Procellariiformes associating with shoaling fish schools – northern New Zealand

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This report was prepared by the Northern New Zealand Seabird Trust for the Department of Conservation in partial fulfilment of the project INT 2016-04 Indirect effects of commercial fishing on Buller's shearwater and red-billed gulls.

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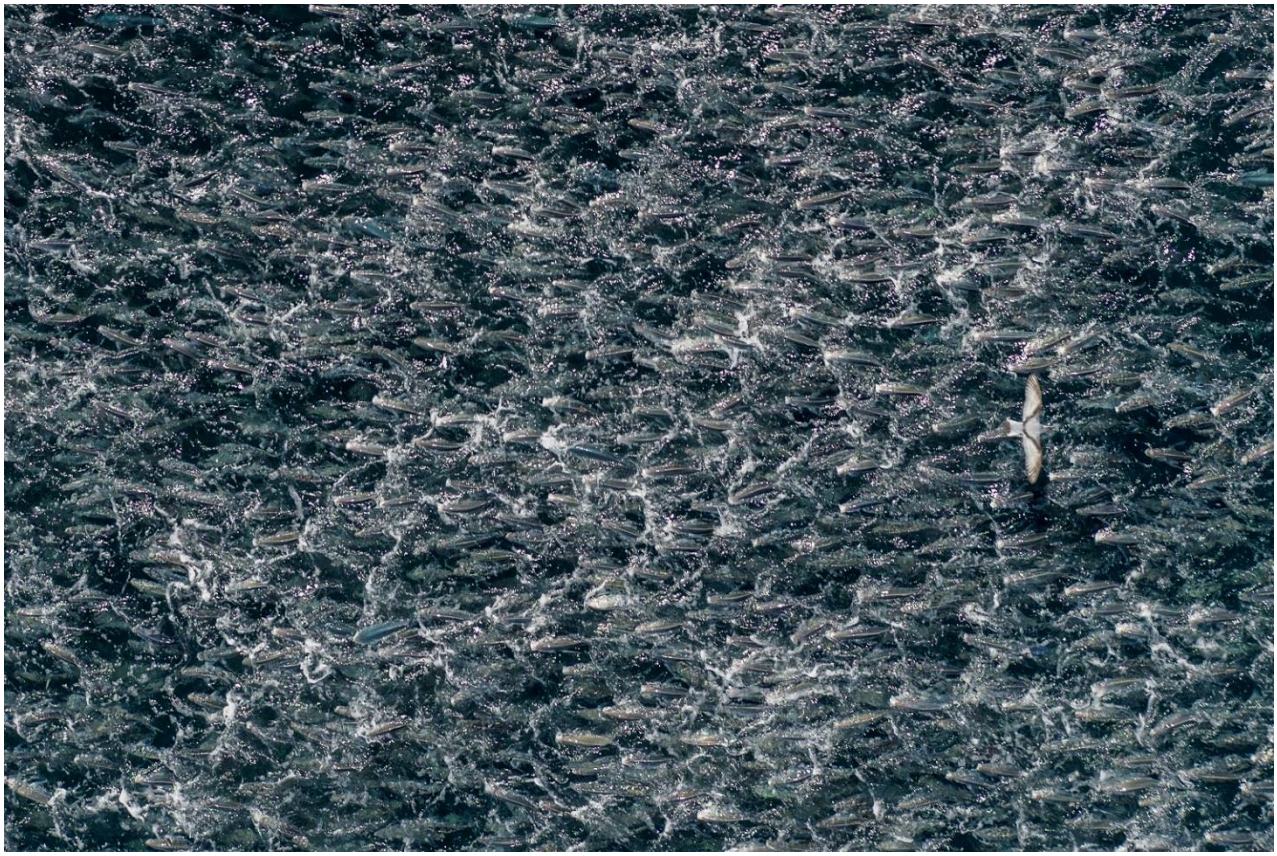

Photo: Solitary fairy prion flying over a densely-packed school of trevally. Photo: Richard Robinson

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Photo: NNZST

Introduction

The main objective of the Department of Conservation funded project INT 2016-04 was to identify potential indirect effects of commercial fishing on Buller's shearwater and red-billed gulls. The purpose of this study is to assess population data for the range of procellariiform species that are known to associate with shoaling fish schools in northern New Zealand waters and to summarise what is known about their general ecology including breeding biology and diet, together with any known recent changes in breeding and foraging behaviour. The key species are Buller's shearwater, fluttering shearwater and fairy prion. Other procellariiform species observed with shoaling fish schools include flesh-footed shearwater, sooty shearwater, white-faced storm-petrel and short-tailed shearwater (Table 1). Opportunistic at-sea observations of interactions between these bird species and shoaling fish are presented, together with comments on bird behaviour associated with fish boil-up activity. The report identifies serious data gaps for most species including a lack of colony counts, especially multi-year surveys to establish trends, information on species' foraging and diets. It also provides recommendations to addressing key issues in the future.

Methods

Data collection

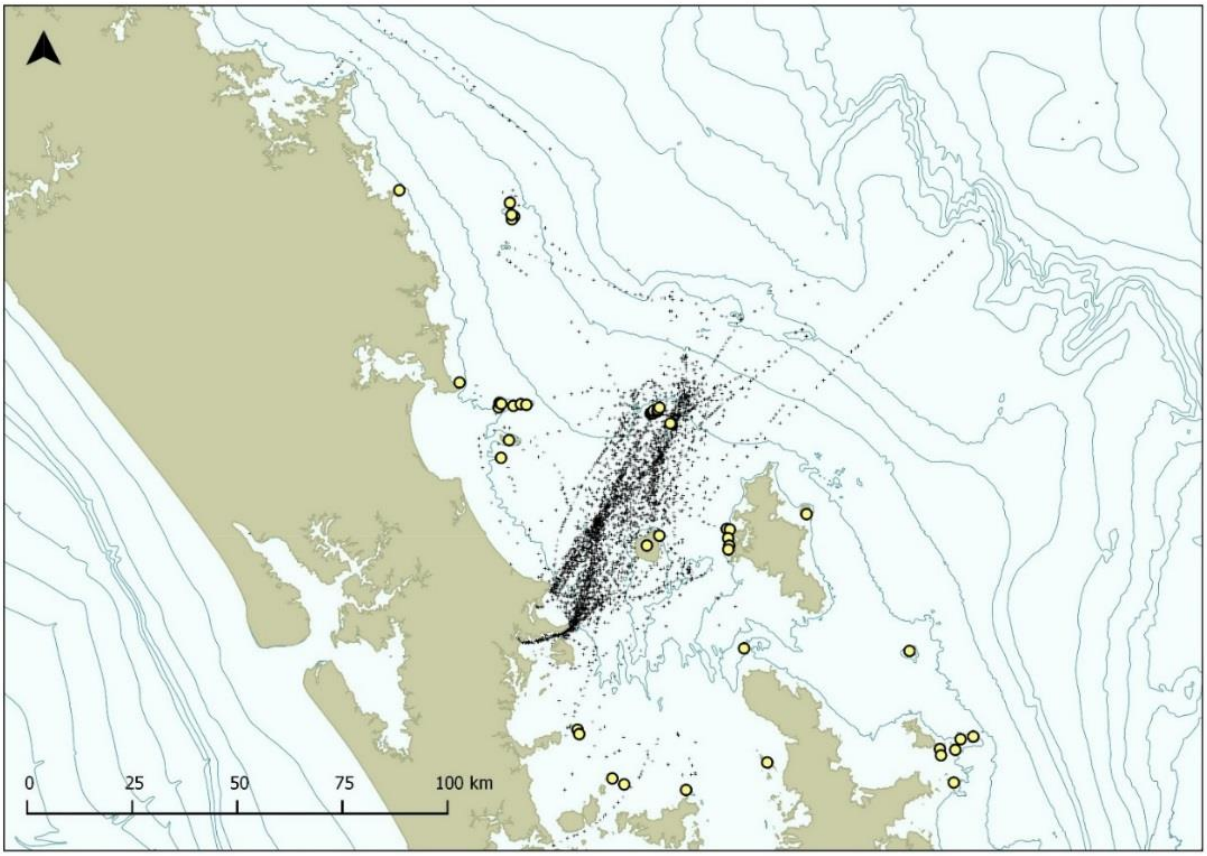
The area covered for colony mapping and population estimates in this study is from the Three Kings to New Plymouth on the west coast and from the Far North to East Cape on the east coast (island sites only). Records have been obtained from the following sources: published papers and reports, Protected Natural Area Programme (PNAP) (Northland only), Classified Summarised Notes (CSN), the first and second OSNZ atlas, Birds New Zealand (OSNZ) and DOC contacts, personal observations, Birding NZ websites, HANZAB and Google searches. Most of the data had previously been collected for three projects: the wider Hauraki Gulf Seabird Plan project (Gaskin & Rayner 2013); the Important Bird Areas (IBA) for New Zealand Seabirds programme (Forest & Bird 2014, 2015); and the Hauraki Gulf Spatial Plan (SeaChange 2016).

Population data has been collected using a variety of methods: 1/ island-wide single-species population and habitat modelling as in Rayner et al (2007) for Cook's petrel on Te Hauturu-o-Toi/Little Barrier Island and adopted by Friesen et al 2016-2017 for Poor Knights Islands, 2/ single species surveys (Baker et al 2012, Bell et al 2016-2017 for flesh-footed shearwater), 3/ single-species surveying within study area (Bell et al 2006- 2017 for black petrel on Aotea/Great Barrier Island) 4/ island visits with ground searches/burrow counts (multiple authors, both published and unpublished, some exhaustive, others cursory), 5/ island visits combined with the use of automated acoustic recorders (as per CG for a number of islands 2010 to present; Landers et al 2015-2016 for Burgess Island, Mokohinau Islands) and adopted on Te Hauturu-o-Toi/Little Barrier Island for black petrel and New Zealand storm-petrel (Bell et al 2015-2017). Species have been included only if they were recorded as breeding at that location. Some historical records are ambiguous. Also, acoustic surveys that record birds calling do not necessarily confirm breeding, ie. Some calls could be from birds overflying the recorder location (i.e. Cook's petrels at Taranga/Hen Island in such significant numbers at all hours of the night as to warrant a ground search (K. Hawkins pres. comm.). Maps showing species' breeding locations are presented in Appendix 2.

At-sea observations of seabird-fish school activity are from personal (CG) observations for the wider Hauraki Gulf (i.e. Cape Brett to Cape Colville and the inner Hauraki Gulf), made principally during commercial and private pelagic seabird-viewing trips, and New Zealand storm-petrel and other at-sea

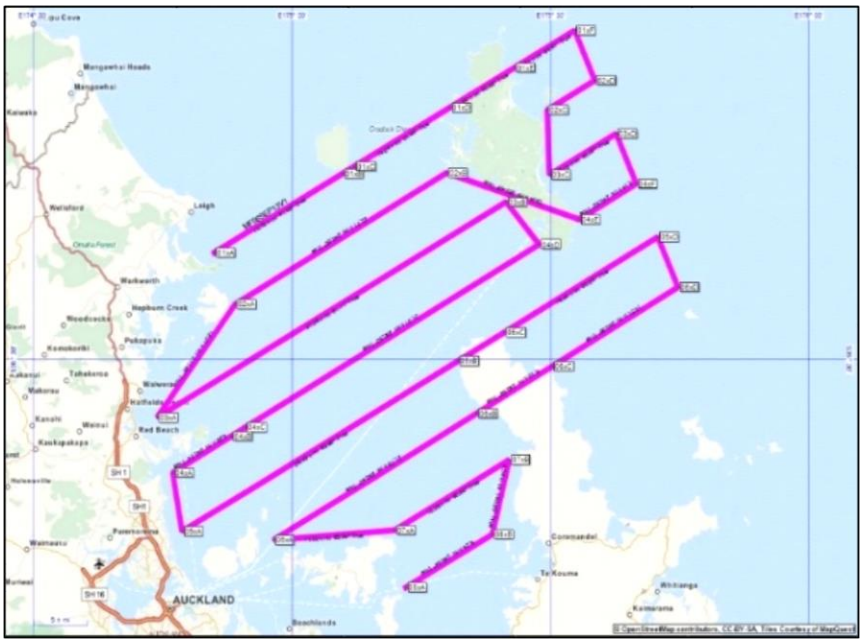
research surveys. Most records are from within the Hauraki Gulf during summer (October to March 2006-2016). Seabirds were recorded while cruising, but slowing down or stopping for closer views of birds (e.g. rafting), bird activity and marine life, including fish school activity. Species seen were recorded with a GPS waypoint taken, numbers grouped in bands (ie. 0, 1-9, 10-49, 50-99, 100-499, 500-999, 1000+) and behaviour noted.

Figure 1. All seabird observations made opportunistically 2006-2016 (crosses), multiple species. Buller's and fluttering shearwater, and fairy prion colony sites (yellow and black circles). Figure 2 (lower). Fairy prions with Buller's and flesh-footed shearwaters, outer Hauraki Gulf, Oct 2010. Photo: Jono Irvine.



