for the safety of crew, particularly when night-setting fishing gear or at anchor near islands, minimizing light-spill and being aware of birds coming aboard the vessel are important to reduce avoidable seabird fatalities from fishing vessels that are not by-catch-related.

## Key measures to reduce threat

1. Install litter/contaminant capture devices in storm-water systems across the region (plastics and contaminant run-off from roads/industrial areas).
2. Support coastal clean-up activities and organisations which focus on this
3. Light restrictions for vessels in the wider Hauraki Gulf region
4. Identify high-risk areas for urban light pollution impacting seabirds, introduce measures to reduce light-spill (as in Kaikoura, see Deppe et al., 2017)
5. Utilise the provisions in the RMA (Resource Management Act) to require and monitor effective sediment run-off control from land development activities/ agriculture.



**Plastic and other rubbish, including the tyre, found during a short walk on Motukorea/Brown's Island.**
Photo: Charlotte Thomas, Sea Cleaners

## 2.4 **Disease**

Disease is a periodic threat to all seabird species, particularly those in dense colonies, and so greater potential for transmission. Outbreaks of disease are often related to extreme climate events where birds are under stress, weakening their immune capabilities (Waller & Underhill, 2007). Disease has the possibility to negatively impact seabird populations by dramatically increasing both adult (Waller & Underhill, 2007) and chick mortality (Weimerskirch, 2004).

Avian cholera as a result of infection by the bacteria *Pasteurella multocida*, has been implicated in the mortality of Indian yellow-nosed albatross (*Thalassarche carteri*) on Amsterdam Island (Weimerskirch, 2004). Avian cholera has its origin from poultry, and the potential of transmission via both bird contact and environmentally. It is a disease that progresses rapidly and can cause mortality within 6-48 hours of exposure. The bacteria has also been identified in two other albatross species on the island and outbreaks are a serious concern for these declining populations (Jaeger et al., 2018). A vaccine is available that is effective for albatross species (Bourret et al., 2018), which may assist in reducing the impacts of outbreaks. Acute mass mortality events in South Africa of Cape cormorants (*Phalacrocorax capensis*) have occurred as a result of avian cholera (Waller & Underhill, 2007). Preventing the spread of this disease to other species via scavenging required dedicated removal of all carcasses on a daily basis for the duration of the outbreak. In New Zealand, avian cholera has been identified in Eastern rockhopper penguins (*Eudyptes filholi*) (de Lisle, Stanislawek, & Moors, 1990). Outbreaks and mass mortality could be disastrous for Northern New Zealand seabirds, particularly those with small population sizes or restricted breeding sites.

Avian malaria is known to cause mortality in little blue penguins in both wild and captive individuals (Sijbranda et al., 2017). *Plasmodium, Babesia,* and *Trypanosoma* blood parasites have all been recorded in wild populations of Little blue penguins in New Zealand, which can have both lethal and sub-lethal impacts on individuals (Vanstreels et al., 2016). Aspergillosis and bacterial infections have been reported as the cause of death for little blue penguins in New Zealand, but of potentially greater concern is the impact of toxic dinoflagellate blooms (see section), which were also implicated in the mass mortality of yellow-eyed penguins in Otago (Duignan, 2001). While penguins are unlikely to consume dinoflagellates themselves, accumulation in their prey species (fish) has the potential to cause neurological impairment and death. This is further discussed in the climate change section.

There has been no research to date on disease prevalence in Northern New Zealand seabirds, which needs to be addressed in order to determine how disease has the potential to impact these species. Potentially the greatest disease threat to seabirds is from contact with humans, particularly researchers working on multiple islands and species. Maintaining strict quarantine measures between island visits and sterilizing equipment between use on different species should curb any negative impacts while the potential for disease transferral remains unknown. Without knowledge of what diseases may be present currently in native populations, we are unable to assess the risks from exotic or domestic species.

### Key measures to reduce threat

1. Assess disease prevalence in seabird species within region
2. Sterilization of all equipment used in seabird field research between uses, particularly between different species and islands

# 2.5 Climate Change

Human-induced climate change has been on the radar of threats to global ecosystems for many years (Oedekoven, Ainley, & Spear, 2001). While annual and decadal climate cycles fluctuate naturally and can severely impact the breeding success of seabirds (Chambers et al., 2009), the rapidity and strength of change as a result of human activity presents new risks that species may struggle to adapt to. Changes in ocean temperature and productivity, current systems, and the greater extremity of natural cycles such as the El Niño Southern Oscillation (ENSO) are projected, which may have implications for the foraging distributions of seabird species.

## 2.5.1 Increased frequency of storm events

The increased intensity and frequency of storm events associated with global climate change, in addition to rising sea levels causing coastal inundation with king tides, has the potential to destroy large amounts of nesting and roosting habitat for seabirds such as terns and gulls. The critically endangered New Zealand fairy tern is at risk of losing its breeding habitat to storm surges, as wash-outs already occur during storm events. Other species nesting on shell banks such as Caspian terns and black-billed gulls are at risk of losing habitat as well, although these birds may move and find alternative habitat elsewhere. If such events occur during breeding seasons, they are also likely to cause mortality of birds, which for the population of New Zealand fairy terns could result in near-extinction of the sub-species.

Burrowing seabirds are also at risk of extreme weather events, such as storms, causing land-slips, erosion of burrow habitat and washout of adults, eggs, or chicks, depending on the time of year. Slips on Aotea (Great Barrier Island) in 2014 reduced some breeding habitat for vulnerable black petrels, and may have result-ed in higher burrow competition in following seasons (author, pers obs, 2015/16). The ma-jor slips occurred outside the main black pet-rel breeding season, overnight on June 10th 2014. Approximately 1.3 ha of nesting habitat inside the black petrel 35 ha study area was lost, and 5 ha of habitat around the summit area immediately outside the study area as well. Other slips in the wider area around the summit and other high points on the island are also likely to have affected available black petrel habitat (at least 10 ha of habitat lost). Given black petrels are found in other areas on Aotea (Great Barrier Island) as well, the loss of habitat could be high-er (although the density of black petrels in those areas is much lower; author, pers. obs, 2014).

Stormy seas from Otata, Inner Hauraki Gulf. Photo: Edin Whitehead

**Dense algal bloom in surf on a Northland west coast beach.** Photo: Brady Doak

Over the following two seasons (2014/15 and 2015/16) there appeared to be higher levels of competition for study burrows with a higher level of crushed eggs and more interlopers fighting over burrows recorded (author, pers obs, 2015/16). This may have been caused by birds returning to the colony that season, finding their burrow destroyed by the storm and having to find a new burrow; resulting in fighting over established burrows within the study area. If the 2014 major event had occurred in the peak breeding season, it could have been more damaging as it would have resulted in a significant number of breeding failures and loss of adult breeding birds.

Increased storm frequency and intensity will also increase the turbidity of coastal waters. In addition to the sedimentation already resulting from coastal development (see 2.3.3. coastal development section), this may pose problems for visual foragers such as penguins, gannets, and shags. Mass mortalities of little blue penguins happen regularly after poor conditions (storms, marine heatwaves), as the birds are unable to forage in such conditions (Crockett & Kearns, 1975; Powlesland, 1984). Although such events occur naturally, an increased frequency of them may pose a risk for populations if the rate of mortality surpasses that of breeding success.

## 2.5.2 Increase in toxic algal blooms

Algal blooms (mass growth of marine algal species, often in dense rafts) are a common phenomenon, however in some cases they can be extremely harmful to species and ecosystems (Hallegraeff, 2003). Toxic algal blooms cause mortality in marine species such as shellfish and finfish which consume toxic macroalgae, and widespread algal blooms can suffocate marine life by causing anoxic conditions (Hallegraeff, 2003). Anomalous temperatures can contribute towards extreme bloom events, such as the one in 1992 that spanned Leigh to Bream Bay and resulted in mortality of finfish, shellfish, kelp beds, and penguins in the area (Rhodes et al., 1993). Seasonal temperature changes as a result of climate change may alter the prevalence of toxic diatom and dinoflagellate species in these blooms (Hallegraeff, 2010). The increased eutrophication of coastal waters from terrestrial runoff may also cause an increase in toxic blooms, which thrive in high-nutrient conditions (Hallegraeff, 2003, 2010). These blooms may impact seabirds, particularly penguins and shags, that forage on prey which have accumulated biotoxins, or simply by reducing prey availability is anoxic conditions cause mass die-offs in coastal waters (Duignan, 2001; Rhodes et al., 1993).

## 2.5.3 Ability of seabirds to adapt to changing conditions

There are both direct and indirect effects of climate change to take into account when considering impacts to seabird populations (Sydeman et al., 2015). Climate change impacts may affect entire ecosystems, altering primary productivity and thus changing trophic relationships among species (Doney et al., 2012). The ability of species to adapt to these changes will dictate the extent to which climate change alters their populations. Understanding which traits make species most vulnerable to projected changes is important for their conservation (Russell et al., 2015). As seabirds are long-lived and many are slow to mature, they may struggle to adapt to rapidly changing environmental conditions compared to species with shorter generation times.

Adaptive strategies for species to mitigate the impacts of climate change involve range-shifts to more optimal environments, phenological shifts in the timing of life history stages, and prey-shifting to more available resources. The capability of seabirds to adapt to climate change by range-shifting is largely unknown, especially for highly philopatric species such as burrowing seabirds (Russell et al., 2015). Species that are less tied to particular breeding sites such as gulls and terns may be better able to adapt to changes in resource distribution or thermal tolerance limits by changing their habitat location, if suitable alternatives exist. The potential effects of climate change on seabird habitat and range must be considered when developing conservation plans for populations, particularly translocations (Burger, 2018).

Changes in the timing of life history states such as moult and breeding have been observed for several seabird species, and are hypothesized to be linked to prey availability (Chambers et al., 2014). For Northern gannets, warmer than average sea temperatures were related to later breeding (Wanless et al., 2008). For little penguins in Australia and New Zealand, however, warmer sea temperatures may result in greater prey availability, earlier breeding, and greater breeding success (Cullen et al., 2009; Perriman et al., 2000). There are no consistent directional changes in phenology over time in seabirds, even within species, although delayed phenology are more common within gulls and terns, and earlier phenology in penguins (Chambers et al., 2014). For species where individuals all breed within a restricted time period, changes to colony arrival and laying dates may severely impact breeding success, and therefore make these species less likely to shift phenological timing in response to environmental change.

**Buller's shearwater.**
Photo: Edin Whitehead

Shifts in the timing and magnitude of seasonal changes in temperature and oceanic productivity (Stine, Huybers, & Fung, 2009) have the potential to cause mismatches between resource pulses (primary and secondary productivity) and the phenology of organisms that rely on these resources (Burrows et al., 2011; Thackeray et al., 2010). Mismatches between trophic levels may reduce prey availability for seabirds, which may reduce breeding success. Alternatively, changes in prey species abundance may favour certain species over others, depending on their diet (Kitaysky & Golubova, 2000). The population of Eastern rockhopper penguins on Campbell island declined by 94% between 1942 and 1984, which is largely attributed to warmer sea temperatures resulting in a lack of food within foraging distance of the colony (Morrison et al., 2015). If food sources move out of range of seabirds during their breeding season, when they are tied to the colony to provision chicks, large-scale breeding failures such as this could result.

Dense euphausiids (krill), trevally and kahawai, Mokohinau Islands.
Screenshot from video: NNZST

## 2.5.4 Prey-shifting

Prey-shifting may occur if climate change results in normal prey-sources becoming unavailable to seabirds, either by range-shifts due to thermal tolerance limits, or phenological mismatch. Little blue penguins can demonstrate prey-shifting in seasons that are poor for their usual prey species, allowing them to breed successfully despite the lack of a particular resource (Perriman et al., 2000). The impacts of this could be either positive or negative for seabird populations. Certain prey species may decline or shift in their pulse timing relative to seabird breeding cycles, but others may take their place, ameliorating the loss of one resource with another (Russell et al., 2015). 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 survival.

## 2.5.5 Large scale events

Global climatic cycles such as the El Niño Southern Oscillation (ENSO) have documented effects on seabirds, altering their breeding and foraging success, often dramatically (Schreiber & Schreiber, 1984; Surman & Nicholson, 2009). With global climate change, more intense peaks in climatic cycles such as El Niño and La Niña events are predicted (Timmermann et al., 1999), along with increased storm intensity and frequency (Easterling et al., 2000; Trenberth, 1999; Walsh & Ryan, 2000). These processes are likely to increase erosion of coastal habitats and potentially reduce available habitat for breeding and roosting seabirds. Increased storms may also cause flooding and washouts of burrow sites, in the short-term impacting breeding success if events occur at critical stages of the breeding season, causing egg or chick loss, or adults to abandon their breeding attempt. In addition, greater storm intensity and frequency will increase the turbidity of coastal waters, which may impact foraging success in visual foragers such as penguins, terns, and shags (Chambers et al., 2009). Temperature anomalies may also cause heat stress and mortality in certain species, particularly surface nesters (Cullen et al., 2009).