Aerial observations are from two aerial surveys: Hauraki Gulf Marine Mega-fauna Survey (O. Hamilton, L. Kozmian-Ledward, R. Constantine, University of Auckland) and West Coast North Island Maui Dolphin and shark Surveys (C. Duffy, L. Kozmian-Ledward, DOC). These surveys used the same methodology with observers searching for megafauna with unaided eye in a strip approximately 500 m either side of the transect line (flight path) (figures 3 & 4). When target species were sighted, the observer recorded the time, from a clock synchronised with the GPS, together with an estimation of group size, sighting conditions (sea state, glare, water colour) and other information such as association species and behaviour. Fish school size was also graded 1-5.

Figure 3. Aerial survey transects for the Hauraki Gulf Mega-fauna Survey.



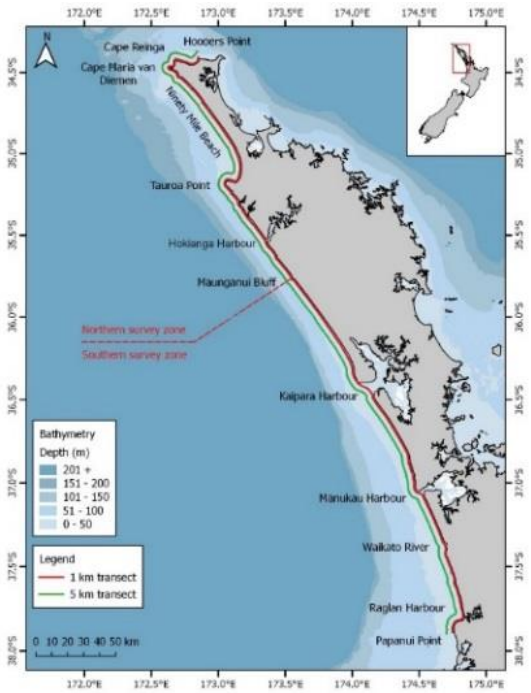


Figure 4. West Coast North Island Mega-fauna survey showing transects at 1km and 5km from coast.

Results

Priority species

The following procellariiform species have been observed feeding in associations with fish schools, and are listed in order of conservation priority (ie. determined in terms of abundance, foraging behaviour and threat classification) (Table 1). The number of events where individual procellariiform species have been observed in proportion to the total number of observed events 2006-2016 is presented in Table 3.

Table 1. Procellariiform species observed feeding in association with fish schools in northern New Zealand waters; also included are species observed in association with feeding cetaceans.

Species names		NZTCS	IUCN Red List
Buller's shearwater	*Ardenna bulleri* (= *Puffinus bulleri*)*	**At Risk – Naturally Uncommon**	Vulnerable
Fluttering shearwater	*Puffinus gavia*	**At Risk - Relict**	Least Concern
Fairy prion	*Pachyptila turtur*	**At Risk - Relict**	Least Concern
Sooty shearwater	*Ardenna grisea* (= *Puffinus griseus*)*	**At Risk - Declining**	Near Threatened
Flesh-footed shearwater	*Ardenna carneipes* (= *Puffinus carneipes*)*	**Nationally Vulnerable**	Near Threatened
White-faced storm petrel	*Pelagodroma marina*	**At Risk - Relict**	Least Concern
Common diving petrel	*Pelecanoides urinatrix*	**Not Threatened**	Least Concern
NZ storm-petrel	*Fregetta maoriana*	**Nationally Vulnerable**	Critically Endangered
Cook's petrel	*Pterodroma cookii*	**At Risk - Relict**	Vulnerable
Black petrel	*Procellaria parkinsoni*	**Nationally Vulnerable**	Vulnerable
Short-tailed shearwater	*Ardenna tenuirostris* (= *Puffinus tenuirostris*)*	**Migrant**	Least Concern

* IUCN Red List (2017) lists these species within the *Ardenna* genus, whereas they are listed in the NZ Checklist (2010) and NZTCS (2016) in *Puffinus*.

NB: Observations presented in this report show that procellariiform species regularly feed around fish schools with other seabirds, most notably Australasian gannet (*Morus serrator*), red-billed gull (*Larus scopulinus*), southern black-backed gull (*L. dominicanus*), white-fronted tern (*Sterna striata*) and grey noddy (grey ternlet) (*Procelsterna cerulea*) – these are covered in a separate report (P. Frost *in prep*).

Colony data

With the exception of black petrel (1998 to present), Cook's petrel (2007) and flesh-footed shearwater (2012 and present), there have been no accurate estimations of populations for the species listed in Table

1. Of those, only black petrel and flesh-footed shearwater populations have been assessed across multiple years using the same methodology to establish population trends. For the other species (excluding short-tailed shearwater which, as far is known, breeds only in Australia), populations are based around limited and occasional island visits, and, in some cases, acoustic surveys to determine presence. These are, for the most part, one-off estimates and in many cases dated (ie. from 1980s and 1990s). Maps showing breeding locations for the species listed above are presented in Appendix 2.

Procellariiform feeding behaviour around fish schools

Several distinct patterns of feeding behaviour have been observed by Procellariiformes in relation to fish school activity. These behaviour patterns are dependent on the types of fish schools and, also what is happening within the fish school activity.

Table 2. Fish school/prey types where Procellariiformes have been observed associating or feeding directly:

	Fish school/prey type	General description of activity	Species
1	Trevally *Pseudocaranyx dentex* (and mixed trevally, kahawai *Arripis trutta* & kingfish *Seriola lalandii*)	Tightly packed, very active dense schools, sometimes with several schools merging to form very large schools. Birds either forage in the wake of the schools, or in some cases feed ahead of and around the schools. Fish will erupt explosively if disturbed either from below (e.g. predatory fish) or from above (e.g. gannets flying low over a school). Shearwaters and prions have been filmed diving in the wake of school activity.	Buller's shearwater, fluttering shearwater, fairy prion, sooty shearwater, flesh-footed shearwater, short-tailed shearwater, white-faced storm-petrel, Cook's petrel (with red-billed gull, white-fronted tern and occasionally grey noddy at some locations)
2	Kahawai	Fast-moving schools, birds moving in 'leap-frogging' formations, shearwaters plunging and diving.	Fluttering shearwater (with white-fronted terns moving with them)
3	Saury *Scomberesox saurus*	One instance of shearwaters and gannets diving on saury, catching fish close to the surface. Out beyond Mokohinau Islands, north of Great Barrier Island.	Flesh-footed shearwater, black petrel and sooty shearwater (with Australasian gannet)
4	Baitfish species (e.g. Jack mackerel *Trachurus novaezelandiae*, pilchard *Sardinops neopilchardus*, koheru *Decapterus koheru*)	Often tightly packed schools, sometimes forming spinning 'bait balls' below the surface. Birds plunging/diving and pursuing prey underwater. Dramatic.	Fluttering shearwater, flesh-footed shearwater, Buller's shearwater, white-faced storm-petrel, Cook's petrel (with Australasian gannet and cetaceans)

5	Skipjack tuna (*Katsuwonus pelamis*)	Fast moving spread-out schools with birds following.	Fluttering shearwater (with gulls and terns)
			Contd.
6	Crustaceans (no visible fish schools)	Mainly euphausiids (*Nyctiphanes australis*) with birds actively feeding from the surface, often well- spread, occasionally across several sq. kms.	Buller's shearwater, fluttering shearwater, fairy prion, common diving petrel, white-faced storm-petrel, sooty shearwater.

A basic analysis of observed events of Procellariiformes feeding in association with fish schools in the Hauraki Gulf is presented in Table 3. It highlights the dominant species in these associations (Buller's and fluttering shearwaters, and fairy prions); but also, shows that other species (e.g. flesh-footed shearwater, Cook's petrel and white-faced storm petrel) are frequently active, albeit in lesser numbers.

Table 3. Number of events where individual procellariiform species have been observed in proportion to the total number of observed events 2006-2016 (n=166); also, mean count (by band) and numbers of events where 500+ individual birds were observed.

Species name	Observed events (n)	Proportion of total (%)	Count per event (inds)	500+ inds (n)
Buller's shearwater	99	60	10-99	8
Fluttering shearwater	81	49	10-99	5
Fairy prion	72	43	50-99	9
Flesh-footed shearwater	75	45	2-9	0
White-faced storm petrel	55	33	10-49	1
Cook's petrel	47	28	10-49	0
Sooty shearwater	24	14	2-9	0
Black petrel	21	13	2-9	0
Common diving petrel	13	8	10-49	1
Short-tailed shearwater	9	5	1	0
NZ storm-petrel	7	4	1	0

Other species recorded: NZ White-capped albatross (*Thalassarche steadi*), Campbell albatross (*T. impavida*), grey-faced petrel (*Pterodroma gouldi*), Hutton's shearwater (*Puffinus huttoni*) and little shearwater (*P. assimilis*).

No analyses for the aerial survey data has been attempted in this study. These will form part of a PhD thesis (O. Hamilton in prep.). Raw data is shown in maps in Appendix 3.

One other pattern of behaviour has been added here: Procellariiformes feeding in association with cetaceans where the latter's feeding generates discards (ie. uneaten parts of prey) that the birds then feed on. This behaviour has been observed with mixed pods of false killer whales (*Pseudorca crassidens*), bottlenose dolphins (*Tursiops trunchatus*) and long-finned pilot whales (*Globicephala meias*). Black petrels dominate this feeding association with large groups of sometimes 100+ birds following pods (especially mixed pods of false killer whales and bottlenose dolphins). The birds will feed aggressively on scraps brought to or close to the surface by the whales' feeding. Black petrels have been observed peering underwater watching the whales' feeding below and will race to where they surface. On occasion the mixed species will feed with these pods; on one occasion between Little Barrier and Great Barrier Islands black petrels, Buller's and fluttering shearwaters, Cook's petrels, white-faced and NZ storm-petrels were seen feeding around one very large pod. The NZ storm-petrels mostly feeding over oily slicks the whales left at the surface. This behaviour, while not directly connected to fish school activity, does highlight interconnectedness within marine ecosystems (see Discussion below and Appendix 4).

Figure 5. Petrels shearwaters and storm-petrels feeding with false killer whales and bottlenose dolphins, Great Barrier Island in the background. Photo: Chris Gaskin

Seabird-fish school distribution for the wider Hauraki Gulf region

At-sea observations of seabird and fish school activity presented here are from the wider Hauraki Gulf region (2006-2017) and were gathered opportunistically (see Methods). The maps presented in Appendix 3 present raw data, and, while the observations are limited to where boats went and sightings took place, a significant number of seabird/fish school observations coincide with major bathymetric features with regular tidal and current flows across or around them (e.g. Maori Rocks, Simpson Rock, the Mokohinau Islands themselves (including Groper Island), Northwest Reef (NW of Little Barrier Island), Horn Rock (SE of Little Barrier Island), Cape Rodney and Leigh Reef, and Tokatu Point and North Kawau Channel). At these locations fish schools, predominantly trevally and mixed trevally and kahawai schools were observed steadily moving around or over the feature, sometimes breaking up into smaller schools (see figure 24) or, if fragmented and spread, coalescing into larger schools. The bird activity that accompanies this movement varies, not only between the types of fish schools (Table 2), but also for the same type. For example, prions and shearwaters will sometimes follow trevally schools feeding on crustaceans and other plankton in the disturbed wake of the schools; compared to other times where they feed in advance of the schools as well as feeding in the wake. With tightly-packed fish schools Procellariiformes and other seabirds will seldom feed amongst the fish, instead they feed around the

perimeter. There are, however, some exceptions (figure 30). Underwater filming by the author (CG) and others of trevally-dominated schools during the period of this study shows the masses of euphausiids these fish and birds are feeding on (figures 28, 29), but also fish larvae and fish spawn (figure 30, 31). Further multi-disciplinary investigation is required to investigate the dynamics of fish schools themselves with the birds' different behaviours potentially acting as indicators for fish activity.

Seabird and fish school activity also occurs in areas where the relationship with tides, currents, up-welling and bathymetric are less direct and obvious. This is shown in the at-sea observational data and confirmed through the aerial surveys. While seemingly more ephemeral and random, the influences are likely to be driven by larger scale factors than those existing over, around or through bathymetric features, including landscape features such as headlands and large islands. The Hauraki Gulf is a dynamic marine environment in which tidal movements, cross-shelf intrusions of sub-tropical water from the East Auckland current, spatial and temporal changes in sea temperature, and salinity, likely influence the distributions of prey and thus top predators such as seabirds. In addition, anthropogenic-related impacts such as increased sediment and nutrient loads and benthic habitat damage from fisheries likely impact the productivity of this dynamic ecological community with the potential for downstream or trickledown effects on top predators (Gaskin & Rayner 2013).

Figure 6. Fairy prions and fluttering, sooty and short-tailed shearwaters feeding on euphausiids around a fish school; Mokohinau Islands in background. Photo: Chris Gaskin

Discussion

Biological diversity underpins ecosystem functioning and the provision of ecosystem services essential for human well-being such as food security, human health, and the provision of clean air and water. Biological diversity also contributes to local livelihoods and economic development (Convention of

Biological Diversity 2010). As predators at the top of the food chain, seabirds are crucial components of marine ecosystems and possess attributes that make them useful as indicators of change in the marine environment. Given that there is an increasing need for relevant indicators for the marine environment, seabird populations represent a viable and relatively cost-effective 'canary in the cage' for the long-term assessment of marine ecosystems across broad spatial scales. However, this oft-touted benefit from seabird research is dependent on several critical factors: accurate up-to-date baseline population data, long-term monitoring of key species and sites using consistent methodology, and adequate resources to support long-term research.