**Landslips on Aotea Great Barrier Island.** Photo: DOC

**White-fronted tern with anchovy.** Photo: Edin Whitehead

Environmental conditions during the non-breeding season have been shown to be equally, if not more, important for predicting breeding success in long-lived seabird species like Black-browed albatross (Jenouvrier et al., 2018). Carry-over effects from poor nutrition can greatly alter reproductive success and may also have an impact on offspring survival post-fledging. Conditions may not cause outright mortality or breeding failure, but it may change the proportion of the population that will breed in any given year as a result of resource constraints during the non-breeding season (Barbraud et al., 2012).

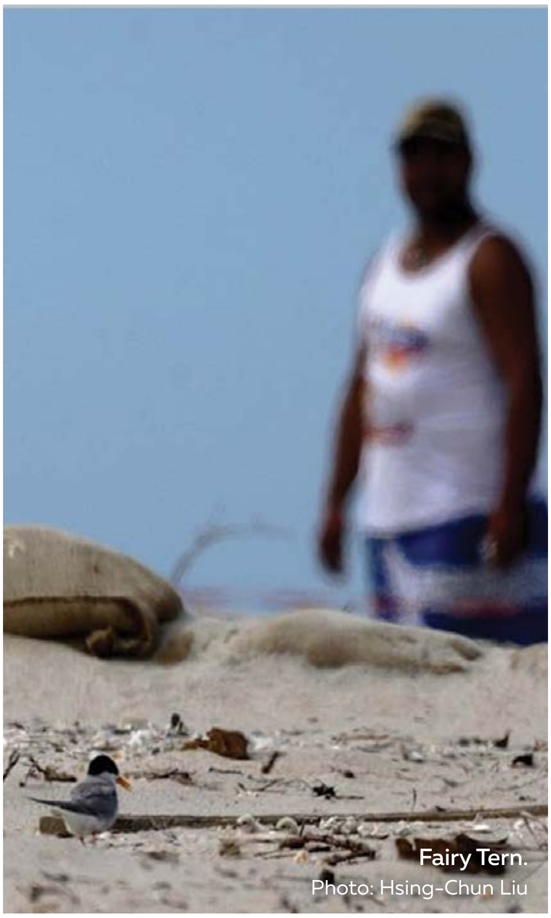
Changes in climate will affect the functional traits of seabirds, which in turn can alter demographic rates and change population trends. What is crucial is linking projected changes in climate to population-level processes and identifying what traits will make seabird species particularly vulnerable to climate change. Identifying tolerance ranges of species to determine what degree of change they can persist under at their current sites and identifying whether alternatives exist for them is also of long-term importance.

How different seabirds will respond to climate and ecosystem changes is related to many factors including their range, foraging behaviour and diet composition, nesting habitat, and life history characteristics. Some characteristics may facilitate adaptation whereas others will limit it. In short, some seabird species may fare well in a warming, and more acidic ocean conditions; others may become locally or globally extinct.

## Key measures to reduce threat

1. Establish new colonies of some highly vulnerable species as insurance against catastrophic events
2. Develop a greater understanding of the life history shifts seabirds undertake in response to specific environmental stresses

**NZ fairy tern.** Photo: Edin Whitehead



Fairy Tern.
Photo: Hsing-Chun Liu

# 2.6 Direct Human Impacts

Many seabird species spend the majority of their lives well out of sight of most people, even those living near their breeding grounds. Petrels and shearwaters are nocturnal over land and only return to breed, only coming into contact with those that also frequent the oceans, or researchers who visit colony sites. Their remarkable life histories are largely unknown to most people. Others that are more conspicuous are frequently regarded as pests or competitors for resources, such as gulls and shags. Lack of respect for seabirds is evidenced through disturbance on land and at sea and their persecution, threats that are highlighted below. Lack of awareness of seabird diversity, their status as a major component of Aotearoa New Zealand's native fauna, and as protected native species, pervades at all levels – general public awareness through to institutional and governmental levels, which does not engender support for research and conservation. Addressing this lack of awareness and respect is the goal of everyone working in seabird conservation and research.

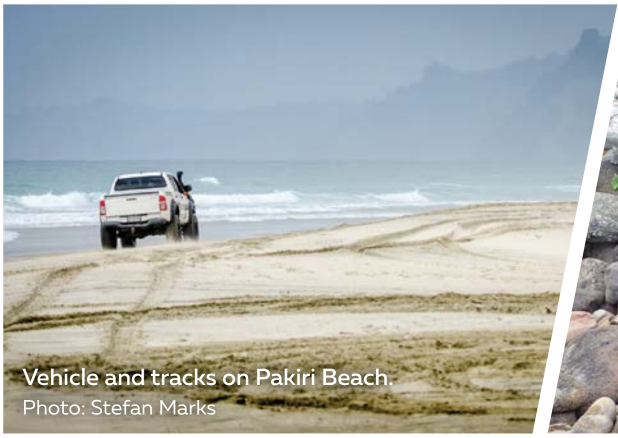
## 2.6.1 Disturbance on land

Human disturbance to seabirds on land is common. Areas that are used as roosts, particularly for terns and gulls, such as beaches and estuaries, are often used as recreational areas for people and their pets. Dog attacks on penguins are a concern throughout coastal New Zealand. Dogs that are poorly controlled can kill or maim seabirds, including moulting penguins, and harass roosting and nesting birds. Penguins moulting are extremely vulnerable to disturbance and attacks by uncontrolled dogs. Roaming pets, both cats and dogs, as well as feral animals, pose a considerable risk to seabirds in coastal settlements. In the Waitakere ranges, roaming cats potentially pose a threat to the relict populations of grey-faced petrels.

Urban development in coastal areas places immense pressure on seabird populations. Coastal subdivisions reduce the feeding, roosting and breeding habitats for seabirds such as gulls, terns, and shags, and increase the presence and access of predators such as cats and rats to colonies. Coastal development reduces biodiversity and compromises ecosystem processes in the nearshore environment (Bilkovic & Roggero, 2008; Lerberg et al., 2000). This may reduce the profitability of foraging in these areas for nearshore feeding seabird species. Other impacts of coastal development place seabirds at risk of road fatalities, particularly penguins. Road-killed little penguins are reported from other mainland colony areas in New Zealand (Heber et al., 2008; Hocken, 2000), including the West Coast of the South Island. Other birds baffled by artificial light at night (see section) may also be run over by motorists. However, the greatest threat is from increased pressure from having more people utilising coastal areas, often with a disregard or ignorance of natural values and the needs of seabirds, including the risk from pets.

Breeding sites for the critically endangered New Zealand fairy tern are on popular beaches north of Auckland, and require constant monitoring, trapping, and ranger presence throughout the summer breeding season so that nests are not disturbed. People visiting places where seabirds are breeding can lead to disturbance, trampling burrows or walking close to or through surface nesting birds, causing them to abandon nests or chicks, or leave chicks vulnerable to avian predators. Most burrowing seabirds in the region are protected from disturbance by virtue of living on islands with restricted access, and those on

Dead red-billed gull on beach.
Photo: Edin Whitehead



Vehicle and tracks on Pakiri Beach.
Photo: Stefan Marks


Remains of fire lit at Burgess Island, Mokohinau Islands.
Photo: Chris Gaskin

the mainland are not generally conspicuous and thus unlikely to be disturbed by people.

Off-road driving on beaches is common throughout New Zealand, and can cause seabird and shorebird fatalities, in many cases of nesting birds that are camouflaged against the sand. An easy way of addressing this threat is to restrict driving on beaches to times of year when seabirds are not breeding, which will reduce the likelihood of birds being run over.

## 2.6.2 Fire

Fires may result from lightning strikes, however human-lit fires pose a considerable risk to seabird populations within the region. Fire restrictions are in place on many islands, for example, Pokohinu (Burgess Island) in the Mokohinau group has a complete fire ban which is signposted on the landing bay. It is the only island in the group that is not a restricted nature reserve and day visitors are allowed to land. Signs of campfires have been observed on the beach near the vegetation, which covers the nests of diving petrels, fluttering shearwaters and little penguins (authors pers. obs, 2019). During dry summers, the potential for a fire to consume vegetation on the island is high, which would destroy habitat for these species, as well as potentially killing adult birds or fledglings. Remote islands such as these are difficult to monitor and enforce, relying on day visitors to act responsibly.

On islands that are regenerating from pasture, fire prone vegetation such as gorse, rank grass, and manuka are common. These habitat types can be around or near seabird colonies (example, Mahuki Island gannet colony), presenting a significant risk of fire damage to breeding sites. Educating day-visitors through detailed information boards may encourage compliance with fire bans, but remote-monitoring may be necessary to prevent potential disasters resulting from irresponsible visitors lighting fires on these sensitive islands.

## 2.6.3 Disturbance on water

Boats approaching too close to shag, gull or tern colonies during breeding can disturb birds, causing them to briefly abandon chicks, leaving them at risk of predation. Seabirds can form large dense groups when feeding or resting on the water's surface. Such groups can be made up of thousands of birds and cover several hundred square metres. The seabirds that most common-

Launch driving at speed through a raft of Buller's shearwaters.
Photo: Edin Whitehead

ly raft in the wider Hauraki Gulf include highly threatened or locally significant species: Buller's shearwater, flesh-footed shearwater, fluttering shearwater, black petrel, Cook's petrel, fairy prion, Northern common diving petrel, little penguin and Australasian gannet. Species composition may vary seasonally, however these large rafts or feeding flocks can be found throughout the Hauraki Gulf all year round. While they are less likely on Auckland's west coast (including the Kaipara and Manukau Harbours) where seabird populations are much smaller, the same risks arise to rafting seabirds there. These flocks often indicate the presence of schooling fish such as trevally (*Pseudocaranx dentex*), kahawai (*Arripis trutta*) and skipjack tuna, and as such, recreational fishing vessels come into contact with them.

Boats have been observed by the authors speeding through resting and feeding flocks. Birds can struggle to take off in front of speeding boats, especially in calm or light conditions. Diving seabirds are at great risk as underwater they need to return to surface to breathe, and if a boat is speeding through a flock they could easily be hit and killed outright or injured. Injured seabirds are unlikely to survive, as if they are unable to fly or swim, they will starve to death. If the bird is a breeding adult, its chick will also be unlikely to survive with only one parent to feed it. Speed is the critical risk factor to seabirds, as given enough time, they can easily avoid moving vessels.

## 2.6.4 Persecution

*"I vividly remember forty or more years ago cruising along the coast of Waiheke.... spotted shags in those days not protected, were flying past in a constant stream all the afternoon, and, as is their habit, swerving in their course to try and pass ahead of the yacht. Two members of the crew armed with shot guns amused themselves for hours practising on the flying birds: shooting went on till all cartridges were expended and probably a hundred or more dead or dying birds were left lying in the water."*

G. Buddle, excerpt from "Bird Secrets" 1951.

Historically, seabirds have been persecuted for 'competing' with human interests, an example being breeding colonies of spotted shags shot to extermination by fishermen in the early 20$^{th}$ century 'because shags eat fish' (T. Lovegrove, pers. comm. 2018). While the persecution of seabirds has declined, and they are no longer shot in large numbers for 'competing' with fishermen, there are still many instances where numbers of individuals are harassed, injured, and even killed. This happens both at sea and on land. Recent examples include a fishermen working off the west coast of the South Island being prosecuted for repeated acts of cruelty over a number of years towards seabirds such as white-capped albatross and cape petrels (**https://www.stuff.co.nz/environment/105239766/fishermen-found-guilty-of-multiple-acts-of-cruelty-to-sea-birds**).

On land, shags, gulls and penguins have been shot or stoned, sometimes in massive numbers as in a few instances with black-billed gulls in Canterbury and Southland, and red-billed gulls shot, run over and stamped to death in Kaikoura (**https://www.stuff.co.nz/environment/104783481/redbilled-gulls-shot-stomped-in-cowardly-cruel-and-malicious-attack-at-kaikoura-wharf**). Black-billed gulls have recently been shot at their declining Rotorua colony (**https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12201154**), and three little blue penguins were removed from their burrows and one killed during a raid in Napier (**https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12202138**). These incidents are common, but penalties are not often enforced. Recreational fishers have also harmed and killed seabirds intentionally at sea (Tennyson, 2015). Greater awareness of the importance of our seabird species in the general public is needed to address this. While there will always be those individuals who care nothing for the natural environment, a national knowledge and pride in our seabird biodiversity could go a long way to preventing active persecution.

## 2.6.5 Researcher disturbance

Research on seabirds is often by nature an invasive process, as gathering data requires either observation or handling of birds. Researchers must work under independent ethical approval to minimise disturbance to their study species, to ensure that any project maximises the knowledge gained while having the least impact on the birds studied. Researcher presence, particularly in dense colonies, can have impacts on survival and breeding success (Smith & Carlile, 1993). In cases where ethical approval is not re-

**Spotted shag.**
Photo: Edin Whitehead

quired for particular projects, researchers must still behave to the highest level of conduct, setting an example to others.

The use of drones to assess surface-nesting seabird colonies presents a method of reducing investigator disturbance and accessing previously inaccessible colonies. This may not be the case for all species, as some birds have aggressive responses to drones (Borrelle & Fletcher, 2017). Within the region gull species, particularly Southern black-backed gulls, have been observed interacting aggressively with drones, which depending on the size of the unit, has the potential to cause birds injury.

The use of thermal imaging technology reduces the impacts of researcher disturbance to nocturnal seabirds such as shearwaters and penguins and is particularly useful for non-invasive monitoring. Lights at night, even headlamps, cause disturbance to these species and alter their behaviours. Studies wishing to observe natural behaviours and perform nocturnal surveys will greatly benefit from this technology. Trail cameras are also useful for observing birds without human presence, capturing behaviours at colony and burrow sites without disturbance.

## 2.6.6 Harvesting

Harvesting of seabirds in New Zealand is tightly regulated by the Wildlife Act. Grey-faced petrels are the 'mutton-bird' of northern iwi, and harvesting chicks is permitted on certain islands. Since the 1970s, Hauraki iwi have placed a rāhui (ban) on cultural harvesting due to concerns that the populations were declining (Lyver et al., 2008). Harvesting may prevent populations from increasing to a level where historical practices would be sustainable. Conservation and restoration goals can be balanced with preserving traditional cultural practice, but this requires reconciling conflicting value systems around preservation and usage. Illegal mutton-birding is reported to occur on some islands, with side effects including destruction of burrows and exposing islands to other threats such as introduction of pests and predators.

Grey-faced petrel chick in
a researcher's lap during study.
Photo: Chris Gaskin

## Key measures to reduce threat

1. Improved controls in Regional and District plans for coastal developments e.g. restricting cat ownership and dog areas; including predator management as a requirement around developments adjacent to key seabird habitat.
2. Protect key coastal seabird habitat from development.
3. Education of fishers around seabird flocks, speed restrictions around flocks in local plans. Instigating a maximum speed of 5 knots around rafting seabirds would reduce the risk of injury and mortality by boat-strike.
5. Addition of IBAs in regional planning documents with rules to protect seabird values.

# 3 Knowledge Gaps - Seabirds

**New Zealand storm petrel.**
Photo: Edin Whitehead

In this section, we summarise crucial gaps in our knowledge regarding seabird species in the region.

## 3.1 Populations

Many seabird species breeding in the region lack reliable, recent population estimates. While knowing exact numbers is not always critical to address threats, this lack of baseline knowledge impedes monitoring population trends, which is important for conservation management. Population estimates for New Zealand storm petrels and Buller's shearwaters are currently underway, however, many other species remain to be surveyed. Also important is determining the location of primary breeding sites for certain species, such as fluttering and little shearwaters. At the same time, identifying sites that are accessible for population monitoring and other ecological work on these species is another important step in developing a monitoring programme to assess the health and trends of these populations in the region.

### Required research:

- Updated population estimates for all breeding seabird species, to be collated for ease of reference.
- Identification of priority sites for ongoing population monitoring and other research.

## 3.2 Foraging Ecology

Observational and tracking data will contribute to determining key foraging areas for seabirds in Northern New Zealand, and monitor seasonal and annual changes in those sites. Identifying how seabirds use the Hauraki Gulf and shelf waters to forage will be important in determining whether there are areas we can impart greater marine protection on to minimise threats to seabirds. These areas may fluctuate seasonally, and as seabirds are often wide-ranging foragers, be distant from their breeding islands.

In addition, dietary studies are required to determine what seabirds in the Gulf are feeding on. From this, competition with fisheries and the indirect effects of fisheries on seabirds can be identified. Seabirds from different colonies may show differences in diet or foraging area, or differences between years, as has recently been seen in Australasian gannets (N. Adams, unpublished data). Use of both foraging movement and dietary data will help in building the case for better marine protection in the region.

### Required research:

- Tracking foraging movements of seabirds in the Hauraki Gulf, particularly during crucial life-history stages such as chick-rearing and juvenile periods, and potentially comparing these to non-breeding birds.
- Identification of marine areas that support a large number of foraging seabirds, "hot-spots" which may vary seasonally.
- Dietary studies of seabirds.

## 3.3 Trophic ecology

In addition to the foraging ecology of seabirds themselves, it is important to build a picture of the wider ecosystem in which they function and the trophic interactions between species. By identifying the key prey species that build the Hauraki Gulf 'food-web', we can form a better understanding of how the system functions and how it may be vulnerable to change as a result of overfishing, climate change, or pollution.

### Required research:

- Identification of primary prey species of Northern New Zealand seabirds, and their prey.
- Modelling of dietary shifts between seasons, breeding stages, and years, to determine impacts of these factors on seabird diet and condition.
- Develop nutritional models of prey targeted by specific species, monitor changes in nutritional value across years.
- Develop a comprehensive 'food-web' for the Hauraki Gulf and Northern New Zealand, identifying key species and interactions, as well as fisheries interactions.

## 3.4 Behaviour

Understanding the capacity of seabirds to adapt to changes in their environment is crucial to determining their resilience to threats. Will species be able to relocate breeding sites should the effects of climate change extirpate them from current sites? Can they shift their breeding cycle to coincide with phenological shifts in their key prey species? Certain species may be more adaptable than others. This is a challenging area of research that will require long term monitoring of populations to identify their tolerance to environmental fluctuations.

### Required research:

- Monitoring of seabird populations and breeding success in association with varying environmental conditions.
- Identification of physiological tolerance limits to fluctuations in temperature, prey availability, etc.

## 3.5 Management

Conservation management is more effective with the above knowledge of seabird biology and ecology. However, it is impossible in many cases to wait for this knowledge before making decisions to intervene and protect at-risk species. Concurrent to the above suggested research, seabird conservation tools must be developed to assist some of our most at-risk species before it is too late (Friesen, Beggs, & Gaskett, 2017).

### Required research:

- Ongoing development of restoration tools and techniques to increase at-risk seabird populations.
- Identify where management is necessary and prioritise action (translocations, passive attraction to predator-free sites, pest control, habitat restoration, legislative change, education).
- Explore the concept of marine temporal planning for free-ranging marine fauna such as seabirds, cetaceans, sharks and other pelagic fish whose movements with northern waters are dictated by searching out prey, and in the case of seabirds passage in and out of colonies during breeding.

# 4 Knowledge Gaps - Threats to Seabirds

Flesh-footed shearwater and mako shark.
Photo: Richard Robinson (Depth NZ)/NNZST/DOC

In this section, we summarise crucial gaps in our knowledge regarding threats to seabird species in the region.

## 4.1 Invasive Alien Species and Biosecurity

This particular threat is one that is being addressed currently, with the nation-wide push for predator-free areas. Improving detection of incursions and efficiency of predator control are areas of research that would benefit not only seabirds, but all of our native species and ecosystems. However ongoing education and engagement with communities is vital to maintaining momentum for these projects and establishing predator-free mainland areas. Alternatives to current predator control methods to assist in safeguarding mainland areas require investigation.

### Required research:

- Development of remote pest monitoring technology for early-detection of incursions of predator-free islands and also for contributing to mainland sites pest management.
- Engagement with local communities on inhabited islands to increase predator control and social capacity for eradication.

## 4.2 Fisheries

The threat of fisheries to seabirds is one that we know enough about to make decisions regarding mitigation without the need for more research. However, there are still gaps in our knowledge to be addressed.

### Required research:

Identify areas of overlap between seabird foraging and fishing (for both by-catch and deck-strike mitigation).

## 4.3 Pollution

Key areas that require investigation in our region are plastics, light pollution, and sedimentation. Key to mitigating these are identifying the main sources and locations and species most at risk.

### Required research:

- Determine primary source(s) of plastic pollution in Northern New Zealand.
- Determine hotspot areas of plastic pollution and areas of overlap with seabird foraging.
- Identify which species are most likely to be impacted by plastics, the extent to which plastic ingestion impacts survival and breeding success.

- Determine which species are most affected by fallout, and how different colour lights may reduce fallout.
- Identify high-risk areas by season (fledging) around seabird islands for vessel light restrictions.
- Assess how sedimentation impacts coastal foragers and identify mitigation strategies that should be built in to coastal development plans.

## 4.4 Disease

We lack any knowledge regarding the immunological status of our resident seabirds, and thus their vulnerability to disease.

### Required research:

- Disease prevalence in seabird species to identify potential disease risks.

## 4.5 Climate Change

The impacts of climate change on seabirds span from habitat loss to changes in resource availability. While the extent and timing of these threats to seabirds is unknown in our region, they are also difficult to assess, and will require some long-term study.

### Required research:

- Assess whether there are suitable alternative areas for seabird breeding habitat if they are forced from their current sites through erosion, storm surges, and identify if populations can be shifted as insurance or their current habitat modified to provide more protection.
- Determine thermal tolerance limits of key prey species and 'tipping points' where changing environmental conditions may alter food-web dynamics.
- Model changes in prey distribution under different warming scenarios, related to seabird foraging capabilities, to determine whether current colonies will still be able to access key prey species.

## 4.6 Direct Human Impacts

Increasing public awareness of seabirds and the threats they face is an important activity to raise their profile. Identifying the most effective ways to achieve behavioural and policy change relevant to all threats is a critical action.

### Required research:

- Establish educational portals and resources to engage different groups (online, social media, public talks, seminars, school programmes).
- Develop tools to enable behavioural and policy change which benefits seabirds.

**Flesh-footed shearwater.**
Photo: Edin Whitehead

# 5 Conclusions

Within our region we have identified many threats to both our native resident seabirds, and those that visit on a seasonal basis. While these threats will impact species to different extents, and in some cases not at all, moving towards reducing, mitigating, and eliminating these threats is important for the conservation of our most threatened species. Balancing the need for research and the need for rapid action to protect our most at-risk species will be the challenge of the next few years.

Although we have separated them into sections, the threats identified here cannot be considered in isolation from one another. They are interactive, and may act synergistically to cause greater harm to seabird populations than any single threat (Sydeman, Thompson, & Kitaysky, 2012). The accumulated pressure of a number of threats may be enough to drive a species to extinction whereas a single one would not. A holistic approach to both research and conservation strategy is required to mitigate the effects of these threats on our seabird species. However, actions that can be taken addressing single threats, such as regulating the extent of artificial light at night, will help lessen the load on these species. Already this particular threat has seen action, with cruise operators in the Hauraki Gulf working to reduce light-spill from vessels (Cropp, 2019). Next to be considered are the impacts of other night-working vessels, and urban lighting.

Support for research is essential for conservation work to be well directed. The Department of Conservation's Conservation Services Programme (CSP) has provided funding for seabird research in the region targeting species identified at-risk from fisheries in both direct and indirect ways. In the Auckland region, support for seabird research is being well addressed by Auckland Council, with a new seabird scientist role and the provision of funds for research contributing to the monitoring and restoration of seabirds in the Auckland region. However, seabirds know no borders, including those between national regions. Many seabird islands lie outside the region administered by Auckland Council, home to species that forage throughout the inner Hauraki Gulf, such as Buller's and fluttering shearwaters. These species face threats at sea as well as on their breeding islands, which need to be addressed in these monitoring and conservation plans. Co-ordinated national effort to improve seabird monitoring and conservation is required, especially in the Northern New Zealand region.

There is always the danger of complacency in recommending more research, as it delays the urgency of action that is required in some cases.

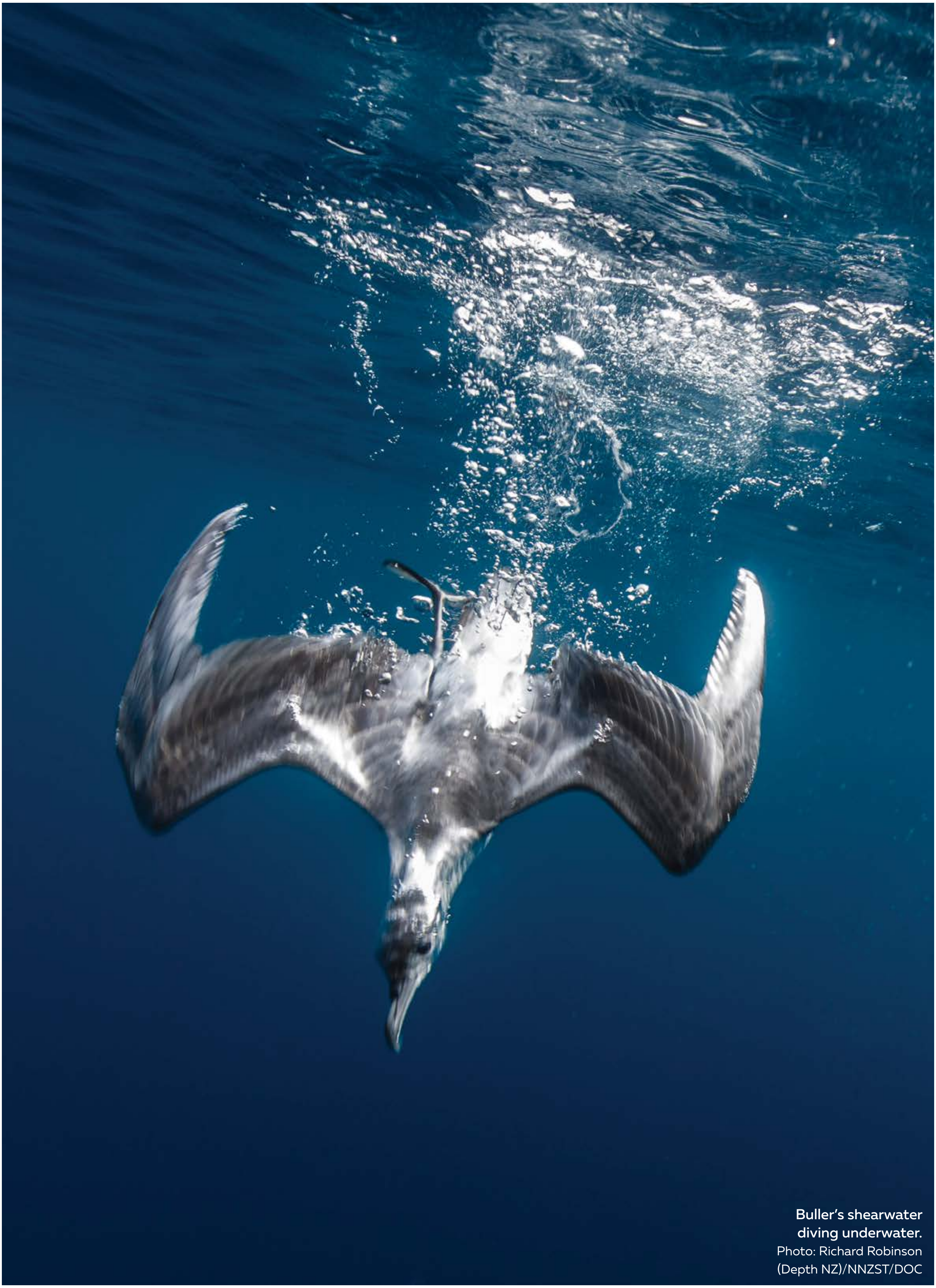
**Buller's and fluttering shearwaters and fairy prions.**
Photo: Edin Whitehead