In northern New Zealand there is a paucity of accurate population data for priority seabird species, and, except for black petrel and flesh-footed shearwater[1], there is no long-term monitoring of populations. As an example, the total population of Buller's shearwaters was believed to be 2.5 million birds (c. 800,000 pairs) in 1981 with c.200,000 breeding pairs nesting on Aorangi Island (Harper 1983, Taylor 2000a). However, following their visit in 2012, G. Taylor and A. Tennyson suggested that the population was more likely of the order of 300,000-400,000 pairs for the Poor Knights Islands based on what they found on Aorangi Island. Surveys to investigate Buller's shearwater populations and breeding biology at the Poor Knights Islands are currently underway by Friesen et al (December 2016 to April 2017) as the first stage of a proposed multi-year project investigating this threatened species. Similarly, the breeding sites for most of the population of Fluttering shearwaters, arguably the most common northern New Zealand species, remain undiscovered. Recent surveying of Tawhiti Rahi at the Poor Knights Islands could not locate 'the many thousands of pairs' of fluttering shearwaters reported by McCallum (1981) (Friesen et al. *in prep*). Fairy prions, another very abundant species in the north, current breeding is known only for the Poor Knights Islands, and its population has only been crudely estimated from numbers seen at sea, spotlighting from boats around the islands and acoustic surveys. The former, mainly to determine their presence on islands within the group particularly the smaller islands; the latter, to get some idea of their relative distribution on the main islands. Of the remaining species listed in Table 1. (i.e. sooty shearwater, common diving petrel, white-faced storm-petrel, and to some extent, NZ storm-petrel), while breeding presence has been confirmed, there are only rough estimates of populations in northern New Zealand. In addition, there are many islands which could hold significant seabird populations, including Three Kings Islands, Simmonds Islands, Moturoa Islands, Mahinepua (Stephenson Island), Cavalli Islands, Bream Islands, Northwest Chickens (all Northland), Channel Island (Colville Channel), Karewa, Motiti Islets and Plate Island (Bay of Plenty), for which there is no or little information.

Populations

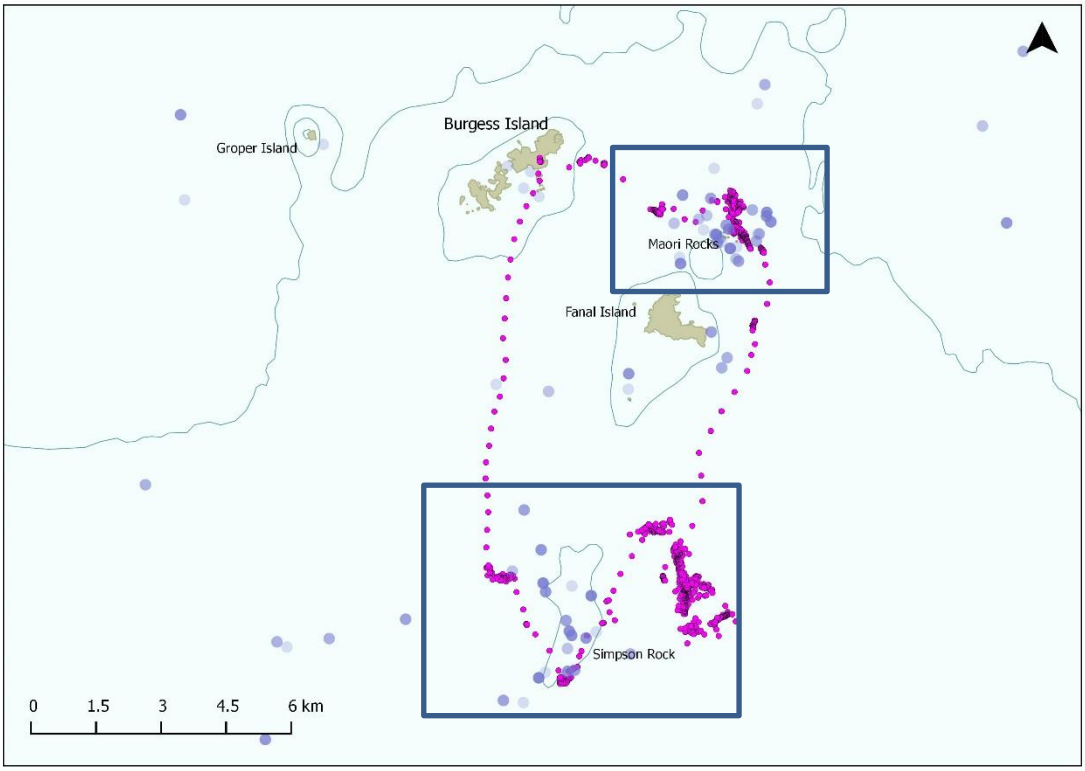
The need for accurate population data for New Zealand's seabirds has been raised by Taylor (2000a, 2000b) and more recently for seabirds in northern New Zealand by Gaskin & Rayner (2013), Waugh et al (2013), Buxton et al (2014), Forest & Bird (2014) and Borrelle et al (2016). A comprehensive survey programme commencing with priority locations is required for the region. The programme should adopt consistent methodology to cover multiple species (ie. compared to single species censuses) and all seasons to ensure accurate baseline data for Procellariiformes in the region are obtained.

[1] Black petrels are the species most at-risk from commercial fishing activities with the New Zealand EEZ. Flesh-footed shearwaters are also amongst the highest risk species (National Plan of Action – Seabirds 2013). These impacts have led to funded population surveys through DOC CSP and MPI.

High resolution tracking

A better understanding of the foraging ecology of high priority seabird species is required. Further research is required to build on the studies into breeding ecology of fairy prion (Harper 1968), fluttering shearwater (Berg 2015-2016), Buller's shearwater (Harper 1983, Taylor 2013, Friesen et al. 2016-2017), and previous work of M. Rayner, E. Bell and M. Young for Cook's petrel, black petrel and white-faced storm-petrel respectively. This research should include establishing a tracking programme using GPS or satellite (PPTs) transmitters, providing foraging data that could potentially be correlated directly to observed fish school activity. The only example of this for northern New Zealand is by Taylor 2013 (unpubl.) during a trial on Burgess Island (Mokohinau Islands) where a GPS transmitter was attached to the back feathers of a fluttering shearwater and the bird tracked over two days (figure 7). Over the same time period fish school activity around the Mokohinau Islands was observed and recorded by CG from the top of the island. While not a constant record for the whole time the transmitter was deployed, the observations were consistent with fluttering shearwaters feeding around fish schools – i.e. at Maori Rocks and Simpsons Rock, both outliers to the Mokohinau Islands and two major bathymetric features where fish activity is common. A further comparison can be made with accumulated observation data which indicates a relationship between significant fish school activity and the bathymetric features that are a feature of the Mokohinau Islands area (figure 7).

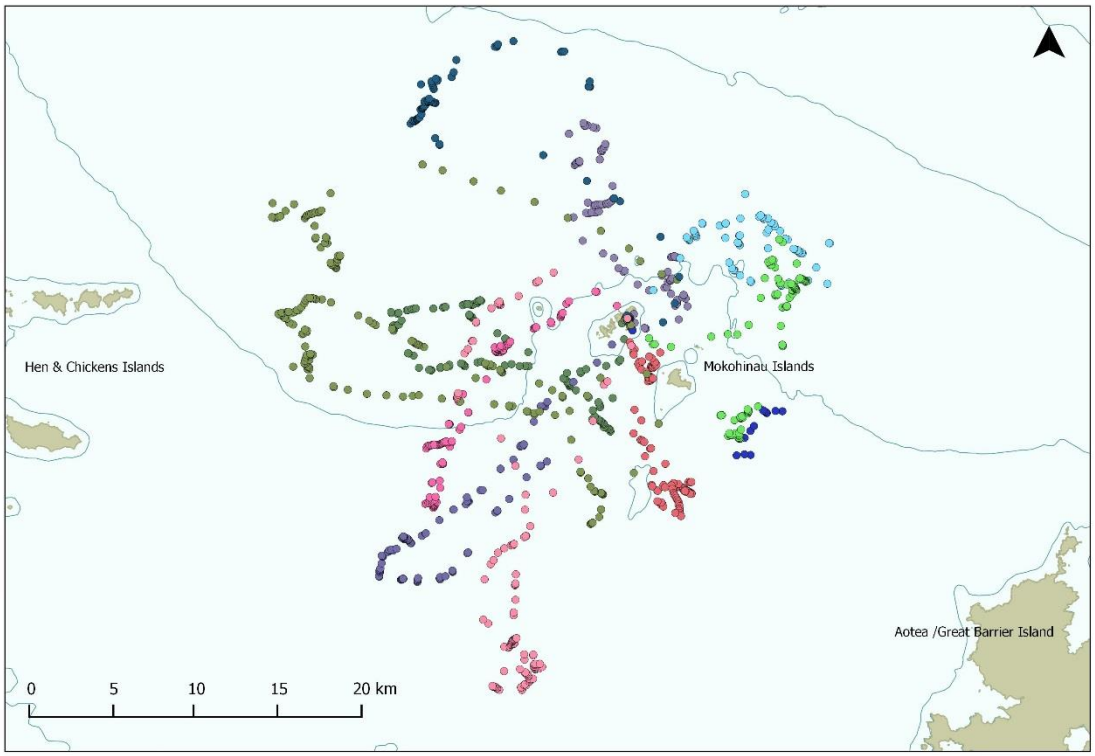
Figure 7. Tracking of a single fluttering shearwater from Burgess Island, Mokohinau Islands, September 2013 (G. Taylor unpublish.). Also shown is accumulated fish school activity observations (blue dots) from at-sea observation data (Gaskin 2006-2017). Rectangles denote areas of prolonged activity (and possibly rafting with other birds) at Maori Rocks and in the vicinity of Simpson Rock.



Further high-resolution tracking has been undertaken by B. Dunphy, S. Vickers and M. Rayner (2016) studying stress physiology of common diving petrels within the Hauraki Gulf. Birds were tracked from two locations, Burgess Island (Mokohinau Islands) (figure 8) and Tiritiri Matangi (inner Hauraki Gulf).

Although common diving petrels have generally not been observed feeding in association with fish schools, these studies, together with tracking of black petrels from Aotea/Great Barrier Island (Freeman et al 2010) and flesh-footed shearwaters from Lady Alice Island, Hen & Chickens Group in 2016 (M. Bell, pers. comm.) provide good local examples of the high-resolution tracking work that could be undertaken for priority northern species, especially if that tracking were matched synchronistically with aerial and/or boat-based surveying for fish school and cetacean activity.

Figure 8. GPS tracking of common diving petrels (n=11) from Burgess Island, Mokohinau Islands, September 2016 (from B. Dunphy, S. Vickers and M. Rayner in prep).



Potential indirect fisheries impact on Procellariiformes

Morrison et al (2014) note that while fisheries research is usually 'operational' in nature and is driven by the immediate management questions at hand, the move towards more ecosystem-based fisheries management has broadened the focus. It can be argued that fisheries and ecologically driven research are now slowly moving towards integration, albeit in an atmosphere of robust debate. It is in this climate of 'robust debate' that concerns have been raised about the potential impact of the purse-seine fishery on marine ecology including seabirds' foraging. Although this was first raised in the 1970s, calls for a full investigation into the broader ecosystem impacts and sustainability of this fishery have increased in recent years (K. Baird (Forest & Bird/BirdLife International), S. Woolford (LegaSea NZ) pers. comms.). Anecdotal historical accounts report diminishing fish school size and frequency, particularly of the formerly 'vast' trevally schools from northern waters (R. Walter, W. Doak, R. Grace pers. comms.). An investigation of the purse seine fishery for trends in catch sizes by trawling through fisheries records has been undertaken simultaneously with this report (F. Hjorvarsdottir, in prep.).

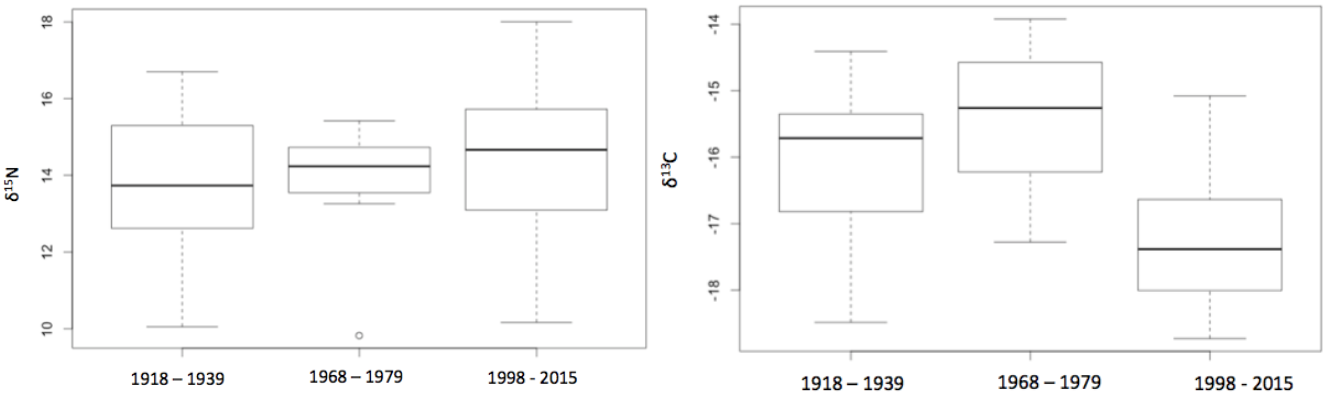
Figure 9. New Zealand-owned purse-seine fishing vessel operating close to the Poor Knights Islands (mid-1970s). Photo: Wade Doak.