For many threats, conservation action can be initiated without the need to know exactly the extent of the threat, as any mitigating actions will be beneficial not just for seabirds, but the marine environment in general. For example, reducing plastics input into the Hauraki Gulf system can only be beneficial for the species living and foraging within its waters, and while we are unaware to what extent plastics are impacting particular seabird species, this does not prevent us from beginning to tackle this problem, particularly as there are other groups of species also impacted and increasing evidence of risks to human health.

Reducing predator presence on the mainland benefits not only seabirds but other terrestrial bird species, reptiles, invertebrates and plants. Communities working on pest control and eradication projects will reap the benefits of more intact ecosystems where native species can flourish and be able to welcome seabirds back to areas they historically have bred. With the intense predator management by the Karioi Maunga project in Raglan, grey-faced petrels are beginning to fledge chicks from burrows along the coastline, sometimes in residential backyards (K. Vanhoute, pers comm, 2018). Similar successes are occurring at Cornwallis, Tuateawa on the Coromandel coast, and on Waiheke Island and inhabited headlands north of Tutukaka.

Support from both national and local governmental bodies is important for the protection of seabirds, as their legislative power is necessary for certain changes to be made. Collaborations between researchers, the Department of Conservation, iwi, councils, and communities will result in better outcomes for the conservation of seabirds. Non-governmental organisations such as the Royal Forest and Bird Protection Society and the Northern New Zealand Seabird Trust play important roles in terms of advocacy and directing and supporting research and conservation efforts. Establishing restoration plans fuels community engagement in these projects, contributing to building awareness around seabirds and the threats they face. Seabird research and conservation is not restricted to scientists and conservation workers – it requires the support of all these interest groups to be most effective. Finally, seabird restoration requires healthy, intact marine ecosystems to support recovering populations, requiring a whole-ecosystem approach to conservation rather than a species-based one.

While it is important to pursue research to better understand seabirds and the threats they face, it is more important to act to conserve them sooner rather than later. These species are the foundation on which our ecosystems rest, and for their own intrinsic value should be protected in the face of damages that we have wrought.



**Buller's shearwater diving underwater.**
Photo: Richard Robinson (Depth NZ)/NNZST/DOC

# References


Abraham, E. R., Berkenbusch, K. N., & Richard, Y. (2010). *The capture of seabirds and marine mammals in New Zealand non-commercial fisheries* (New Zealand Aquatic Environment and Biodiversity Report No. 64). Wellington: Ministry of Fisheries. Retrieved from https://www.dragonfly.co.nz/publications/pdf/Abrahametal_2010_AEBR64.pdf

Abrahim, G., & Parker, R. (2002). Heavy-metal contaminants in Tamaki Estuary: impact of city development and growth, Auckland, New Zealand. *Environmental Geology*, *42*(8), 883–890.

ACAP. (2017). *ACAP Review and Best Practice Advice for Reducing the Impact of Pelagic Longline Fisheries on Seabirds*. Retrieved from https://www.acap.aq/en/resources/bycatch-mitigation/mitigation-advice/3242-acap-2017-review-and-best-practice-advice-for-reducing-the-impact-of-pelagic-longline-fisheries-on-seabirds/file

Alonso-Alvarez, C., Munilla, I., López-Alonso, M., & Velando, A. (2007). Sublethal toxicity of the Prestige oil spill on yellow-legged gulls. *Environment International*, *33*(6), 773–781. https://doi.org/10.1016/j.envint.2007.02.012

Anderson, O. R. J., Small, C. J., Croxall, J. P., Dunn, E. K., Sullivan, B. J., Yates, O., & Black, A. (2011). Global seabird bycatch in longline fisheries. *Endangered Species Research*, *14*(2), 91–106. https://doi.org/10.3354/esr00347

Anderson, S. H. (1992). Shearwaters and Saddleback as prey at a Morepork ground nest. *Notornis*, *39*, 69–70.

Andrady, A. L. (2015). Persistence of Plastic Litter in the Oceans. In M. Bergmann, L. Gutow, & M. Klages (Eds.), *Marine Anthropogenic Litter* (pp. 57–72). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-16510-3_3

Artham, T., Sudhakar, M., Venkatesan, R., Madhavan Nair, C., Murty, K. V. G. K., & Doble, M. (2009). Biofouling and stability of synthetic polymers in sea water. *International Biodeterioration & Biodegradation*, *63*(7), 884–890. https://doi.org/10.1016/j.ibiod.2009.03.003

Ashton, K., Holmes, L., & Turner, A. (2010). Association of metals with plastic production pellets in the marine environment. *Marine Pollution Bulletin*, *60*(11), 2050–2055. https://doi.org/10.1016/j.marpolbul.2010.07.014

Atkinson, I. A. E. (1985). The spread of commensal species of Rattus to islands and their effects on island avifaunas. In *Conservation of Island Birds* (pp. 35–81). Cambridge.

Au, D. W., & Pitman, R. L. (1986). Seabird interactions with dolphins and tuna in the eastern tropical Pacific. *Condor*, *88*, 304–317.

Auman, H. J., Ludwig, J. P., Giesy, J. P., & Colborn, C. (1998). Plastic ingestion by Laysan Albatross chicks on Sand Island, Midway Atoll, in 1994 and 1995. Retrieved from http://www.surreybeatty.com.au/Birds.html

Azzarello, M. Y., & Van Vleet, E. S. (1987). Marine birds and plastic pollution. *Marine Ecology Progress Series*, *37*(2/3), 295–303. Retrieved from http://www.jstor.org.ezproxy.auckland.ac.nz/stable/24824704

Barbraud, C., Rolland, V., Jenouvrier, S., Nevoux, M., Delord, K., & Weimerskirch, H. (2012). Effects of climate change and fisheries bycatch on Southern Ocean seabirds: a review. *Marine Ecology Progress Series*, *454*, 285–307. https://doi.org/10.3354/meps09616

Barbraud, C., & Weimerskirch, H. (2006). Antarctic birds breed later in response to climate change. *Proceedings of the National Academy of Sciences*, *103*(16), 6248–6251. https://doi.org/10.1073/pnas.0510397103

Barnes, D. K. A., Galgani, F., Thompson, R. C., & Barlaz, M. (2009). Accumulation and fragmentation of plastic debris in global environments. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *364*(1526), 1985–1998. https://doi.org/10.1098/rstb.2008.0205

Barros, Á., Álvarez, D., & Velando, A. (2014). Long-term reproductive impairment in a seabird after the Prestige oil spill. *Biology Letters*, *10*(4), 20131041. https://doi.org/10.1098/rsbl.2013.1041

Bartle, J. A. (1990). Sexual segregation of foraging zones in procellariiform birds: implications of accidental capture on commercial fishery longlines of grey petrels (Procellaria cinerea). *Notornis*, *37*(2), 146–150.

Bassett, I. E., Cook, J., Buchanan, F., & Russell, J. C. (2016). Treasure Islands: biosecurity in the Hauraki Gulf Marine Park. *New Zealand Journal of Ecology*, *40*(2), 250–266. Retrieved from http://www.jstor.org.ezproxy.auckland.ac.nz/stable/26198757

Bell, E. A. (2011). *Identification of seabirds captured in New Zealand fisheries: 1 October 2010 – 30 June 2011*. (CSP Contract Report). Wellington: Department of Conservation. Retrieved from http://www.doc.govt.nz/documents/conservation/marine- and-coastal/marine-conservation-services/int-2010-01-seabird-id-final-report-oct- 2010-to-june-2011.pdf

Bell, E. A. (2012). *Identification of seabirds captured in New Zealand fisheries: 1 July 2011 – 30 June 2012*. (CSP Contract Report). Wellington: Department of Conservation. Retrieved from http://www.doc.govt.nz/Documents/conservation/marine- and-coastal/marine-conservation-services/int-2010-02-seabird-id-final-report- 2011-12.pdf

Bell, E. A. (2014). *Identification of seabirds captured in New Zealand fisheries: 1 July 2012–30 June 2013*. (CSP Contract Report) Wellington: Department of Conservation. Retrieved from https://www.doc.govt.nz/our-work/conservation-services-programme/csp-reports/2012-13/identification-of-seabirds-captured-in-nz-fisheries-2012-13/

Bell, E. A., Mischler, C., MacArthur, N., Sim, J. L., & Scofield, P. (2016). *Population parameters of the black petrels (Procellaria parkinsoni) on Great Barrier Island (Aotea Island), 2015/16* (Report to the Conservation Services Programme). Wellington, New Zealand: Department of Conservation. Retrieved from https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-conservation-services/reports/pop2015-01-black-petrel-gbi-final.pdf

Bell, E. A., & Sim, J. L. (2005). *Survey and monitoring of black petrels on Great Barrier Island, 2003/04*. (DOC Research and Development Series No. 213). Wellington: Department of Conservation. Retrieved from https://www.doc.govt.nz/globalassets/documents/science-and-technical/drds213.pdf

Bell, Elizabeth A., Bell, B. D., & Merton, D. V. (2016). The legacy of Big South Cape. *New Zealand Journal of Ecology*, *40*(2), 212–218.

Bellingham, P. J., Towns, D. R., Cameron, E. K., Davis, J. J., Wardle, D. A., Wilmshurst, J. M., & Mulder, C. P. (2010). New Zealand island restoration: seabirds, predators, and the importance of history. *New Zealand Journal of Ecology*, *34*, 115.

Bilkovic, D. M., & Roggero, M. M. (2008). Effects of coastal development on nearshore estuarine nekton communities. *Marine Ecology Progress Series*, *358*, 27–39. https://doi.org/10.3354/meps07279

Borrelle, S. B., Boersch-Supan, P. H., Gaskin, C. P., & Towns, D. R. (2016). Influences on recovery of seabirds on islands where invasive predators have been eradicated, with a focus on Procellariiformes. *Oryx*, *52*(2), 1–13. https://doi.org/10.1017/S0030605316000880

Borrelle, S. B., & Fletcher, A. T. (2017). Will drones reduce investigator disturbance to surface-nesting seabirds? *Marine Ornithology*, *45*, 89–94.

Bouland, A. J., White, A. E., Lonabaugh, K. P., Varian-Ramos, C. W., & Cristol, D. A. (2012). Female-biased offspring sex ratios in birds at a mercury-contaminated river. *Journal of Avian Biology*, *43*(3), 244–251. **https://doi.org/10.1111/j.1600-048X.2012.05612.x**

Bourret, V., Gamble, A., Tornos, J., Jaeger, A., Delord, K., Barbraud, C., Tortosa, P., Kada, S., Thiebot, J.-B., Thibault, E., Gantelet, H., Weimerskirch, H., Garnier, R., & Boulinier, T. (2018). Vaccination protects endangered albatross chicks against avian cholera. *Conservation Letters*, *11*(4), e12443.

Bregnballe, T., & Frederiksen, M. (2006). Net-entrapment of great cormorants Phalacrocorax carbo sinensis in relation to individual age and population size. *Wildlife Biology*, *12*(2), 143–150. https://doi.org/10.2981/0909-6396(2006)12[143:NOGCPC]2.0.CO;2

Brooke, M. (2004). *Albatrosses and petrels across the world*. Oxford University Press.

Brooke, M. D. L., Bonnaud, E., Dilley, B. J., Flint, E. N., Holmes, N. D., Jones, H. P., & Buxton, R. T. (2018). Seabird population changes following mammal eradications on islands. *Animal Conservation*, *21*(1), 3–12.

Browne, M. A., Niven, S. J., Galloway, T. S., Rowland, S. J., & Thompson, R. C. (2013). Microplastic Moves Pollutants and Additives to Worms, Reducing Functions Linked to Health and Biodiversity. *Current Biology*, *23*(23), 2388–2392. https://doi.org/10.1016/j.cub.2013.10.012

Bugoni, L., Griffiths, K., & Furness, R. W. (2011). Sex-biased incidental mortality of albatrosses and petrels in longline fisheries: differential distributions at sea or differential access to baits mediated by sexual size dimorphism? *Journal of Ornithology*, *152*(2), 261–268. https://doi.org/10.1007/s10336-010-0577-x

Bull, L. S. (2007a). *A review of methodologies for mitigating incidental catch of seabirds in New Zealand fisheries* (Science & Technical Publication). Department of Conservation.

Bull, L. S. (2007b). Reducing seabird bycatch in longline, trawl and gillnet fisheries. *Fish and Fisheries*, *8*(1), 31–56. https://doi.org/10.1111/j.1467-2979.2007.00234.x

Bull, L. S. (2009). New mitigation measures reducing seabird by-catch in trawl fisheries. *Fish and Fisheries*, *10*(4), 408–427. https://doi.org/10.1111/j.1467-2979.2009.00327.x

Burger, J. (2018). Understanding population changes in seabirds requires examining multiple causal factors and developing science-based adaptive species conservation plans. *Animal Conservation*, *21*(1), 17–18.

Burger, J., & Gochfeld, M. (2004). Marine birds as sentinels of environmental pollution. *EcoHealth*, *1*(3), 263–274.

Burrows, M. T., Schoeman, D. S., Buckley, L. B., Moore, P., Poloczanska, E. S., Brander, K. M., … Richardson, A. J. (2011). The Pace of Shifting Climate in Marine and Terrestrial Ecosystems. *Science*, *334*(6056), 652–655. https://doi.org/10.1126/science.1210288

Buxton, R. T., Currey, C. A., Lyver, P. O., & Jones, C. J. (2013). Incidence of plastic fragments among burrow-nesting seabird colonies on offshore islands in northern New Zealand. *Marine Pollution Bulletin*, *74*(1), 420–424. https://doi.org/10.1016/j.marpolbul.2013.07.011

Cadée, G. C. (2002). Seabirds and floating plastic debris. *Marine Pollution Bulletin*, *44*(11), 1294–1295. https://doi.org/10.1016/S0025-326X(02)00264-3

Cairns, D. K. (1987). Seabirds as indicators of marine food supplies. *Biological Oceanography*, *5*, 261–271.

Chambers, L., Congdon, B., Dunlop, N., Dann, P., Devney, C., & P And Devney, D. (2009). *Seabirds and Climate Change* (A Marine Climate Change Impacts and Adaptation Report Card for Australia 2009). NCCARF. Retrieved from https://www.researchgate.net/profile/Peter_Dann/publication/228472983_Seabirds_and_Climate_Change/links/0046352442848bfa0c000000/Seabirds-and-Climate-Change.pdf

Chambers, L. E., Dann, P., Cannell, B., & Woehler, E. J. (2014). Climate as a driver of phenological change in southern seabirds. *International Journal of Biometeorology*, *58*(4), 603–612. https://doi.org/10.1007/s00484-013-0711-6

Crawford, R., Ellenberg, U., Frere, E., Hagen, C., Baird, K., Brewin, P., Crofts, S., Glass, J., Mattern, T., Pompert, J., Ross, K., Kemper, J., Ludynia, K., Sherley, R. B., Steinfurth, A., Suazo, C. G., Yorio, P., Tamini, L., Mangel, J. C., Bugoni, L., Uzcátegui, G. J., Simeone, A., Luna-Jorquera, G., Gandini, P., Woehler, E. J., Pütz, K., Dann, P., Chiaradia, A., & Small, C. (2017). Tangled and drowned: a global review of penguin bycatch in fisheries. *Endangered Species Research*, *34*, 373–396. https://doi.org/10.3354/esr00869

Crawford, R. J. M., Davis, S. A., Harding, R. T., Jackson, L. F., Leshoro, T. M., Meyer, M. A., Randall., R. M., Underhill, L. G., Upfold, L., Van Dalsen, A. P., van der Merwe, E., Whittington, P. A., Williams, A. J., & Wolfaardt, A. C. (2000). Initial impact of the treasure oil spill on seabirds off western South Africa. *African Journal of Marine Science*, *22*, 157-176.

Crockett, D. E., & Kearns, M. P. (1975). Northern little blue penguin mortality in Northland. *Notornis*, (22), 69–72.

Croll, D. A., Maron, J. L., Estes, J. A., Danner, E. M., & Byrd, G. V. (2005). Introduced predators transform subarctic islands from grassland to tundra. *Science*, *307*, 1959–1961.

Cropp, A. (2019). Bird deaths lead cruise industry to dim dazzling lights at night. Retrieved from https://www.stuff.co.nz/business/110146483/bird-deaths-lead-cruise-industry-to-dim-dazzling-lights-at-night

Croxall, J. P. (2008). Seabird mortality and trawl fisheries. *Animal Conservation*, *11*(4), 255–256.

Croxall, J. P., Rothery, P., Pickering, S. P. C., & Prince, P. A. (1990). Reproductive performance, recruitment and survival of wandering albatrosses *Diomedea exulans* at Bird Island, South Georgia. *The Journal of Animal Ecology*, *59*(2), 775–796.

Croxall, John P., Butchart, S. H., Lascelles, B. E. N., Stattersfield, A. J., Sullivan, B. E. N., Symes, A., & Taylor, P. (2012). Seabird conservation status, threats and priority actions: a global assessment. *Bird Conservation International*, *22*, 1–34.

Cullen, J. M., Chambers, L. E., Coutin, P. C., & Dann, P. (2009). Predicting onset and success of breeding in little penguins Eudyptula minor from ocean temperatures. *Marine Ecology Progress Series*, *378*, 269–278. https://doi.org/10.3354/meps07881

Dawson, S. M., & Slooten, E. (2005). Management of gillnet bycatch of cetaceans in New Zealand. *Journal of Cetacean Research and Management*, *7*(1), 59.

de Lisle, G. W., Stanislawek, W. L., & Moors, P. J. (1990). Pasteurella multocida Infections in Rockhopper Penguins (Eudyptes chrysocome) from Campbell Island, New Zealand. *Journal of Wildlife Diseases*, *26*(2), 283–285.

Dell'Ariccia, G., Célérier, A., Gabirot, M., Palmas, P., Massa, B., & Bonadonna, F. (2014). Olfactory foraging in temperate waters: sensitivity to dimethylsulphide of shearwaters in the Atlantic Ocean and Mediterranean Sea. *Journal of Experimental Biology*, *217*(10), 1701–1709.

Deppe, L., Rowley, O., Rowe, L. K., Shi, N., Gooday, O., & Goldstien, S. J. (2017). Investigation of fallout events in Hutton's shearwaters (*Puffinus huttoni*) associated with artificial lighting. *Notornis*, *64*(4), 181–191.

Dillingham, P. W., & Fletcher, D. (2011). Potential biological removal of albatrosses and petrels with minimal demographic information. *Biological Conservation*, *144*(6), 1885–1894.

Dire warnings over wreck of the Niagara. (2017). Retrieved from https://www.radionz.co.nz/news/national/338308/dire-warnings-over-wreck-of-the-niagara

Dirty water raises health risks at Auckland beaches. (2018). *Radio New Zealand*. Retrieved from https://www.radionz.co.nz/news/national/379052/dirty-water-raises-health-risks-at-auckland-beaches

Doney, S. C., Ruckelshaus, M., Emmett Duffy, J., Barry, J. P., Chan, F., English, C. A., Galindo, H. M., Grebmeier, J. M., Hollowed, A. B., Knowlton, N., Polovina, J., Rabalais, N. N., Sydeman, W. J., & Talley, L. D. (2012). Climate Change Impacts on Marine Ecosystems. *Annual Review of Marine Science*, *4*(1), 11–37. https://doi.org/10.1146/annurev-marine-041911-111611

Duffy, D. C. (1983). Environmental uncertainty and commercial fishing: Effects on Peruvian guano birds. *Biological Conservation*, *26*(3), 227–238. https://doi.org/10.1016/0006-3207(83)90075-7

Duignan, P. J. (2001). Diseases of penguins. *Surveillance*, *28*(4), 5–11.

Easterling, D. R., Meehl, G. A., Parmesan, C., Changnon, S. A., Karl, T. R., & Mearns, L. O. (2000). Climate Extremes: Observations, Modeling, and Impacts. *Science*, *289*(5487), 2068–2074. https://doi.org/10.1126/science.289.5487.2068

Elliott, G., & Walker, K. (2017). *Antipodean wandering albatross census and population study 2017*. (Albatross Research). Department of Conservation. Retrieved from https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-conservation-services/reports/antipodean-albatross-adams-island-2017.pdf

Fontaine, R., Gimenez, O., & Bried, J. (2011). The impact of introduced predators, light-induced mortality of fledglings and poaching on the dynamics of the Cory's shearwater (Calonectris diomedea) population from the Azores, northeastern subtropical Atlantic. *Biological Conservation*, *144*(7), 1998–2011. https://doi.org/10.1016/j.biocon.2011.04.022

Forest & Bird. (2014). *New Zealand Seabirds: Important Bird Areas and Conservation* (No. 0473285215) (p. 72). Wellington.

Friesen, M. R., Beggs, J. R., & Gaskett, A. C. (2017). Sensory-based conservation of seabirds: a review of management strategies and animal behaviours that facilitate success. *Biological Reviews*, *92*(3), 1769–1784.

Fry, D. M., Fefer, S. I., & Sileo, L. (1987). Ingestion of plastic debris by Laysan Albatrosses and Wedge-tailed Shearwaters in the Hawaiian Islands. *Marine Pollution Bulletin*, *18*(6, Supplement B), 339–343. https://doi.org/10.1016/S0025-326X(87)80022-X

Furness, R. W. (2003). Impacts of fisheries on seabird communities. *Scientia Marina*, *67*(S2), 33–45. https://doi.org/10.3989/scimar.2003.67s233

Gales, R., Brothers, N., & Reid, T. (1998). Seabird mortality in the Japanese tuna longline fishery around Australia, 1988–1995. *Biological Conservation*, *86*(1), 37–56. https://doi.org/10.1016/S0006-3207(98)00011-1

Gaskin, C. P. (2013). Fluttering shearwater. Retrieved from http://nzbirdsonline.org.nz/species/fluttering-shearwater

Gaskin, C. P. Statement of primary evidence of Chris Gaskin on behalf of the Environmental Defence Society Incorporated and Royal Forest and Bird Protection society of New Zealand Submission Numbers 4735 and 4848: Hearing Topic 23 – SEA and Vegetation Management 15 July 2015. (2015).

Gaskin, C. P. (2017). *Procellariiformes associating with shoaling fish schools – northern New Zealand* (Conservation Services Program). Department of Conservation.

Gaskin, C., & Rayner, M. J. (2013). *Seabirds of the Hauraki Gulf: natural history, research and conservation*. Auckland Council: Auckland Council.

Gianuca, D., Phillips, R. A., Townley, S., & Votier, S. C. (2017). Global patterns of sex- and age-specific variation in seabird bycatch. *Biological Conservation*, *205*, 60–76. https://doi.org/10.1016/j.biocon.2016.11.028

Glagani, F., Hanke, G., & Maes, T. (2015). Global distribution, composition and abundance of marine litter. In *Marine anthropogenic litter* (pp. 29–56). Springer, Cham.

Glen, A. S., Atkinson, R., Campbell, K. J., Hagen, E., Holmes, N. D., Bradford, S. K., Parkes, J. P., Saunders, A., Sawyer, J., & Torres, H. (2013). Eradicating multiple invasive species on inhabited islands: the next big step in island restoration? *Biological Invasions*, *15*(12), 2589–2603. https://doi.org/10.1007/s10530-013-0495-y

Goad, D., & Sullivan, B. (2018). *Testing the Hookpod-mini in the New Zealand pelagic longline fishery Final Report* (p. 21). Department of Conservation. Retrieved from https://www.doc.govt.nz/Documents/conservation/marine-and-coastal/marine-conservation-services/reports/mit2015-02-hookpod-trials-final-report.pdf

Good, T. P., June, J. A., Etnier, M. A., & Broadhurst, G. (2009). Ghosts of the Salish sea: threats to marine birds in Puget sound and the northwest straits from derelict fishing gear. *Marine Ornithology*, *37*, 67–76.

Gregory, M. R. (1991). The hazards of persistent marine pollution: drift plastics and conservation islands. *Journal of the Royal Society of New Zealand*, *21*(2), 83–100. https://doi.org/10.1080/03036758.1991.10431398

Gregory, M. R. (2009). Environmental implications of plastic debris in marine settings—entanglement, ingestion, smothering, hangers-on, hitch-hiking and alien invasions. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *364*(1526), 2013–2025. https://doi.org/10.1098/rstb.2008.0265

Grémillet, D., Ponchon, A., Paleczny, M., Palomares, M., Karpouzi, V., & Pauly, D. (2018). Persisting worldwide seabird-fishery competition despite seabird community decline. *Current Biology*, *28*(24), 4009–4013.