Making the connection between Procellariiformes foraging and any diminishing of fish schools is challenging, especially with poor baseline population and foraging data. However, data collected recently suggests that there is a need to investigate this relationship in detail. These data relate to the top two priority procellariiform species of this study; Buller's shearwater and fluttering shearwater.

1/ Foraging times as measured by days away from the nest of breeding Buller's shearwaters during the incubation period may have increased in the past 40 years from 4 days to up to 14 days (Harper 1983, Taylor 2013). Additionally, new at-sea records of adults suggest they could be traveling further south in single foraging bouts during chick provisioning. This change in foraging locations is evidenced by increased sightings by observers off Kaikoura, South Island, New Zealand (Richard et al 2014). These behavioral changes, together with recent poor breeding seasons (G. Taylor, pers. comm.), suggest that the population may be under stress. It is possible Buller's shearwaters are less reliably catching prey in northern New Zealand waters and therefore need to travel farther afield to obtain food. During the non-breeding season, Buller's shearwaters migrate to the North Pacific Ocean (Everett & Pitman 1993, Taylor 2013) and may have different foraging strategies and be subjected to different environmental pressures to those in southern waters.

2/ In his study on fluttering shearwaters that included breeding biology, year-round distribution, activity patterns and habitat use) M. Berg (in prep.) found through stable isotope analysis of feathers 1918-2015 that $\delta^{13}C$ values had declined in recent years (1998-2015) compared to earlier (1968-1979; 1918-1939) (figure 10). Berg proposed four possible scenarios for this decline: baseline shift, new prey type, reduced primary production, and extended foraging range.

Figure 10. Stable isotope analysis of feathers showing $\delta^{15}N$ (left) and $\delta^{13}C$ (right) values. From M. Berg (MSc Candidate, Lund University). Have ecosystem changes in the Hauraki Gulf altered the trophic niche of the Fluttering Shearwater? Presentation at International Albatross & Petrels Conference (IAPC) 2016, Barcelona, Spain.



A number of authors have examined indirect effects of fishing on seabirds internationally (e.g. Tasker et al 2000,), in relation to fisheries targeting forage fish which the birds compete for, forage fish depletion (Cury et al 2011), or, where seabirds are feeding in association with subsurface predators (Hebshi et al 2008). Au & Pitman (1986) found that the number of seabirds in a flock was positively correlated with the size of the sub-surface predator school. Hebshi et al (2008) subsequently hypothesized that larger schools are indicative of larger prey concentrations and provide a larger surface area for a greater number of seabirds to access prey resources. These studies further underline the need for fisheries and wildlife management to address potential indirect ecological effects of fishing.

Data gaps

Major data gaps exist in the following areas:

1. Data detailing the distribution of seabird breeding colonies, their size and population trends are essential for sound conservation management of seabirds. As outlined above, there is a paucity of accurate, up-to-date population and trend data for Procellariiformes in the region, including those breeding at several globally important sites. While species presence and diversity is generally known for many islands, the coverage is extremely patchy.
2. The foraging behaviour and diet of Buller's shearwater, fluttering shearwater and fairy prion is relatively unknown, especially with respect to their relationship with fish school activity.
3. The question of what drives fish school activity needs to be much better understood, especially in terms of 1/ bathymetric features; 2/ oceanographic and environmental factors; and 3/ krill and other prey availability; 4/ fish spawning; and 5/ seasonality.
4. The contribution this feeding association with fish schools has for the diet of key procellariiform species at critical stages of their life cycles is unknown.

Given the number of breeding sites for priority species, it will not be practical to address all the information gaps, nor to work on all species, in the short to medium term. The question then comes down to where and how best to invest relatively limited research resources for the best return. This

should be resolved in terms of increased science understanding, and associated improved management, leading to generating accurate baseline data for ongoing study into population trends.

Recommendations

Listed in order of priority.

Priority	Task	Agency *
1	Investigate prey types of priority procellariiform species using regurgitations gathered opportunistically, stable isotopes (current and historical), and sampling through fish schools including trawling with micron-mesh nets for fish spawn and studying stomach contents of fish species. The latter derived from both the purse-seining fishery and targeted sampling.	CSP
2	Determine the contribution feeding in associations with fish schools is for the diet of priority procellariiform species at critical stages of breeding.	CSP
3	Data collection within seabird colonies (ie. chick development, adult attendance, provisioning and breeding success) for Buller's and fluttering shearwaters, and initiate a contemporary survey and breeding study for fairy prion over five years.	External
4	Baseline population estimates for priority procellariiform species and key breeding sites.	External
5	Ensemble modelling using at-sea and aerial survey data (using existing Hauraki Gulf subset) of observed seabird/fish school events to predict likely fish school occurrence with priority procellariiform species in north-eastern North Island.	CSP
6	Initiate a GPS and PTT tracking programme of priority procellariiform species at different stages of breeding.	CSP
7	The tracking programme undertaken synchronistically with aerial and/or boat-based surveying for fish school and cetacean feeding to 'ground truth' activity observed from the tracking data. These surveys would also provide a means to document through photography and video imaging of fish school activity as it relates to seabird activity.	CSP
8	Island surveys for burrowing seabirds throughout northern North Island offshore islands working to a priority list (Appendix 5).	External
9	Investigate cetacean and Procellariiformes associations – importance for diet of black petrel.	External

* Suggested lead agency. External, whether a single agency or joint venture, would ideally require CSP TWG support and advocacy.

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APPENDICES

Photo: Richard Robinson, Depth NZ

APPENDIX 1

Species notes [2]

Buller's shearwater *Puffinus bulleri* (Salvin 1888) Endemic

Maori name: Rako

Other names	New Zealand shearwater (USA)
Average length & weight	46 cm, 425 g
Breeding season	October-May, 1 egg laid Nov-Dec, incubation c. 51 days, chicks fledge in April-May after c. 100 days.
Breeding habitats	Breed colonially in forested habitat, nesting in under-ground burrows.
Foraging habitat and movements	Offshore foraging habitats, shelf break and pelagic waters. Migrates to North Pacific during winter non-breeding period.

Buller's shearwaters are medium to large-sized seabirds with long slender hooked bills. They breed only at the Poor Knights Islands near Whangarei, northern New Zealand. Buller's shearwaters are common around much of New Zealand, especially in the Hauraki Gulf and Bay of Plenty. The shearwaters dominate their sole breeding islands, excluding most other large species of petrels.

Within the Poor Knights Islands, Buller's shearwaters are extremely abundant on both main islands. The breeding burrows are normally dug on well-drained slopes in dry spongy soils or in clay soils amongst rocks. The nests are under tall pohutukawa forest, amongst Astelia or Xeronema patches on ridgetops, or steep slopes under flax and tussock. Some burrows are under low coastal shrubs such as ngaio. Buller's shearwaters forage over warm water north of 45°S, either over shallow inshore seas or over deep water beyond the continental shelf. After the breeding season, they migrate to the central South Pacific before heading north to complete the annual feather moult in the North Pacific Ocean where they congregate along oceanic currents east of Japan, in particular the Emperor Seamount chain north-west of the Hawaiian Chain. Buller's shearwaters are also regular visitors to the North American coast in the boreal autumn.

Buller's shearwaters breed from September to May with the single large (65 x 43 mm) white egg laid from late November to mid- December and hatching in January. The egg is laid in a lightly lined nest at the back of burrows that are 0.6-3.2 m long. Buller's shearwaters have been considered sensitive to human disturbance and thus the breeding biology is still poorly. Incubation takes about 51 days, and the chicks fledge in May, when about 100 days old. There is no information available on age of first breeding or annual breeding success rates.

Buller's shearwaters are nocturnally active at breeding grounds. The first birds start flying over the islands soon after sunset, in the main are silent, and come ashore throughout the night. Once on land, prospecting birds are noisy on the surface at night, calling from burrow entrances and near burrows. The

[2] From NZ Birds Online, supplemented with information from Gaskin & Rayner (2013) and author.

calls resemble those of sooty shearwaters. The birds are most vocal in the two hours before their departure from the colonies just before dawn. At sea, Buller's shearwaters range widely away from the breeding colonies, foraging over the continental shelf around both the North and South Islands, but also regularly flying east towards the Chatham Islands and beyond. They are often seen from ships and boats but normally don't follow boats unless food scraps or offal are available. Buller's shearwaters are recorded caught in the surface long-line and trawl fisheries (National Plan of Action – seabirds 2013).

The diet of Buller's shearwaters is still poorly known. Small krill are sometimes regurgitated by adults when handled. Small fish are also likely to be taken and squid beaks have been reported from some birds. There is no information yet on whether they feed at night as well as during the day.

From: Taylor, G.A. 2013. Buller's shearwater. *In* Miskelly, C.M. (ed.) *New Zealand Birds Online*. www.nzbirdsonline.org.nz

Fluttering shearwater *Puffinus gavia* (J.R. Forster, 1844) Endemic

Maori name: Pakaha

Other names	Flutterer
Average length & weight	33 cm, 300 g
Breeding season	July, 1 egg laid Sept-Oct, eggs hatch Oct-Nov and chicks fledge Jan.
Breeding habitats	Breed colonially in forested and or scrub or open habitats, nesting in underground burrows and under boulders.
Foraging habitat and movements	Common inshore species but also offshore foraging. Post-breeding, most birds remain in local waters. At least partial migration to eastern Australian seabird during winter non-breeding period.

The fluttering shearwater, with its distinctive, 'flutter-glide' flight, is a ubiquitous seabird of inshore waters in the top half of New Zealand, especially in the northern-eastern North Island and Marlborough Sounds-Cook Strait regions. It is often seen in flocks, sometimes numbering thousands of birds, moving rapidly while foraging. Fluttering shearwaters feeds in association with schools of fish (e.g. kahawai, trevally) or in massive groups at the surface on crustaceans; and at times, resting in large, dense rafts. During the post-breeding period, a considerable proportion of the population remain within in local waters where it is a common sight inshore throughout winter months. It has been observed visiting colonies during non-breeding period. However, it is also a trans-Tasman migrant and is recorded in considerable numbers in eastern and south-eastern Australian waters February to August. These birds may all be pre-breeders, and have included band recoveries of recently-fledged chicks.

Fluttering shearwaters nest in short burrows, under scrub or in forest; colonies can be extremely dense where populations are large; in places co-exist with other species (e.g. common diving petrel, grey-faced petrel). The single large (57 x 40 mm) white egg is laid from late September through to late October.

Incubation and chick-care is shared, but there are no data on incubation length or nestling period. Chicks fledge in January (northern New Zealand).

Fluttering shearwaters eat small fish (e.g. pilchards, sprats) and crustacea (e.g. the small euphausiid *Nyctiphanes australis*). Fish are caught by pursuit diving, using partially-folded wings for propulsion. Pelagic crustaceans are caught while moving forward, head often submerged to look underwater, sometimes with wings raised, and partially spread. Foraging fluttering shearwaters are a spectacular sight when feeding in fast-moving flocks in pursuit of fish schools. There is frenetic activity, with many birds splashing into the water and disappearing below the surface to emerge and repeat the action.

From: Gaskin, C.P. 2013. Fluttering shearwater. *In* Miskelly, C.M. (ed.) *New Zealand Birds Online*. www.nzbirdsonline.org.nz

Fairy prion *Pachyptila turtur* (Kuhl, 1820)

Maori name: Titi wainui

Other names	Dove petrel
Average length & weight	25 cm, 125 g
Breeding season	Aug-Jan, 1 egg laid October, chicks fledge in Jan
Breeding habitats	Breed colonially, nesting in underground burrows and rock crevices on offshore islands.
Foraging habitat and movements	Essentially unknown

The fairy prion is an abundant and familiar petrel of exposed coastal waters around New Zealand, especially from Cook Strait southwards, including on the Chatham Islands and several subantarctic island groups. The Poor Knights Islands are the only northern breeding site. Fairy prions, along with other prion species, are often found storm-wrecked on beaches exposed to the open ocean, especially on the west coast of both main islands.

Fairy prions are colonial breeders, nesting in short burrows or rock crevices, mainly on small islands. They excavate their own burrows, or utilise caves and rock crevices. Fairy prions visit breeding sites after dark and depart before dawn, or stay in burrows or nest crevices during daylight hours. They breed as monogamous pairs, which typically remain together over many seasons. The breeding season is earlier in the north, with peak laying of the single egg in mid-October at the Poor Knights, and early November on the Snares Islands. Incubation is shared and takes 44-54 days. The chick is left unattended during daylight hours when only 1-5 days old. One or both parents visit most nights and feed the chick by regurgitation right through to fledging at 43-56 days old. Young birds return to colonies when 2-3 years old, and first breed when 3-4 years old.

Fairy prions often occur in large flocks at sea. They are generally not attracted to boats, except where surface berley (chum) is deployed, sometimes attracting numbers of birds. Food items are mainly captured by shallow dives, or surface-seizing while surface dabbling or (sometimes) hydroplaning – facing into the wind with wings extended, and dipping the head and neck into the upper 10 cm of the

water column. They are largely non-migratory, staying in New Zealand waters throughout the year. Birds can be found ashore at colonies in any month of the year, though few are present for 1-2 months after breeding (March in Cook Strait, April on Snares Islands).

Fairy prions mainly eat small pelagic crustaceans, along with small fish and squid. The small krill species *Nyctiphanes australis* is by far the predominant species eaten in New Zealand, followed by pelagic amphipods and copepods.

From: Miskelly, C.M. 2013. Fairy prion. *In* Miskelly, C.M. (ed.) *New Zealand Birds Online*. www.nzbirdsonline.org.nz

Sooty shearwater *Ardenna grisea* (Salvin 1888)

Maori name: Titi, hakoakoa

Other names	Muttonbird
Average length & weight	44 cm, 800 g
Breeding season	Sept-May, 1 egg laid Nov-Dec, eggs hatch Jan after c. 53 days, chicks fledge April-May after c. 97 days.
Breeding habitats	Breed colonially in forested and or scrub or open habitats, nesting in underground burrows.
Foraging habitat and movements	Offshore foraging within region and to Subantarctic waters Migration to North Pacific Ocean during winter non-breeding period.

Sooty shearwaters are the common dark seabird of coastal New Zealand, occurring in spectacular flocks of tens of thousands, particularly around the southern South Island and Stewart Island. In northern New Zealand waters they are regularly seen, but in small numbers, often in the midst of multi species flocks of shearwaters and prions, when they congregate on bait balls of crustaceans and feed by flying into the water from a shallow angle. Large flocks can be seen in the north and along the east coast of the North Island during September on their return to New Zealand waters following migration.

Sooty shearwaters breed in large, dense colonies in southern New Zealand, and the Chatham and Subantarctic Islands. In the north, they breed in small colonies, mostly amongst other species. They are monogamous with shared incubation and chick care. The nest is lined with leaf litter and is in a chamber at the end of a burrow. However, the burrow system is complex and varies with locality so that several pairs may share a common entrance or there may be several entrances to one burrow system. Birds tend to return to the same area from year to year, but may not use the same burrow in successive years. A single large (77 x 4 mm) white egg is laid from late November to mid-December. Incubation takes 53-56 days; chicks fledge at about 86-106 days and are independent at fledging (late April to early June).

At sea, sooty shearwaters feed on concentrations of crustaceans or small fish. They often dive to obtain food, using their half-opened wings and webbed feet for propulsion.

Sooty shearwaters generally start coming ashore after sunset and throughout the early part of the night. When landing, they tend to crash through the vegetation and land near their burrow. During the early part of the breeding season colonies are very busy and noisy with birds cleaning out burrows and others courting. Their departure from the colonies begins about two hours before dawn and is equally noisy, with unemployed birds emerging from burrows and moving through the colony to some well-defined cliff top or well-placed tree from which they can launch off and return to the sea. Sooty shearwaters are annual breeders that usually return to the area year after year, often with the same partner. After breeding the colonies are deserted and the birds migrate to the North Pacific Ocean. Banding shows that about 92% of breeders survive from one year to the next, and so oldest birds would live for over 20 years.

Sooty shearwaters eat fish, squid, krill, and offal from fishing vessels taken from the surface and by diving. Birds frequently plunge or dive for food to depths averaging 16 m, and have been recorded swimming to depths of over 60 m.

From: Sagar, P.M. 2013. Sooty shearwater. *In* Miskelly, C.M. (ed.) *New Zealand Birds Online*. www.nzbirdsonline.org.nz

Flesh-footed shearwater *Ardenna carneipis* (Gould 1844)

Maori name: Toanui

Average length & weight	44 cm, 650 g
Breeding season	Sept-May, 1 egg laid Dec, incubation c. 53 days, chicks fledge April-May after c. 92 days.
Breeding habitats	Breed colonially in forested and or open habitats, nesting in underground burrows.
Foraging habitat and movements	Offshore pelagic foraging habitats during breeding season. Migrates to North Pacific Ocean winter non-breeding period.

Flesh-footed shearwaters are medium to large-sized dark seabirds with long powerful hooked bills. They nest on offshore islands around northern New Zealand and in Cook Strait. Flesh-footed shearwaters are attracted to boats and are commonly observed over inshore seas, especially in the Hauraki Gulf and Bay of Plenty. They often sit behind recreational fishing boats and dive to retrieve bait and discarded fish scraps. Their persistence in taking bait from fishing lines puts them into conflict with both recreational and commercial fishers, often with fatal consequences.

Flesh-footed shearwaters nest on 15 islands around northern New Zealand and in Cook Strait, with the largest colonies on the Chickens and Mercury groups plus Ohinau and Karewa Islands. Elsewhere, there are colonies on Lord Howe Island, islands off Western Australia and on Ile St Paul in Indian Ocean. The breeding burrows are normally dug on well drained sites with sandy or clay soils, and under tall forest or low coastal shrubs such as taupata or kanuka. The birds are powerful diggers and dig burrows 1-4 m in length. Flesh-footed shearwaters forage over warmer water north of 43°S, either over shallow inshore seas or over deep water beyond the continental shelf. After the breeding season, they migrate north

past Fiji and Tonga to complete the annual feather moult in the North Pacific Ocean off Japan. The return migration is through the central Pacific Ocean.

Flesh-footed shearwaters breed from September to May with the single large (69 x 46 mm) white egg laid from early to mid-December and hatching in late January or early February. Chicks depart in May. The egg is laid in a lightly-lined nest at the back of burrows (1-4 m long). Flesh-footed shearwaters can be sensitive to human disturbance and sometimes temporarily desert nests by day after handling, although the birds normally return to the nest within a day or two. Flesh-footed shearwater breeding success is affected by oceanic conditions, with good year's dependent on ocean currents bringing lots of small fish to seas near the colonies. Immature flesh-footed shearwaters start to return to colonies as 4-year-olds and first start breeding at 5-6 years of age.

Flesh-footed shearwaters are nocturnally active at breeding grounds. The first birds start flying over the islands soon after sunset and birds can come ashore throughout the night. Prospecting birds are very noisy on the surface at night, calling from burrow entrances and in flight over the colony. The birds are especially noisy in the period just before dawn and on large colonies it is nearly impossible for people to sleep through the dawn exodus period. The calls resemble those of cats having a huge fight. At sea, the birds range widely away from the breeding colonies, foraging over the continental shelf. They mainly forage around the North Island, but also regularly north and west towards Norfolk and Lord Howe Islands. They are often seen from ships and boats, and will follow boats hoping for fish scraps or offal to be discharged. Flesh-footed shearwaters can be very aggressive around fishing vessels and are caught in both commercial and recreational fisheries.

Flesh-footed shearwaters specialise on small fish caught by shallow dives into shoals, or occasional deeper dives reaching 30 m in depth. They sometimes eat small squid. Chicks are fed 80-90 g meals every 2-3 days on average. Activity sensors applied to the shearwaters legs suggest most feeding occurs during the hours of daylight.

From: Taylor, G.A. 2013. Flesh-footed shearwater. In Miskelly, C.M. (ed.) *New Zealand Birds Online*. www.nzbirdsonline.org.nz

White-faced storm-petrel *Pelagodroma marina* (Latham, 1790)

Maori names: Takahikare

Other names	Jesus bird, frigate petrel, Mother Carey's chicken
Average length & weight	20 cm, 45 g
Breeding season	Aug - Feb, 1 egg laid October-November (incubation c. 50 days), chick fledge Jan-March (c. 68 days)
Breeding habitats	Breed colonially, nesting in underground burrows, rock crevices and or under dense mats of vegetation.
Foraging habitat and movements	Forages offshore breeding and migrates to eastern tropical Pacific during austral winter. Poorly known.

White-faced storm petrels are very small seabirds well known to fishermen and boaties venturing a little offshore as "Jesus Christ Birds" as they are often seen walking on water. When feeding, they move in bounding hops with little wing action and hover in place, paddling to pick up food.

They breed in colonies on small islands scattered irregularly around the New Zealand coast, returning for parental duties at night. Their small size makes them extremely vulnerable on land and they are only able to breed on islands that are for the most part free of exotic predators. White-faced storm petrels burrow into shallow soil, mainly on the flat tops of islands. Where they burrow in deeper soil (e.g. Rangatira Island), many burrows are taken over and enlarged by larger petrel species, e.g. broad-billed prions and common diving petrels. White-faced storm petrels also nest in or under dense mats of vegetation such as iceplant, Muehlenbeckia vine and rushes.

White-faced storm petrels are sometimes solitary at sea, but small to extremely large and sometimes widespread flocks form over good patches of food which they seem to locate from some distance by an acute sense of smell. White-faced storm petrels mainly eat planktonic crustaceans and some small fish, picked up from the surface of the water.

From: Southey, I. 2013. White-faced storm petrel. In Miskelly, C.M. (ed.) New Zealand Birds Online. *www.nzbirdsonline.org.nz*

Common diving petrel *Pelecanoides urinatrix* (Gmelin, 1789)

Maori name: Kuaka

Other names	Diving petrel
Average length & weight	20 cm, 130 g
Breeding season	March -Jan, 1 egg laid Jul-Oct, incubation c. 53 days, chicks fledge Nov-Jan after c. 52 days.
Breeding habitats	Breed colonially, nesting in underground burrows or on surfaces under dense vegetation.
Foraging habitat and movements	Inshore and offshore foraging habitats near breeding colonies. Migrates south during summer non-breeding period.

The common diving petrel is an abundant small seabird of exposed coastal waters around New Zealand. It occurs from the Three Kings Islands south to Campbell Island and east to the Chatham Islands. Although it doesn't form dense flocks, hundreds, sometimes thousands, can be in view at a time, looking like miniature penguins on the sea surface, or buzzing over the wave crests. Diving petrels are remarkably similar in appearance and behaviour to little auks (dovekies) of Arctic seas, but the two are not closely related (auks are more closely related to gulls and terns). This is the most frequently cited example of convergent evolution among birds. Diving petrels from the Hauraki Gulf migrate to the South Polar Front, c. 3000km south east of New Zealand from November-December to April-May (Rayner et al in press).

Common diving petrels are colonial breeders, nesting in short burrows, rock crevices or under dense vegetation. The breeding season is earlier in the north, with peak laying of the single egg in August in the Mercury Islands, and mid-October on the Snares Islands. Incubation is shared and takes about 53 days. The chick is left unattended during daylight when 9-15 days old. Both parents visit most nights and feed the chick by regurgitation, right through to fledging at 44-55 days old. Young birds return to colonies when 1-2 years old, and first breed when 1-3 years old. They are the only petrel species known to breed at a year old (2 females and 1 male recorded on Mana Island). The common diving petrel is one of few petrel species that can lay a replacement egg if the first egg fails early in incubation.

Common diving petrels often occur in large, dispersed flocks at sea. They are not attracted to boats and are non-migratory, staying in New Zealand waters throughout the year. Birds can be found ashore at colonies in any month of the year, though few are present for 1-2 months after breeding (January-February in Cook Strait). They excavate their own burrows, and breed as monogamous pairs, which can remain together over many seasons (though divorces are frequent). Common diving petrels visit breeding sites after dark and depart before dawn, or stay in burrows or nest crevices during daylight. Colonies can be low density, or up to 6 burrows per square metre.

Common diving petrels mainly eat small pelagic crustaceans, especially the krill *Nyctiphanes australis* and copepods. Prey is captured by pursuit diving, with the partially folded wings used for propulsion. Diving petrels are well named – they have remarkable diving ability for their size. A New Zealand study of 6 birds recorded a mean dive depth of 11 metres and a maximum of 22 metres, but they have been recorded diving to depths of 64 metres off the Kerguelen Islands.

From: Miskelly, C.M. 2013. Common diving petrel. *In* Miskelly, C.M. (ed.) *New Zealand Birds Online*. www.nzbirdsonline.org.nz

Cook's petrel *Pterodroma cookii* (G. R. Gray, 1843)

Maori name: Titi

Other names	Blue-footed petrel
Average length & weight	25-30 cm, c. 190 g
Breeding season	Sept-April, 1 egg laid mid-November, incubation 46-50 days, chick rearing approximately 88 days (Imber 2003, Rayner 2008)
Breeding habitats	Burrow nesting in forest predominantly between 300 – 700 m on Little Barrier Island.
Foraging habitat and movements	Pelagic foraging in Tasman Sea and Pacific Ocean during breeding. Migrates to North Pacific Ocean during New Zealand winter.

Cook's petrels are small seabirds that breed on Te Hauturu-o-Toi/Little Barrier Island and Aotea/Great Barrier Island, off north-eastern North Island, and Whenua Hou/Codfish Island, near Stewart Island. They are commonly seen in large flocks off Little Barrier Island during the summer, and their calls are often heard at night during the spring and summer as birds cross over the Auckland isthmus and Northland

after feeding in the Tasman Sea. They feed on small crustaceans and squid, mostly picked off the ocean surface during long distance flights covering many thousands of kilometres. Cooks petrels have responded well to pest control on their main breeding islands and both populations are increasing rapidly.