Hall, M. A., Alverson, D. L., & Metuzals, K. I. (2000). By-Catch: Problems and Solutions. *Marine Pollution Bulletin*, *41*(1), 204–219. https://doi.org/10.1016/S0025-326X(00)00111-9

Hallegraeff, G. M. (2003). Harmful algal blooms: a global overview. *Manual on Harmful Marine Microalgae*, *33*, 1–22.

Hallegraeff, Gustaaf M. (2010). Ocean Climate Change, Phytoplankton Community Responses, and Harmful Algal Blooms: A Formidable Predictive Challenge1. *Journal of Phycology*, *46*(2), 220–235. https://doi.org/10.1111/j.1529-8817.2010.00815.x

Harper, G. (2006). Weka (Gallirallus australis) depredation of sooty shearwater/titi (Puffinus griseus) chicks. *Notornis*, *53*(3), 318.

Harper, P. C., & Fowler, J. A. (1987). Plastic pellets in New Zealand storm-killed prions (Pachyptila spp.). *Notornis*, *34*, 65–70.

Harrigan, K. E. (1991). Causes of Mortality of Little Penguins Eudyptula minor in Victoria. *Emu – Austral Ornithology*, *91*(5), 273–277. https://doi.org/10.1071/MU9910273

Hartill, B. (2014). *Recreational Fisheries in the Hauraki Gulf*. Oral Presentation presented at the SeaChange – Tai Timu Tai Pari Working Group. Retrieved from https://seachange.org.nz/assets/Sea-Change/SWG/Recreational-Fisheries-in-the-Hauraki-Gulf-Bruce-Hartill-NIWA.pdf

Hauraki Gulf Forum. (2010). *Fishing the Gulf* (Hauraki Gulf Marine Park Act Guidance Series). Auckland, New Zealand. Retrieved from https://www.aucklandcouncil.govt.nz/about-auckland-council/how-auckland-council-works/harbour-forums/docshaurakigulfguidanceseries/fishing-gulf-implementing.pdf

Heber, S., Wilson, K.-J., & Molles, L. (2008). Breeding biology and breeding success of the blue penguin (Eudyptula minor) on the West Coast of New Zealand's South Island. *New Zealand Journal of Zoology*, *35*(1), 63–71. https://doi.org/10.1080/03014220809510103

Hebshi, A. J., Duffy, D. C., & Hyrenbach, K. D. (2008). Associations between seabirds and subsurface predators around Oahu, Hawaii. *Aquatic Biology*, *4*(1), 89–98. https://doi.org/10.3354/ab00098

Heggie, K., & Savage, C. (2009). Nitrogen yields from New Zealand coastal catchments to receiving estuaries. *New Zealand Journal of Marine and Freshwater Research*, *43*(5), 1039–1052.

Hilton, G. M., & Cuthbert, R. J. (2010). Review article: The catastrophic impact of invasive mammalian predators on birds of the UK Overseas Territories: a review and synthesis. *Ibis*, *152*(3), 443–458. https://doi.org/10.1111/j.1474-919X.2010.01031.x

Hocken, A. G. (2000). Cause of death in blue penguins (Eudyptula m. minor) in North Otago, New Zealand. *New Zealand Journal of Zoology*, *27*(4), 305–309. https://doi.org/10.1080/03014223.2000.9518239

Hocken, A. G. (2005). Necropsy findings in yellow-eyed penguins (Megadyptes antipodes) from Otago, New Zealand. *New Zealand Journal of Zoology*, *32*(1), 1–8. https://doi.org/10.1080/03014223.2005.9518391

Holmes, L. A., Turner, A., & Thompson, R. C. (2012). Adsorption of trace metals to plastic resin pellets in the marine environment. *Environmental Pollution*, *160*, 42–48. https://doi.org/10.1016/j.envpol.2011.08.052

Hutchinson, L. V., & Wenzel, B. M. (1980). Olfactory guidance in foraging procellariiformes. *Condor*, *82*, 314–319.

Hutton, I., Carlile, N., & Priddel, D. (2008). Plastic Ingestion by Flesh-Footed (puffinus Carneipes) and Wedge-Tailed (p. Pacificus) Shearwaters. *Papers and Proceedings of the Royal Society of Tasmania*, *142*(1).

Imber, M. J. (1975). Behaviour of petrels in relation to the moon and artificial lights. *Notornis*, *22*, 302–306.

Imber, M. J. (1987). Breeding ecology and conservation of the black petrel *Procellaria parkinsoni*. *Notornis*, *34*, 19–39.

Imber, M. J., West, J. A., & Cooper, W. J. (2003). Cook's petrel (*Pterodroma cookii*): historic distribution, breeding biology and effects of predators. *Notornis*, *50*(4), 221–230.

Ismar, S. M. H., Baird, K. A., Gaskin, C. P., Taylor, G. A., Tennyson, A. J. D., Rayner, M. J., … Imber, M. J. (2014). A case of natural recovery after the removal of invasive predators – community assemblage changes in the avifauna of Burgess Island. *Notornis*, *61*, 188–195.

Jaeger, A., Lebarbenchon, C., Bourret, V., Bastien, M., Lagadec, E., Thiebot, J. B., Boulinier, T., Delord, K., Barbraud, C., Marteau, C., Dellagi, K., Tortosa, P., & Weimerskirch, H. (2018). Avian cholera outbreaks threaten seabird species on Amsterdam Island. *PLoS One*, *13*(5), p.e0197291.

Jenouvrier, S., Desprez, M., Fay, R., Barbraud, C., Weimerskirch, H., Delord, K., & Caswell, H. (2018). Climate change and functional traits affect population dynamics of a long-lived seabird. *Journal of Animal Ecology*, *87*(4), 906–920.

Johnston, E. L., & Roberts, D. A. (2009). Contaminants reduce the richness and evenness of marine communities: a review and meta-analysis. *Environmental Pollution*, *157*(6), 1745–1752.

Jones, H. P. (2010). Seabird islands take mere decades to recover following rat eradication. *Ecological Applications*, *20*(8), 2075–2080.

Jones, H. P., Holmes, N. D., Butchart, S. H., Tershy, B. R., Kappes, P. J., Corkery, I., Aguirre-Muñoz, A., Armstrong, D. P., Bonnaud, E., Burbidge, A. A., Campbell, K., Courchamp, F., Cowan, P. E., Cuthbert, R. J., Ebbert, S., Genovesi, P., Howald, G. R., Keitt, B. S., Kress, S. W., Miskelly, C. M., Oppel, S., Poncet, S., Rauzon, M. J., Rocamora, G., Russell, J. C., Samaniego-Herrera, A., Seddon, P. J., Spatz, D. R., Towns, D. R., & Croll. D. A. (2016). Invasive mammal eradication on islands results in substantial conservation gains. *Proceedings of the National Academy of Sciences*, *113*(15), 4033-4038.

Karpouzi, V. S., Watson, R., & Pauly, D. (2007). Modelling and mapping resource overlap between seabirds and fisheries on a global scale: a preliminary assessment. *Marine Ecology Progress Series*, *343*, 87–99. https://doi.org/10.3354/meps06860

Kingsford, M. J., & Choat, J. H. (1986). Influence of surface slicks on the distribution and onshore movements of small fish. *Marine Biology*, *91*(2), 161–171. https://doi.org/10.1007/BF00569432

Kingston, P. F. (2002). Long-term Environmental Impact of Oil Spills. *Spill Science & Technology Bulletin*, *7*(1), 53–61. https://doi.org/10.1016/S1353-2561(02)00051-8

Kitaysky, A. S., & Golubova, E. G. (2000). Climate Change Causes Contrasting Trends in Reproductive Performance of Planktivorous and Piscivorous alcids. *Journal of Animal Ecology*, *69*(2), 248–262.

Laist, D. W. (1997). Impacts of Marine Debris: Entanglement of Marine Life in Marine Debris Including a Comprehensive List of Species with Entanglement and Ingestion Records. In *Marine Debris* (pp. 99–139). Springer, New York, NY. https://doi.org/10.1007/978-1-4613-8486-1_10

Landers, T. J. (2017). *Muriwai Beach to Te Henga (Bethells) 2016 grey-faced petrel and little penguin survey*. Auckland Council. Retrieved from http://www.knowledgeauckland.org.nz/assets/publications/TR2017-027-Muriwai-Beach-2016-grey-faced-petrel-and-little-penguin-survey.pdf

Lavers, J. L., & Bond, A. L. (2016a). Ingested plastic as a route for trace metals in Laysan Albatross (*Phoebastria immutabilis*) and Bonin Petrel (*Pterodroma hypoleuca*) from Midway Atoll. *Marine Pollution Bulletin*, *110*(1), 493–500. https://doi.org/10.1016/j.marpolbul.2016.06.001

Lavers, J. L., & Bond, A. L. (2016b). Selectivity of flesh-footed shearwaters for plastic colour: Evidence for differential provisioning in adults and fledglings. *Marine Environmental Research*, *113*, 1–6. https://doi.org/10.1016/j.marenvres.2015.10.011

Le Corre, M., Ollivier, A., Ribes, S., & Jouventin, P. (2002). Light-induced mortality of petrels: a 4-year study from Réunion Island (Indian Ocean). *Biological Conservation*, *105*(1), 93–102. https://doi.org/10.1016/S0006-3207(01)00207-5

Lee, K. W., Shim, W. J., Kwon, O. Y., & Kang, J. H. (2013). Size-Dependent Effects of Micro Polystyrene Particles in the Marine Copepod Tigriopus japonicus. *Environmental Science & Technology*, *47*(19), 11278–11283. https://doi.org/10.1021/es401932b

Lerberg, S. B., Holland, A. F., & Sanger, D. M. (2000). Responses of tidal creek macrobenthic communities to the effects of watershed development. *Estuaries*, *23*(6), 838–853. https://doi.org/10.2307/1353001

Lobelle, D., & Cunliffe, M. (2011). Early microbial biofilm formation on marine plastic debris. *Marine Pollution Bulletin*, *62*(1), 197–200. https://doi.org/10.1016/j.marpolbul.2010.10.013

Lyver, P. O. B., Aldridge, S. P., Gormley, A. M., Gaw, S., Webb, S., Buxton, R. T., & Jones, C. J. (2017). Elevated mercury concentrations in the feathers of grey-faced petrels (*Pterodroma gouldi*) in New Zealand. *Marine Pollution Bulletin*, *119*(1), 195–203. https://doi.org/10.1016/j.marpolbul.2017.03.055

Lyver, P. O., Davis, J., Ngamane, L., Anderson, L., & Clarkin, P. (2008). Hauraki Maori Matauranga for the conservation and harvest of Titi, *Pterodroma macroptera gouldi* (Vol. 142, pp. 149–159). Presented at the Papers and Proceedings of the Royal Society of Tasmania.

MacKay, J., & Russell, J. C. (2005). *Eradication of ship rats from Goat Island April-October 2005*. Department of Conservation.

Markwell, T. J., & Daugherty, C. H. (2002). Invertebrate and lizard abundance is greater on seabird-inhabited islands than on seabird-free islands in the Marlborough Sounds, New Zealand. *Écoscience*, *9*(3), 293–299. https://doi.org/10.1080/11956860.2002.11682715

Maron, J. L., Estes, J. A., Croll, D. A., Danner, E. M., Elmendorf, S. C., & Buckelew, S. L. (2006). An introduced predator alters Aleutian Island plant communities by thwarting nutrient subsidies. *Ecological Monographs*, *76*, 3–24.

McEntee, M., & Johnson, S. (2015). *Enabling an ecological vision for Aotea Great Barrier Island: under- standing community perspectives and aspirations*. Auckland, New Zealand: Aranovus Ltd.

Melvin, E. F., & Parrish, J. K. (2001). *Seabird bycatch. Trends, roadblocks and solution*. Fairbanks, Alaska: University of Alaska Sea Grant.

Melvin, Edward F., Guy, T. J., & Read, L. B. (2014). Best practice seabird bycatch mitigation for pelagic longline fisheries targeting tuna and related species. *Fisheries Research*, *149*, 5–18. https://doi.org/10.1016/j.fishres.2013.07.012

Miles, W., Money, S., Luxmoore, R., & Furness, R. W. (2010). Effects of artificial lights and moonlight on petrels at St Kilda. *Bird Study*, *57*(2), 244–251. https://doi.org/10.1080/00063651003605064

Ministry for Primary Industries Manatū Ahu Matua. (2017). *Aquatic Environment and Biodiversity Annual Review 2017*. (p. 724). Wellington, New Zealand.

Miskelly, C. M. (2012). Discovery and extinction of the South Island snipe *Coenocorypha iredalei* on islands around Stewart Island. *Notornis*, (59), 15–31.

Miskelly, C. M., Baylis, S., Tennyson, A. J. D., Waugh, S., Bartle, S., Hunter, S., Gartrell, B., & Morgan, K. (2012). *Impacts of the RENA oil spill on New Zealand seabirds*. Poster.