Cook's petrels are specialist deep water (pelagic) foragers. At-sea distribution during breeding is within deep oceanic waters of the Tasman Sea and western South Pacific from approximately 32°S to the sub-tropical convergence zone. After breeding they migrate to the North Pacific transition and California Current system (northern populations), or to the Humboldt Current off Peru and Chile (Codfish population) to complete the annual feather moult.

The breeding season for Cook's petrel runs from September to April, with the northern population breeding one month earlier. Following a first burrow visit in September, birds depart on a pre-laying exodus of approximately 27 days. A single white egg (53 x 39 mm) is laid in November and hatches from December to January after 47 days of incubation. The well-lined nest chamber is at the back of a very long burrow that can run across the slope amongst tree roots. Most birds breed annually and the same pairs can breed together and rear many chicks over multiple years. Both adults share incubation shifts of about 14 days and share in the feeding of their chick. The chick is independent of the parents at fledging in March (c.88 days old); the parents leave on their migration approximately 10 days before the chick departs. Age of first return to colonies is unknown (probably c.3 years).

Cook's petrels are nocturnally active at breeding grounds, arriving about an hour after sunset. Their activity ashore peaks on dark nights or during periods of wet, stormy weather. On Little Barrier Island their calls can be almost deafening as thousands of birds descend upon the island after dark. However, very few birds call on the ground. Recent tracking studies show that Cook's petrels mostly forage at the sea surface, but can dive down to 20 m or more. They cover hundreds or even thousands of kilometres during single foraging trips.

Cook's petrels feed mainly on small squid, plus some fish and crustaceans. Chicks are fed an average of 37g of food, with adult foraging trips averaging approximately 6 days and chicks thus being fed approximately every 3 days. The type of foods eaten suggests most of the feeding is done at night, although activity loggers showed that birds were also active by day during the breeding season.

From: Taylor, G.A.; Rayner, M.J. 2013. Cook's petrel. *In* Miskelly, C.M. (ed.) *New Zealand Birds Online*. www.nzbirdsonline.org.nz

Black petrel *Procellaria parkinsoni* (G.R. Gray 1862)

Maori name: Taiko

Other names	Parkinson's petrel
Average length & weight	46 cm, 700 g
Breeding season	October-July, 1 egg laid Nov-Dec, incubation c. 57 days, chicks hatch end Jan-Feb, chicks fledge April-July after c. 107 days
Breeding habitats	Breed colonially in forested habitat, nesting in underground burrows
Foraging habitat and movements	Offshore foraging habitats, shelf break and pelagic waters. Migrates to eastern Pacific off South America during winter non-breeding period

The black petrel is a familiar petrel of pelagic waters and shelf break edges around northern New Zealand, especially the outer Hauraki Gulf. Generally solitary at sea, it often feeds in small groups associated with dolphins and whales or following fishing vessels. The smallest of the Procellaria group, it is a medium-sized, uniformly black, stocky bird with black legs and feet and a yellowish bill with a grey/black tip. Black petrels usually fly just above the water, but can soar much higher. They breed in burrows on Great Barrier Island (Aotea) and Hauturu/Little Barrier Island in the Hauraki Gulf. The largest colony is on Great Barrier Island which holds an estimated 2000 breeding pairs.

Black petrels breed on Aotea/Great Barrier Island and Te Hauturu-o-Toi/Little Barrier Island in the Hauraki Gulf, Auckland. They are most often seen in the outer Hauraki Gulf or in pelagic waters near continental shelf breaks or sea mounts. During the breeding season, black petrels occur in subtropical waters around New Zealand, eastern Australia and the Pacific Islands. Black petrels migrate to South American waters during the non-breeding period, congregating in offshore and pelagic waters off Ecuador. During the non-breeding season, black petrels have been reported off the coasts of Panama, Costa Rica, Guatemala, Mexico and Galapagos.

Black petrels are colonial breeders, nesting in short to medium (0.5-2 m) burrows on Great Barrier Island (Aotea) and Hauturu/Little Barrier Island. They are monogamous, with shared incubation and chick care. Black petrels attend the colony from October to July, with a single egg laid from mid-November to late January. Incubation is shared and takes 57 days. Chicks are left unattended during daylight when 3-7 days old. One or both parents visit every 2-3 nights and feed the chick by regurgitation through to fledging at 96 to 122 days old. Young birds return to the colonies when 4-6 years old and first breed when 5-7 years old.

Black petrels are generally solitary at sea, but also form flocks around fishing vessels and in association with cetaceans. They characteristically feed by surface feeding and shallow diving at night. Black petrels excavate their own burrows, or utilise caves, hollow logs and cavities under banks and bases of trees. They breed as monogamous pairs, which typically remain together throughout their breeding lives. Black petrels visit the breeding colonies after dark and depart before dawn, or stay in burrows during daylight. After breeding, they migrate to South America, staying in eastern tropical Pacific waters from July to

October. Black petrels feed predominately at night on bioluminescent squid (particularly Ommastrephidae, Histioteuthidae and Cranchidae) supplemented by fish, tunicates, crustaceans and cyclostomes. Black petrels also feed of fish and squid scraps in association with feeding cetaceans (this report).

From: Bell, E.A. 2013. Black petrel. *In* Miskelly, C.M. (ed.) New Zealand Birds Online. *www.nzbirdsonline.org.nz*

Short-tailed shearwater *Puffinus tenuirostris* (Temminck, 1836)

Maori name: none

Other names: Tasmanian muttonbird

The short-tailed shearwater is probably the most numerous of the world's 37 shearwater species, with an estimated global population of 23 million birds. They breed on islands off southern Australia, mainly in Bass Strait and around Tasmania. Short-tailed shearwaters migrate annually, travelling further north than the related sooty shearwater, from the Aleutian Islands through Bering Strait into the Arctic Ocean. They return across the central Pacific, some migrating south along the west coast of North America. Birds fly around 15,000 km each way, a journey that takes six weeks in both directions. Short-tailed shearwaters are often seen at sea off mainland New Zealand from October to January and in May. Here, they are often mistaken for sooty shearwaters, which are slightly larger, with paler underwings. Short-tailed shearwaters are often seen in large rafts at sea off Tasmania during the breeding season. They feed in flocks of up to 20,000 birds, sometimes with other seabirds or with dolphins when around schooling fish. Short-tailed shearwaters take fish and other prey by plunging into the water and pursuing it underwater, up to 10 metres below the surface. They also seize prey at the surface and hydroplane, holding their head in the water while flying low over the surface, grabbing any prey within reach.

From: Szabo, M.J. 2013. Short-tailed shearwater. *In* Miskelly, C.M. (ed.) New Zealand Birds Online. *www.nzbirdsonline.org.nz*

APPENDIX 2

Figure 10. All sites where Buller's shearwaters are breeding, or have been recorded breeding in northern New Zealand. The Poor Knights Islands are main known breeding site for the species. The latter are two single records: breeding on Simmonds Island (PNAP 1991) and the Three Kings Islands (Falla 1934).

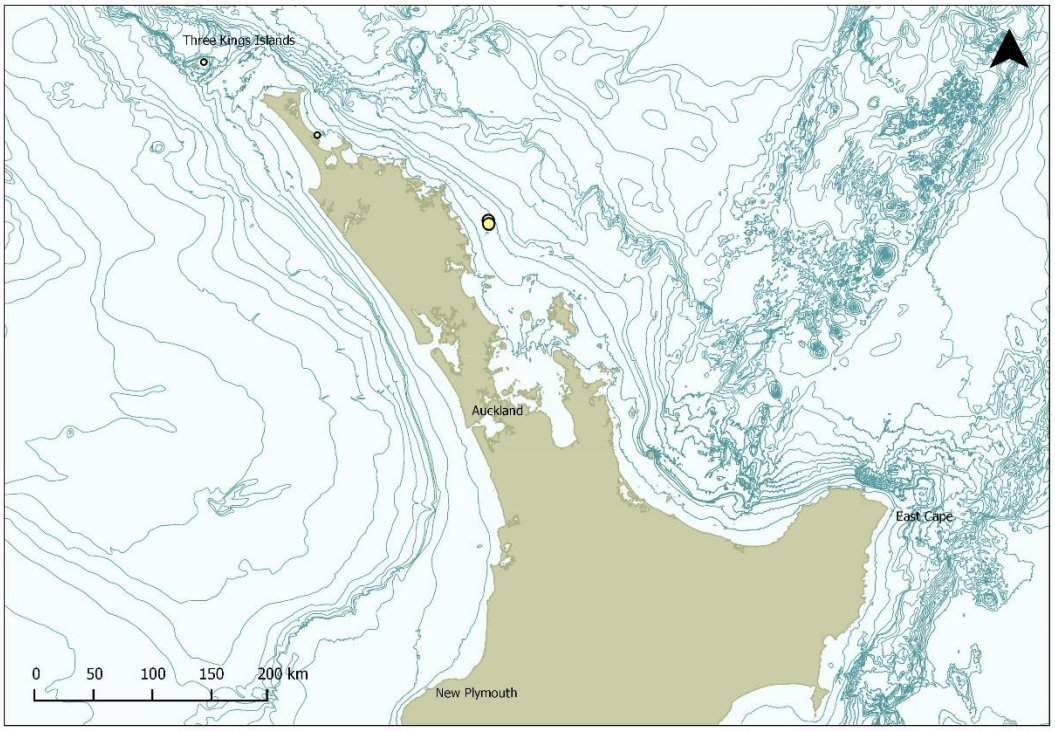


Figure 11. All sites where fluttering shearwater are breeding, or have been recorded breeding in northern New Zealand.

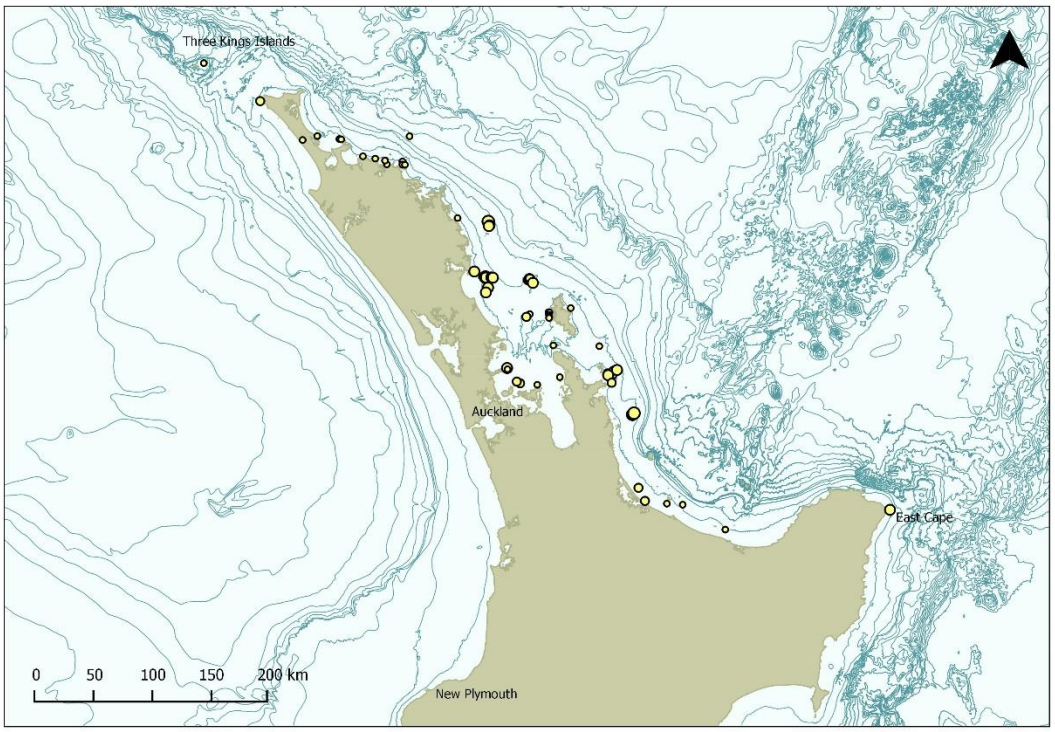


Figure 12. All sites where fairy prions are breeding, or have been recorded breeding in northern New Zealand. The Poor Knights Islands are main known breeding site for the species. Single record for Mahinepua (Stephenson Island) (PNAP 1998).

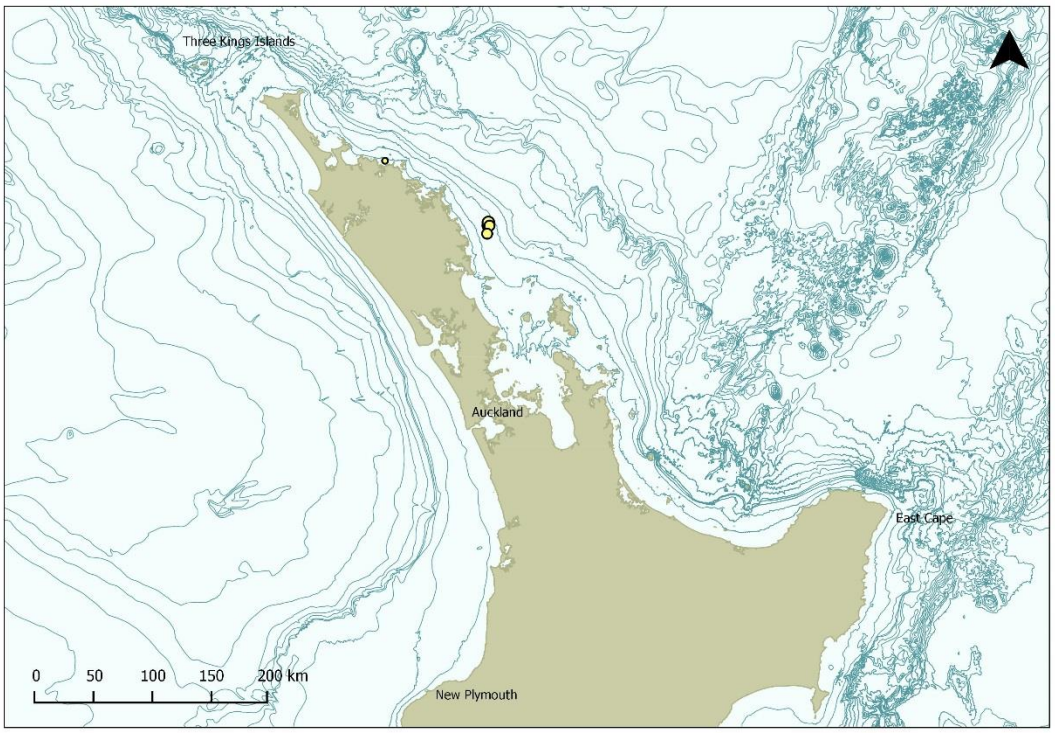


Figure 14. All sites where flesh-footed shearwater is breeding, or have been recorded breeding in northern New Zealand.

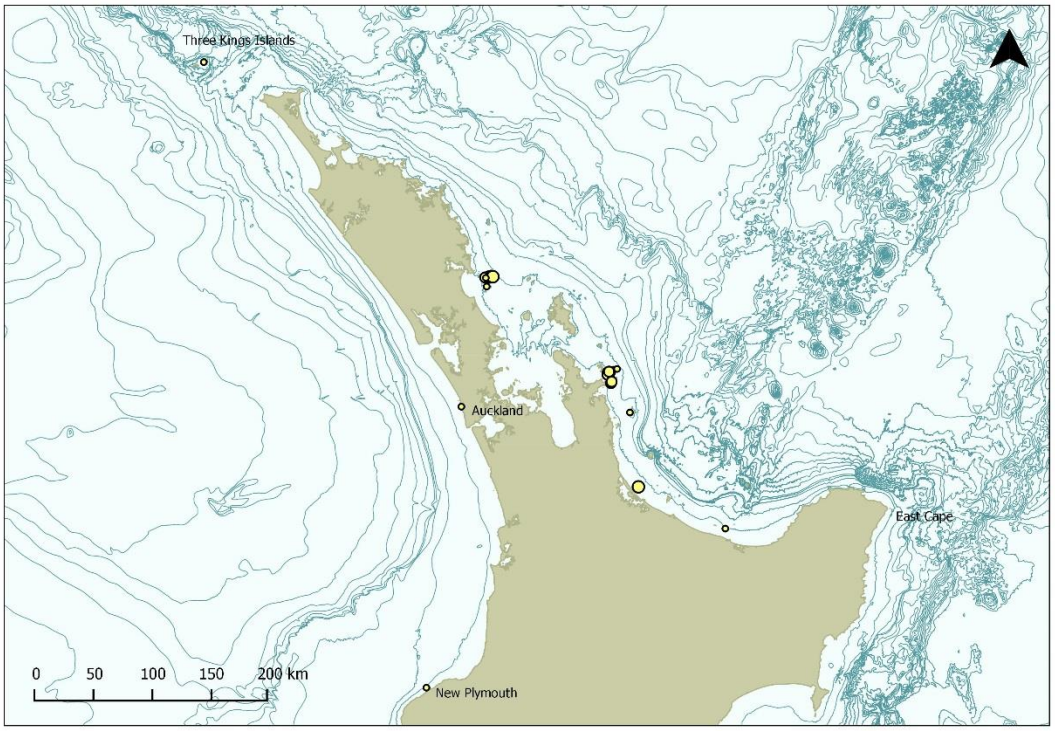


Figure 15. All sites where sooty shearwaters are breeding, or have been recorded breeding in northern New Zealand.

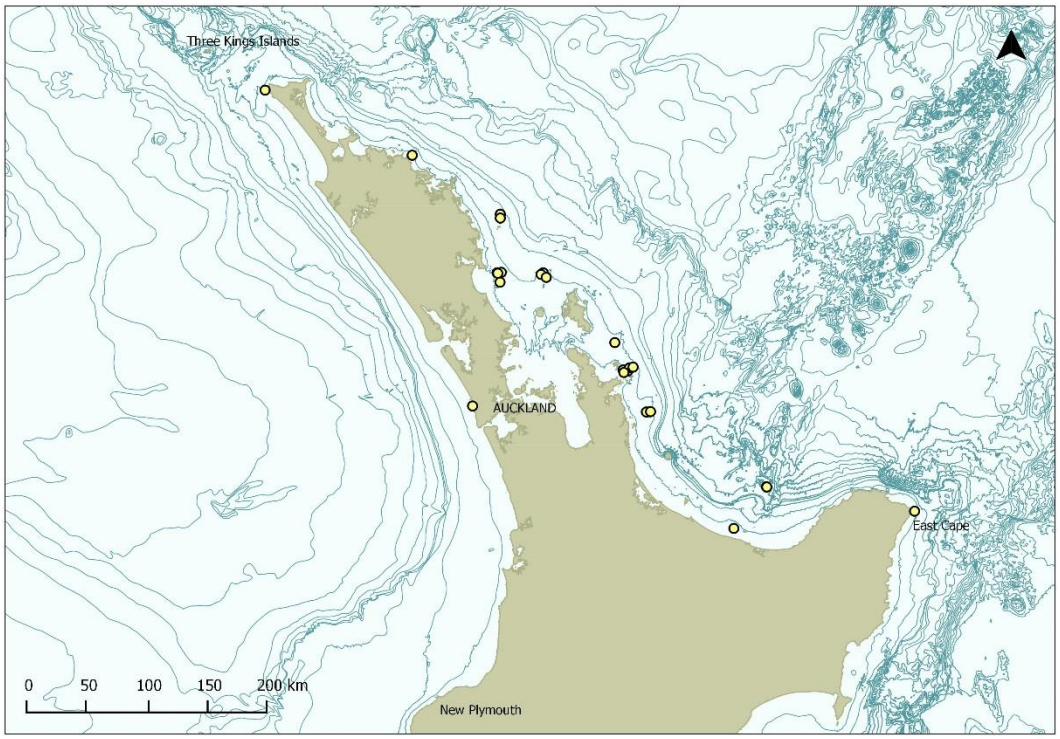
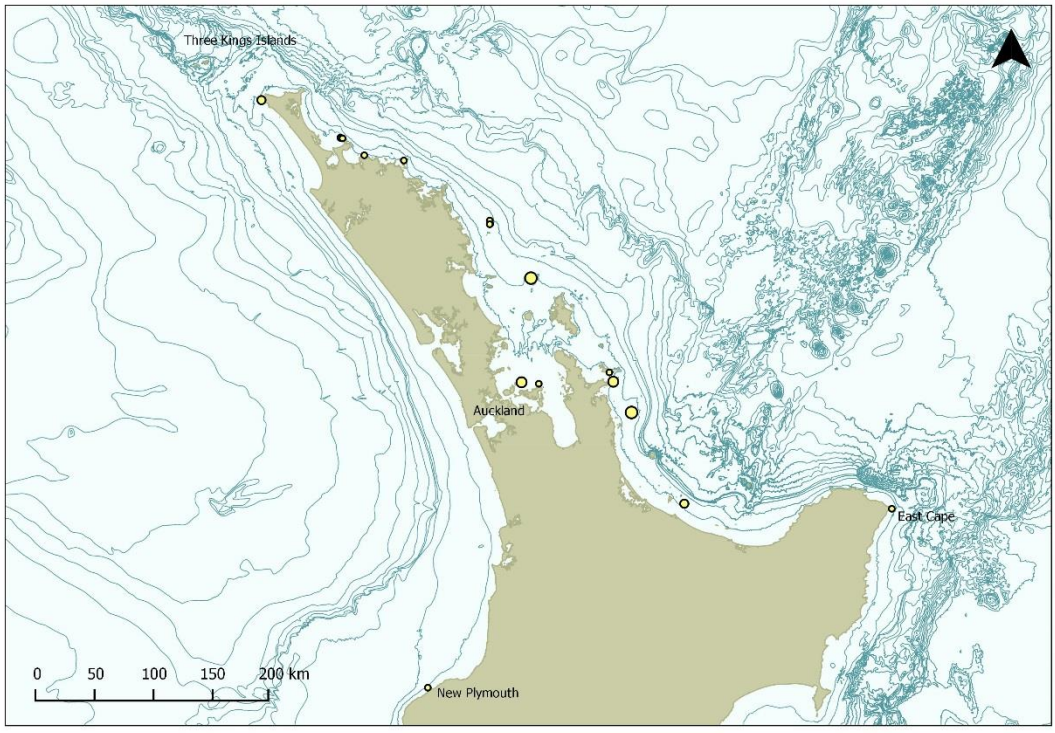


Figure 15. All sites where white-faced storm-petrel is breeding, or have been recorded breeding in northern New Zealand.



APPENDIX 3

At sea-observations

Figure 16. Accumulated seabird-fish school observations (boat-based observations 2006-2016). Buller's and fluttering shearwater, and fairy prion colony sites (yellow and black circles).

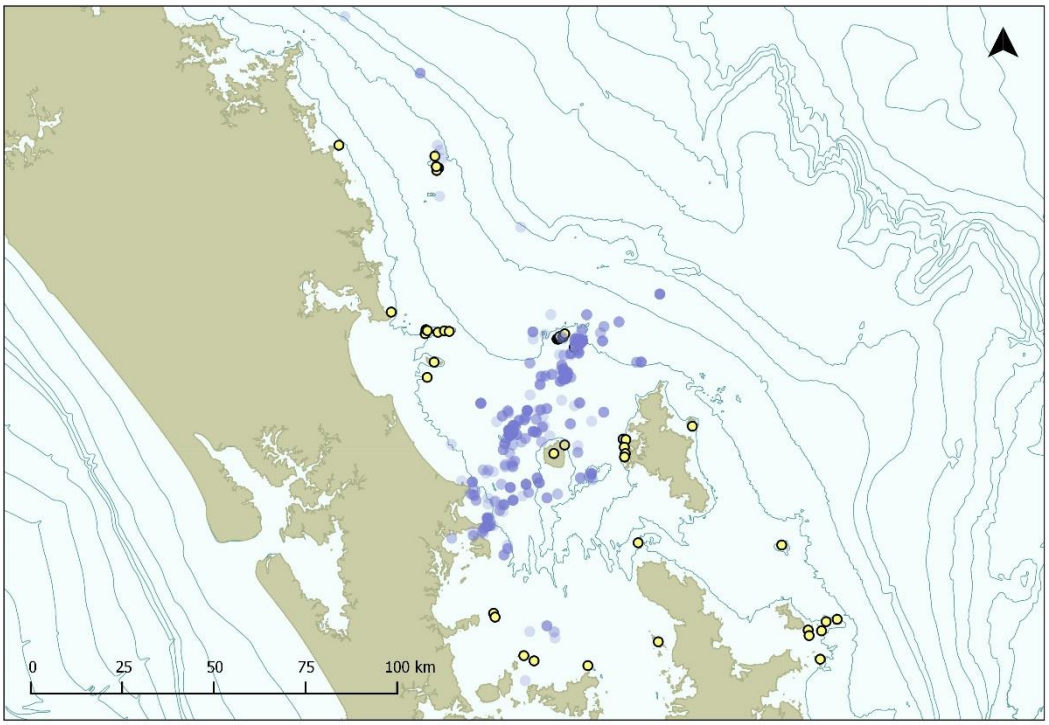


Figure 17. Annotated accumulated seabird-fish school observations in the outer Hauraki Gulf (boat-based observations 2006-2016).