Montevecchi, W. A. (2013). Influences of Artificial Light on Marine Birds. In C. Rich & T. Longcore (Eds.), *Ecological Consequences of Artificial Night Lighting* (pp. 94–109). Island Press.

Moors, P. (1985). Eradication campaigns against Rattus norvigecus on the Noises Islands, New Zealand using brodifacoum and 1080. *ICBP Technical Publication*, *3*, 143–155.

Morrison, K. W., Battley, P. F., Sagar, P. M., & Thompson, D. R. (2015). Population dynamics of Eastern Rockhopper Penguins on Campbell Island in relation to sea surface temperature 1942–2012: current warming hiatus pauses a long-term decline. *Polar Biology*, *38*(2), 163–177.

Morton, J. (2018a). Auckland's polluted beaches: the five big questions. *New Zealand Herald*. Retrieved from https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=11968589

Morton, J. (2018b). Conservationists saddened after seabirds die in boxes. *NZ Herald*. Retrieved from https://www.nzherald.co.nz/nz/news/article.cfm?c_id=1&objectid=12057912

Mulder, C. P. H., Anderson, W. B., Towns, D. R., & Bellingham, P. J. (2011). *Seabird islands: ecology, invasion and restoration*. Oxford: Oxford University Press.

Nevitt, G. A., & Bonadonna, F. (2005). Sensitivity to dimethyl sulphide suggests a mechanism for olfactory navigation by seabirds. *Biology Letters*, *1*(3), 303–305. https://doi.org/10.1098/rsbl.2005.0350

Oedekoven, C. S., Ainley, D. G., & Spear, L. B. (2001). Variable responses of seabirds to change in marine climate:: California Current, 1985–1994. *Marine Ecology Progress Series*, *212*, 265–281. Retrieved from http://www.jstor.org.ezproxy.auckland.ac.nz/stable/24864192

Oehlmann, J., Schulte-Oehlmann, U., Kloas, W., Jagnytsch, O., Lutz, I., Kusk, K. O., Wollenberger, L., Santos, E. M., Paul, G. C., van Look, K. J. W., & Tyler, C. R. (2009). A critical analysis of the biological impacts of plasticizers on wildlife. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *364*(1526), 2047–2062. https://doi.org/10.1098/rstb.2008.0242

Parsons, M., Mitchell, I., Butler, A., Ratcliffe, N., Frederiksen, M., Foster, S., & Reid, J. B. (2008). Seabirds as indicators of the marine environment. *ICES Journal of Marine Science*, *65*(8), 1520–1526. https://doi.org/10.1093/icesjms/fsn155

Paul, L. J. (2014). *History of, and trends in, the commercial landings of finfish from the Hauraki Gulf, 1850–2006* (124). Ministry for Primary Industries Manatū Ahu Matua. Retrieved from http://www.mpi.govt.nz/news-resources/publications.aspx

Pennycuick, C. J. (1982). The flight of petrels and albatrosses (Procellariiformes), observed in South Georgia and its vicinity. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *300*, 75–106.

Perriman, L., Houston, D., Steen, H., & Johannesen, E. (2000). Climate fluctuation effects on breeding of blue penguins (Eudyptula minor). *New Zealand Journal of Zoology*, *27*(4), 261–267. https://doi.org/10.1080/03014223.2000.9518234

Peterson, C. H., Rice, S. D., Short, J. W., Esler, D., Bodkin, J. L., Ballachey, B. E., & Irons, D. B. (2003). Long-Term Ecosystem Response to the Exxon Valdez Oil Spill. *Science*, *302*(5653), 2082–2086. https://doi.org/10.1126/science.1084282

Pierce, K. E., Harris, R. J., Larned, L., & Pokras, M. (2004). Obstruction and starvation associated with plastic ingestion in a Northern Gannet Morus bassanus and a Greater Shearwater Puffinus gravis. *Marine Ornithology*, *32*, 187–189.

Pinkerton, M. H., MacDiarmid, A., Beaumont, J., Bradford-Grieve, J., Francis, M. P., Jones, E., Lalas, C., Lundquist, C. J., McKenzie, A., Nodder, S. D., Paul, L., Stenton-Dozey, J., Thompson, D., & Zeldis, J. (2015). *Changes to the food-web of the Hauraki Gulf during the period of human occupation: a mass-balance model approach* (New Zealand Aquatic Environment and Biodiversity Report No. 160). Wellington: Ministry for Primary Industries Manatū Ahu Matua.

Powlesland, R. G. (1984). Seabirds found dead on New Zealand beaches in 1982 and a review of penguin recoveries since 1960. *Notornis*, (31), 155–171.

Provencher, J. F., Borrelle, S. B., Sherley, R. B., Avery-Gomm, S., Hodum, P., Bond, A. L., Major, H. L., McCoy, K. D., Crawford, R. Merkel, F., & Votier, S. C. (2019). Seabirds. In *World Seas: an Environmental Evaluation* (pp. 133–162). Academic Press.

Pulham, G., & Wilson, D. (2015). Fairy tern. Retrieved from http://www.nzbirdsonline.org.nz/species/fairy-tern

Rankin, L., & Jones, H. P. (2017). *Nearshore recovery of seabird islands following invasive species eradication*. Poster.

Rayner, M. J., Hauber, M. E., Clout, M. N., Seldon, D. S., Van Dijken, S., Bury, S., & Phillips, R. A. (2008). Foraging ecology of the Cook's petrel *Pterodroma cookii* during the austral breeding season: a comparison of its two populations. *Marine Ecology Progress Series*, *370*, 271–284.

Rayner, M. J., Taylor, G. A., Thompson, D. R., Torres, L. G., Sagar, P. M., & Shaffer, S. A. (2011). Migration and diving activity in three post-breeding flesh-footed shearwaters (*Puffinus carneipes*). *Journal of Avian Biology*, *42*, 266–270. https://doi.org/10.1111/j.1600-048X.2010.05238.x

Rayner, Matt J., Gaskin, C. P., Fitzgerald, N. B., Baird, K. A., Berg, M. M., Boyle, D., … Ismar, S. M. H. (2015). Using miniaturized radiotelemetry to discover the breeding grounds of the endangered New Zealand Storm Petrel *Fregetta maoriana*. *Ibis*, *157*(4), 754–766. https://doi.org/10.1111/ibi.12287

Rhodes, L. L., Haywood, A. J., Ballantine, W. J., & MacKenzie, A. L. (1993). Algal blooms and climate anomalies in north-east New Zealand, August-December 1992. *New Zealand Journal of Marine and Freshwater Research*, *27*(4), 419–430.

Richard, Y., & Abraham, E. R. (2013). *Risk of commercial fisheries to New Zealand seabird populations.* (New Zealand Aquatic Environment and Biodiversity Report No. 109). Wellington: Ministry for Primary Industries Manatū Ahu Matua. Retrieved from https://files.dragonfly.co.nz/publications/pdf/Richard_Abraham_2013_AEBR109S.pdf

Richard, Y., Abraham, E. R., & Filippi, D. (2015). *Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006-07 to 2012-13.* Ministry for Primary Industries Manatū Ahu Matua.

Roberts, C. M., Duncan, R. P., & Wilson, K.-J. (2007). Burrowing seabirds affect forest regeneration, Rangatira Island, Chatham Islands, New Zealand. *New Zealand Journal of Ecology*, 208–222.

Rodríguez, A., Holmes, N. D., Ryan, P. G., Wilson, K.-J., Faulquier, L., Murillo, Y., Raine, A. F., Penniman, J. F., Neves, V., Rodríguez, B., Negro, J. J., Chiaradia, A., Dann, P., Anderson, T., Metzger, B., Shirai, M., Deppe, L., Wheeler, J., Hodum, P., Gouveia, C., Carmo, V., Carreira, G. P., Delgado-Alburqueque, L., Guerra-Correa, C., Couzi, F.-X., Travers, M., & Corre, M. L. (2017). Seabird mortality induced by land-based artificial lights. *Conservation Biology*, *31*(5), 986–1001. https://doi.org/10.1111/cobi.12900

Rodríguez, A., Arcos, J. M., Bretagnolle, V., Dias, M. P., Holmes, N. D., Louzao, M., Provencher, J., Raine, A. F., Ramírez, F., Rodríguez, B., Ronconi, R. A., Taylor, R. S., Bonnaud, E., Borrelle, S. B., Cortés, V., Descamps, S., Friesen, V. L., Genovart, M., Hedd, A., Hodum, P., Humphries, G. R. W., Le Corre, M., Lebarbenchon, C., Martin, R., Melvin, E. F., Montevecchi, W. A., Pinet, P., Pollet, I. L., Ramos, R., Russell, J. C., Ryan, P. G., Sanz-Aguilar, A., Spatz, D. R., Travers, M., Votier, S. C., Wanless, R. M., Woehler, E., & Chiaradia, A. (2019). Future Directions in Conservation Research on Petrels and Shearwaters. *Frontiers in Marine Science*, *6*, 94.

Roman, L., Bell, E., Wilcox, C., Hardesty, B., & Hindell, M. (2019). Ecological drivers of marine debris ingestion in Procellariiform Seabirds. *Scientific Reports*, *9*(1), 916.

Russell, D. J. F., Wanless, S., Collingham, Y. C., Huntley, B., & Hamer, K. C. (2015). Predicting Future European Breeding Distributions of British Seabird Species under Climate Change and Unlimited/No Dispersal Scenarios. *Diversity*, *7*(4), 342–359. https://doi.org/10.3390/d7040342

Russell, J. C., Innes, J. G., Brown, P. H., & Byrom, A. E. (2015). Predator-free New Zealand: conservation country. *BioScience*, biv012.

Russell, J. C., MacKay, J., & Abdelkrim, J. (2009). Insular pest control within a metapopulation context. *Biological Conservation*, *142*(7), 1404–1410.

Russell, J. C., Taylor, C. N., & Aley, J. P. (2018). Social assessment of inhabited islands for wildlife management and eradication. *Australasian Journal of Environmental Management*, *25*(1), 24–42.

Ryan, P. G., Connell, A. D., & Gardner, B. D. (1988). Plastic ingestion and PCBs in seabirds: Is there a relationship? *Marine Pollution Bulletin*, *19*(4), 174–176. https://doi.org/10.1016/0025-326X(88)90674-1

Ryan, Peter G. (2008). Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans. *Marine Pollution Bulletin*, *56*(8), 1406–1409. https://doi.org/10.1016/j.marpolbul.2008.05.004

Ryan, Peter G. (2015). How quickly do albatrosses and petrels digest plastic particles? *Environmental Pollution*, *207*, 438–440. https://doi.org/10.1016/j.envpol.2015.08.005

Ryan, Peter G. (2016). Ingestion of Plastics by Marine Organisms. In *Hazardous Chemicals Associated with Plastics in the Marine Environment* (pp. 1–32). Springer, Berlin, Heidelberg. https://doi.org/10.1007/698_2016_21

Ryan, Peter G. (2018). Entanglement of birds in plastics and other synthetic materials. *Marine Pollution Bulletin*, *135*, 159–164. https://doi.org/10.1016/j.marpolbul.2018.06.057

Savoca, M. S., Wohlfeil, M. E., Ebeler, S. E., & Nevitt, G. A. (2016). Marine plastic debris emits a keystone infochemical for olfactory foraging seabirds. *Science Advances*, *2*(11), e1600395. https://doi.org/10.1126/sciadv.1600395

Schiel, D. R., Ross, P. M., & Battershill, C. N. (2016). Environmental effects of the MV Rena shipwreck: cross-disciplinary investigations of oil and debris impacts on a coastal ecosystem. *New Zealand Journal of Marine and Freshwater Research*, *50*(1), 1–9. https://doi.org/10.1080/00288330.2015.1133665

Schreiber, E. A., & Burger, J. (2002). Seabirds in the marine environment. In *The Biology of Marine Birds* (pp. 1-34). CRC Press, New York.

Schreiber, R. W., & Schreiber, E. A. (1984). Central Pacific Seabirds and the El Niño Southern Oscillation: 1982 to 1983 Perspectives. *Science*, *225*(4663), 713–716. https://doi.org/10.1126/science.225.4663.713

Seaton, R., Galbraith, M., & Hyde, N. (2013). Swamp harrier. Retrieved from http://nzbirdsonline.org.nz/species/swamp-harrier

Shaffer, S. A., Tremblay, Y., Weimerskirch, H., Scott, D., Thompson, D. R., Sagar, P. M., Moller, H., Taylor, G. A., Foley, D. G., Block, B. A., & Costa, D. P. (2006). Migratory shearwaters integrate oceanic resources across the Pacific Ocean in an endless summer. *Proceedings of the National Academy of Sciences*, *103*(34), 12799–12802. https://doi.org/10.1073/pnas.0603715103

Sievwright, K. A. (2014). *Post-release survival and productivity of oiled little blue penguins (Eudyptula minor) rehabilitated after the 2011 C/V Rena oil spill : a thesis presented in partial fulfilment of the requirements for the degree of Master of Science in Conservation Biology at Massey University, Palmerston North, New Zealand* (Master of Science). Massey University. Retrieved from https://mro-massey-ac-nz.ezproxy.auckland.ac.nz/handle/10179/6315

Sijbranda, D. C., Hunter, S., Howe, L., Lenting, B., Argilla, L., & Gartrell, B. D. (2017). Cases of mortality in little penguins (Eudyptula minor) in New Zealand associated with avian malaria. *New Zealand Veterinary Journal*, *65*(6), 332–337. https://doi.org/10.1080/00480169.2017.1359124

Sileo, L., Sievert, P. R., & Samuel, M. D. (1990). Causes of mortality of albatross chicks at midway atoll. *Journal of Wildlife Diseases*, *26*(3), 329–338. https://doi.org/10.7589/0090-3558-26.3.329

Skira, I. J. (1986). Food of the Short-Tailed Shearwater, Puffinus-Tenuirostris, in Tasmania. *Wildlife Research*, *13*(3), 481–488. https://doi.org/10.1071/wr9860481

Smith, G. C., & Carlile, N. (1993). Methods for population control within a Silver Gull colony. *Wildlife Research*, *20*(2), 219–225.

Smith, J. L., Mulder, C. P. H., & Ellis, J. C. (2011). Seabirds as ecosystem engineers: nutrient inputs and physical disturbance. In *Seabird islands. Ecology, invasion and restoration. Oxford University Press, New York* (pp. 27–55).

Stine, A. R., Huybers, P., & Fung, I. Y. (2009). Changes in the phase of the annual cycle of surface temperature. *Nature*, *457*(7228), 435–440. https://doi.org/10.1038/nature07675

Sullivan, B. J., Kibel, B., Kibel, P., Yates, O., Potts, J. M., Ingham, B., Domingo, A., Gianuca, D., Jiménez, S., Lebepe, B., Maree, B. A., Neves, T., Peppes, F., Rasehlomi, T., Silva-Costa, A., & Wanless, R. M. (2018). At-sea trialling of the Hookpod: a 'one-stop' mitigation solution for seabird bycatch in pelagic longline fisheries. *Animal Conservation*, *21*(2), 159–167.

Sullivan, B. J., Reid, T. A., & Bugoni, L. (2006). Seabird mortality on factory trawlers in the Falkland Islands and beyond. *Biological Conservation*, *131*(4), 495–504. https://doi.org/10.1016/j.biocon.2006.02.007

Surman, C., & Nicholson, L. (2009). The Good, the Bad, and the Ugly: ENSO-driven oceanographic variability and it's influence on seabird diet and reproduction at the Houtman Abrolhos, Eastern Indian Ocean. *Marine Ornithology*, *37*, 129–138.

Sydeman, W. J., Poloczanska, E., Reed, T. E., & Thompson, S. A. (2015). Climate change and marine vertebrates. *Science*, *350*(6262), 772–777. https://doi.org/10.1126/science.aac9874

Sydeman, W. J., Thompson, S. A., & Kitaysky, A. S. (2012). Seabirds and climate change: roadmap for the future. *Marine Ecology Progress Series*, (454), 107–117.

Tanaka, K., Takada, H., Yamashita, R., Mizukawa, K., Fukuwaka, M., & Watanuki, Y. (2013). Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics. *Marine Pollution Bulletin*, *69*(1), 219–222. https://doi.org/10.1016/j.marpolbul.2012.12.010

Tavares, D. C., de Moura, J. F., Merico, A., & Siciliano, S. (2017). Incidence of marine debris in seabirds feeding at different water depths. *Marine Pollution Bulletin*, *119*(2), 68–73. https://doi.org/10.1016/j.marpolbul.2017.04.012

Taylor, G. A. (2008). Maximum dive depths of eight New Zealand Procellariiformes, including Pterodroma species. *Papers and Proceedings of the Royal Society of Tasmania*, *142*, 89–97.

Telfer, T. C., Sincock, J. L., Byrd, G. V., & Reed, J. R. (1987). Attraction of Hawaiian Seabirds to Lights: Conservation Efforts and Effects of Moon Phase. *Wildlife Society Bulletin (1973-2006)*, *15*(3), 406–413. Retrieved from http://www.jstor.org.ezproxy.auckland.ac.nz/stable/3782548

Tennyson, A. J. D. (1995). Flora of Karewa Island, Bay of Plenty. *Tane*, *35*, 17–23.

Tennyson, A. J. D., Hunter, S., Miskelly, C. M., Baylis, S., Waugh, S., Bartle, S., Gartrell, B., & Morgan, K. (2012). Causes of seabird mortality in the Bay of Plenty, Oct-Nov 2011. In *Abstracts of papers presented at the Ornithological Society of New Zealand AGM and Conference, 2-3 June 2012, Tauranga, New Zealand*. Tauranga.

Teuten, E. L., Saquing, J. M., Knappe, D. R. U., Barlaz, M. A., Jonsson, S., Björn, A., Rowland, S. J., Thompson, R. C., Galloway, T. S., Yamashita, R., Ochi, D., Watanuki, Y., Moore, C., Viet, P. H., Tana, T. S., Prudente, M., Boonyatumanond, R., Zakaria, M. P., Akkhavong, K., Ogata, Y., Hirai, H., Iwasa, S., Mizukawa, K., Hagino, Y., Imamura, A., Saha, M., & Takada, H. (2009). Transport and release of chemicals from plastics to the environment and to wildlife. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *364*(1526), 2027–2045. https://doi.org/10.1098/rstb.2008.0284

Thackeray, S. J., Sparks, T. H., Frederiksen, M., Burthe, S., Bacon, P. J., Bell, J. R., Botham, M. S., Brereton, T. M., Bright, P. W., Carvalho, L., Clutton-Brock, T., Dawson, A., Edwards, M., Elliot, J. M., Harrington, R., Johns, D., Jones, I. D., Jones, J. T., Leech, D. I., Roy, D. B., Scott, W. A., Smith, M., Smithers, R. J., Winfield, I J., & Wanless, S. (2010). Trophic level asynchrony in rates of phenological change for marine, freshwater and terrestrial environments. *Global Change Biology*, *16*(12), 3304–3313. https://doi.org/10.1111/j.1365-2486.2010.02165.x

Timmermann, A., Oberhuber, J., Bacher, A., Esch, M., Latif, M., & Roeckner, E. (1999). Increased El Niño frequency in a climate model forced by future greenhouse warming. *Nature*, *398*(6729), 694–697. https://doi.org/10.1038/19505

Towns, D. R., Atkinson, I. A. E., & Daugherty, C. H. (2006). Have the harmful effects of introduced rats on islands been exaggerated? *Biological Invasions*, *8*, 863–891.

Towns, D. R., & Broome, K. G. (2003). From small Maria to massive Campbell: forty years of rats eradications from New Zealand islands. *New Zealand Journal of Zoology*, *30*, 377–398.

Trenberth, K. E. (1999). Conceptual Framework for Changes of Extremes of the Hydrological Cycle With Climate Change. In *Weather and Climate Extremes* (pp. 327–339). Springer, Dordrecht. https://doi.org/10.1007/978-94-015-9265-9_18

Troisi, G., Barton, S., & Bexton, S. (2016). Impacts of oil spills on seabirds: Unsustainable impacts of non-renewable energy. *International Journal of Hydrogen Energy*, *41*(37), 16549–16555. https://doi.org/10.1016/j.ijhydene.2016.04.011

Uhlmann, S., Fletcher, D., & Moller, H. (2005). Estimating incidental takes of shearwaters in driftnet fisheries: lessons for the conservation of seabirds. *Biological Conservation*, *123*(2), 151–163. https://doi.org/10.1016/j.biocon.2004.11.003

Vanstreels, R. E. T., Braga, É. M., & Catão-Dias, J. L. (2016). Blood parasites of penguins: a critical review. *Parasitology*, *143*(8), 931–956. https://doi.org/10.1017/S0031182016000251

Velando, A., Munilla, I., & Leyenda, P. M. (2005). Short-term indirect effects of the 'Prestige' oil spill on European shags: changes in availability of prey. *Marine Ecology Progress Series*, *302*, 263–274. https://doi.org/10.3354/meps302263

Vlietstra, L. S., & Parga, J. A. (2002). Long-term changes in the type, but not amount, of ingested plastic particles in short-tailed shearwaters in the southeastern Bering Sea. *Marine Pollution Bulletin*, *44*(9), 945–955. https://doi.org/10.1016/S0025-326X(02)00130-3

Votier, S. C., Archibald, K., Morgan, G., & Morgan, L. (2011). The use of plastic debris as nesting material by a colonial seabird and associated entanglement mortality. *Marine Pollution Bulletin*, *62*(1), 168–172. https://doi.org/10.1016/j.marpolbul.2010.11.009

Waller, L. J., & Underhill, L. G. (2007). Management of avian cholera Pasteurella multocida outbreaks on Dyer Island, South Africa, 2002–2005. *African Journal of Marine Science*, *29*(1), 105–111. https://doi.org/10.2989/AJMS.2007.29.1.9.74

Walsh, K. J. E., & Ryan, B. F. (2000). Tropical Cyclone Intensity Increase near Australia as a Result of Climate Change. *Journal of Climate*, *13*(16), 3029–3036. https://doi.org/10.1175/1520-0442(2000)013<3029:TCIINA>2.0.CO;2

Wanless, S., Harris, M. P., Lewis, S., Frederiksen, M., & Murray, S. (2008). Later breeding in northern gannets in the eastern Atlantic. *Marine Ecology Progress Series*, *370*, 263–269. https://doi.org/10.3354/meps07712

Warham, J. (1990). *The Petrels: Their Ecology and Breeding Systems*. Academic Press.

Warham, J. (1996). *The behaviour, population biology and physiology of the petrels*. Academic Press.

Warne, K. (2012). Black Tide – the Rena accident and its implications. Retrieved from https://www.nzgeo.com/stories/black-tide-the-rena-accident-and-its-implications/

Watkins, B. ., Petersen, S. L., & Ryan, P. G. (2008). Interactions between seabirds and deep-water hake trawl gear: an assessment of impacts in South African waters. *Animal Conservation*, *11*(4), 247–254.

Waugh, S., MacKenzie, D., & Fletcher, D. (2008). Seabird bycatch in New Zealand trawl and longline fisheries. *Papers and Proceedings of the Royal Society of Tasmania*, *142*(1), 45.

Weimerskirch, H. (2004). Diseases threaten Southern Ocean albatrosses. *Polar Biology*, *27*(6), 374–379. https://doi.org/10.1007/s00300-004-0600-x

Wilcox, C., Sebille, E. V., & Hardesty, B. D. (2015). Threat of plastic pollution to seabirds is global, pervasive, and increasing. *Proceedings of the National Academy of Sciences*, *112*(38), 11899–11904. https://doi.org/10.1073/pnas.1502108112

Wilson, K.-J. (2016). *A Review of the Biology and Ecology and an Evaluation of Threats to the Westland Petrel Procellaria westlandica*. West Coast Penguin Trust. Retrieved from http://www. bluepenguin.org.nz/wp-content/uploads/Westland-petrel-threats-report-June-2016-Kerry-Jayne-Wilson1.pdf

Wright, S. L., Thompson, R. C., & Galloway, T. S. (2013). The physical impacts of microplastics on marine organisms: A review. *Environmental Pollution*, *Complete*(178), 483–492. https://doi.org/10.1016/j.envpol.2013.02.031

Young, M., & Adams, N. J. (2010). Plastic debris and seabird presence in the Hauraki Gulf, New Zealand. *New Zealand Journal of Marine and Freshwater Research*, *44*(3), 167–175. https://doi.org/10.1080/00288330.2010.498089

Žydelis, R., Bellebaum, J., Österblom, H., Vetemaa, M., Schirmeister, B., Stipniece, A., Dagys, M., van Eerden, M., & Garthe, S. (2009). Bycatch in gillnet fisheries – An overlooked threat to waterbird populations. *Biological Conservation*, *142*(7), 1269–1281. https://doi.org/10.1016/j.biocon.2009.02.025

Žydelis, R., Small, C., & French, G. (2013). The incidental catch of seabirds in gillnet fisheries: A global review. *Biological Conservation*, *162*, 76–88. https://doi.org/10.1016/j.biocon.2013.04.002

# Glossary

**Anoxic** – an absence of oxygen, referring in this text to marine systems where dissolved oxygen has been depleted

**Biotoxin** – a toxic substance produced by a living organism, such as algae

**By-catch** – used with respect to fisheries for the unintended capture of non-target species such as seabirds, dolphins, marine turtles and fish.

**Demographic** – relating to the population of a species, the age structure, trends, and sex ratio

**Pelagic** – the pelagic zone consists of the water column of the open ocean

**Phenology / Phenological** – relating to the timing of life history stages such as mating, egg-laying and migration

**Procellariiformes** – a family of seabirds including petrels, shearwaters and albatrosses.

**Terrestrial** – relating to the earth or its inhabitants including birds – i.e. land birds

**Tube-nosed seabirds** – a colloquial term for Procellariiformes. Also referred to in-text as burrow-nesting seabirds.

Container ship passing between the Mokohinau Islands and Taranga/Hen Island, precious seabird islands. View from Burgess Island.
Photo: Edin Whitehead