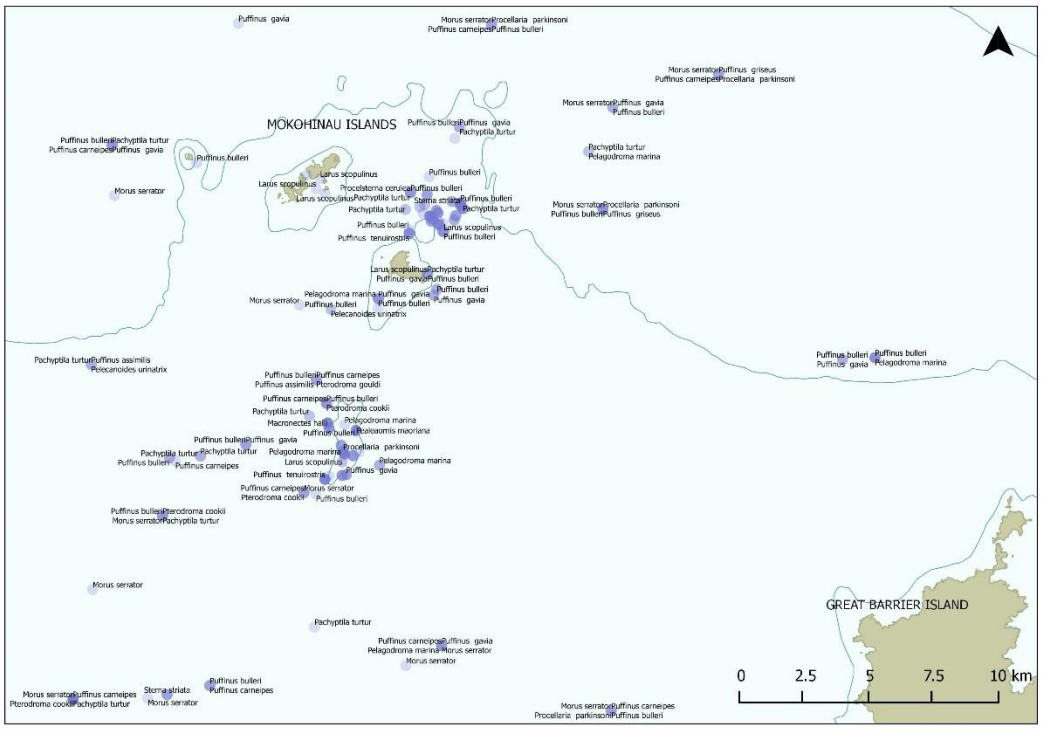


Figure 18. Annotated accumulated seabird-fish school observations near the Mokohinau Islands (boat-based observations 2006-2016).

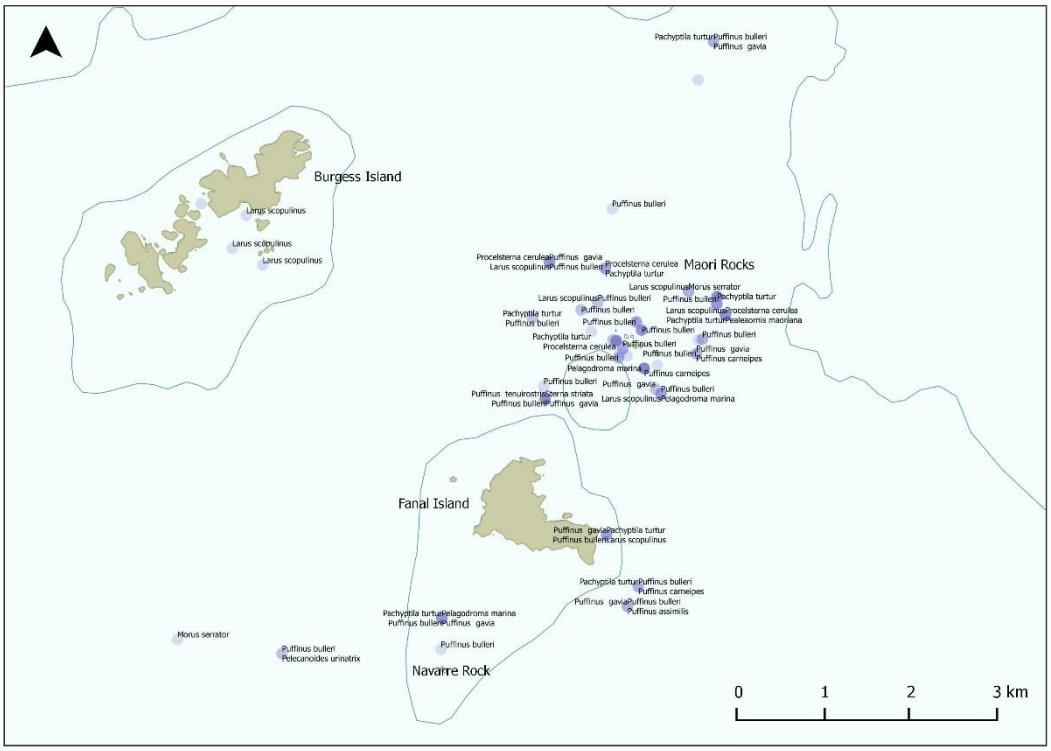
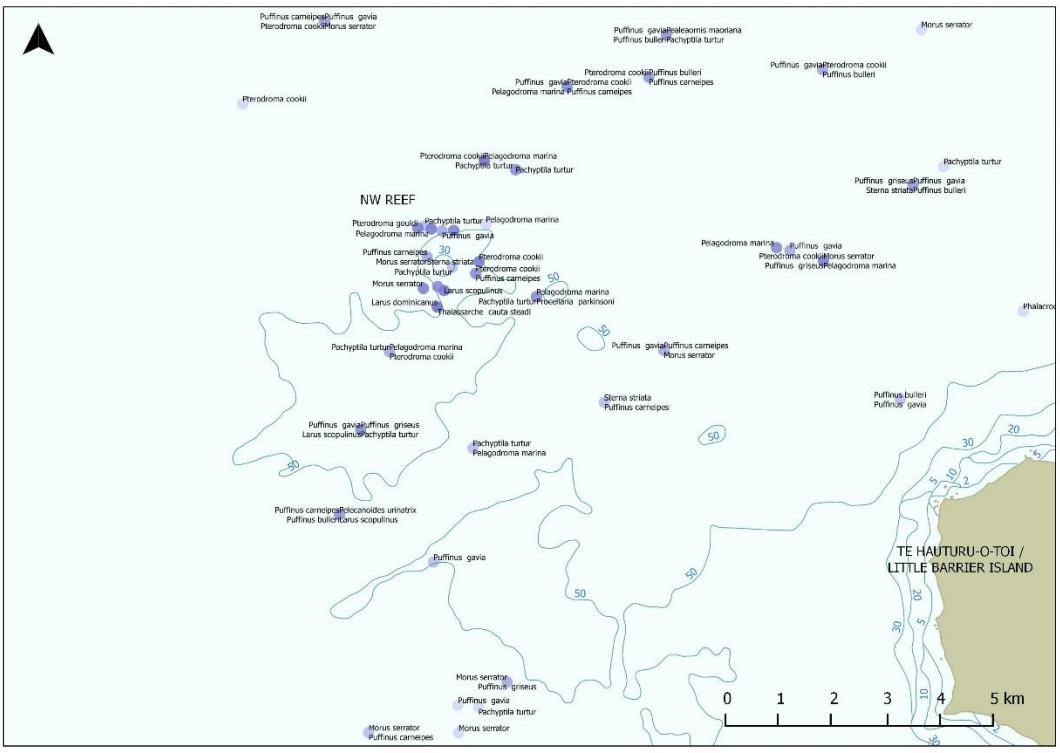
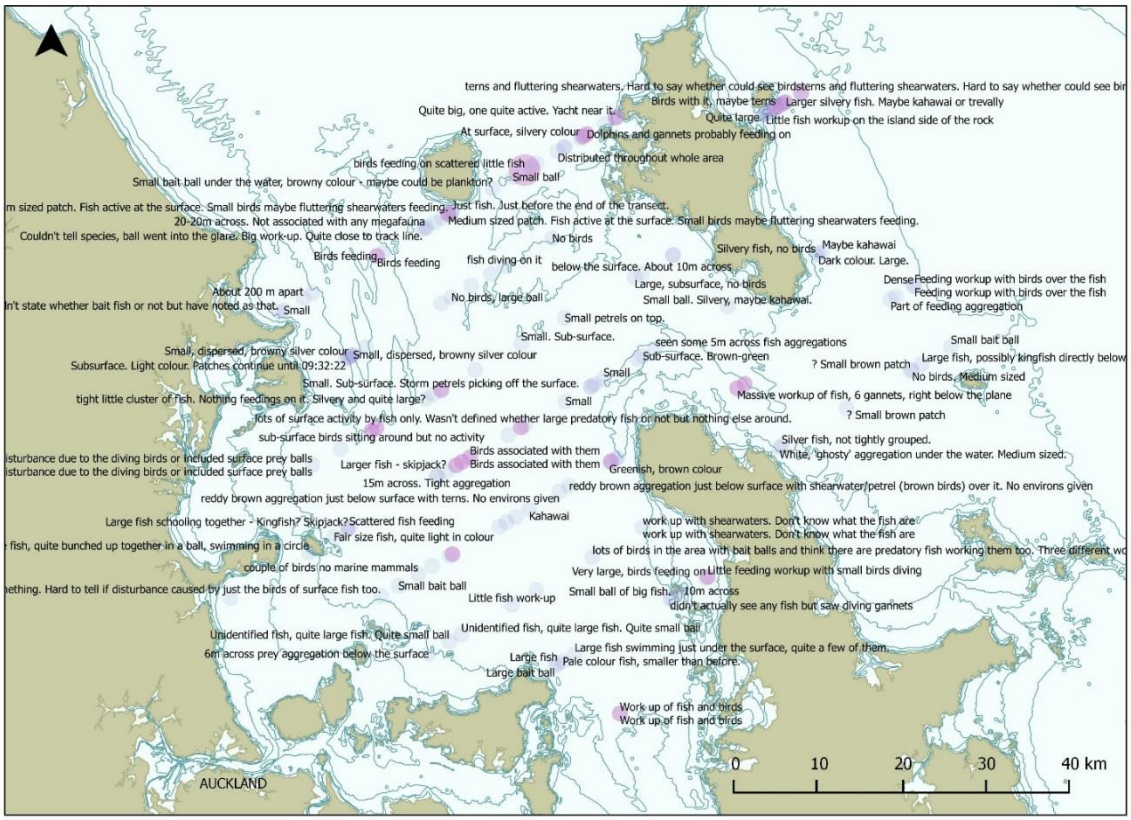


Figure 19. Annotated accumulated seabird-fish school observations in the NW Reef area (boat-based observations 2006-2016).



Aerial surveys

Figure 20. Annotated accumulated observations from Hauraki Gulf Marine Mega-fauna Surveys Sept 2013-Oct 2014 (O. Hamilton, L, Kozmian-Ledward, University of Auckland). Purple discs denote seabird and fish school activity; blue discs fish schools (no seabirds). Figure 21 (lower). Detail showing seabirds-fish schools only.



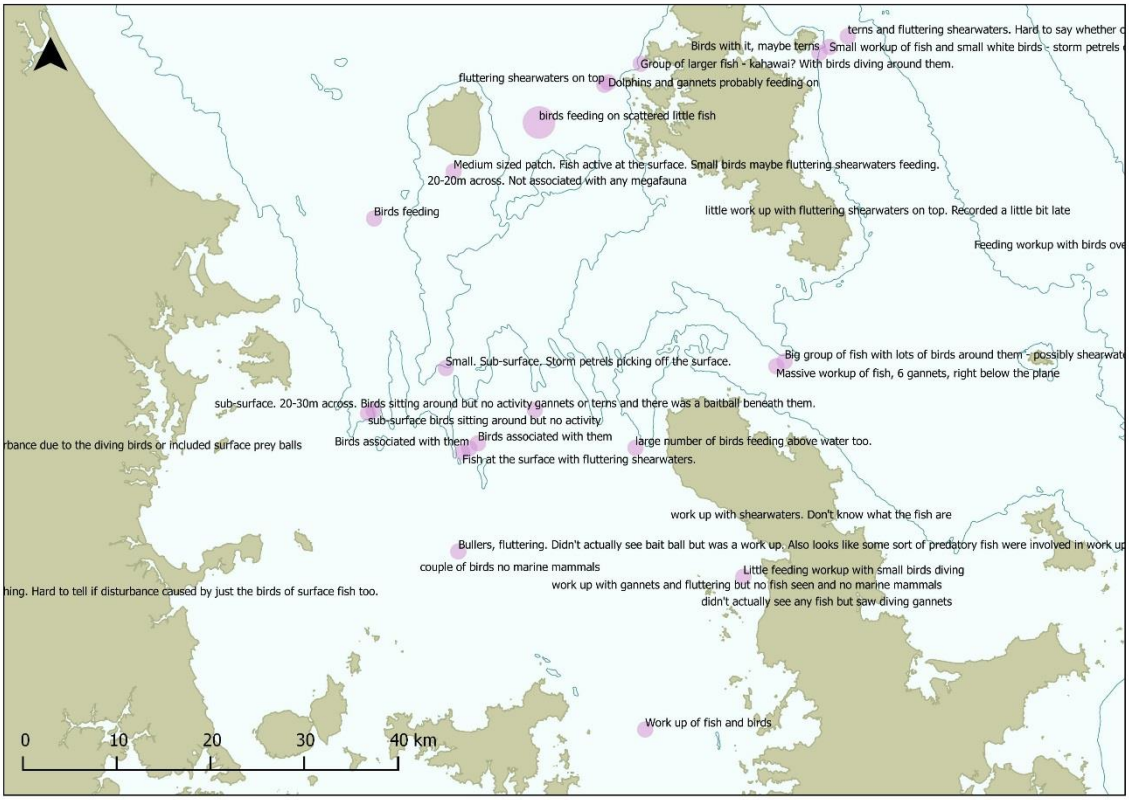
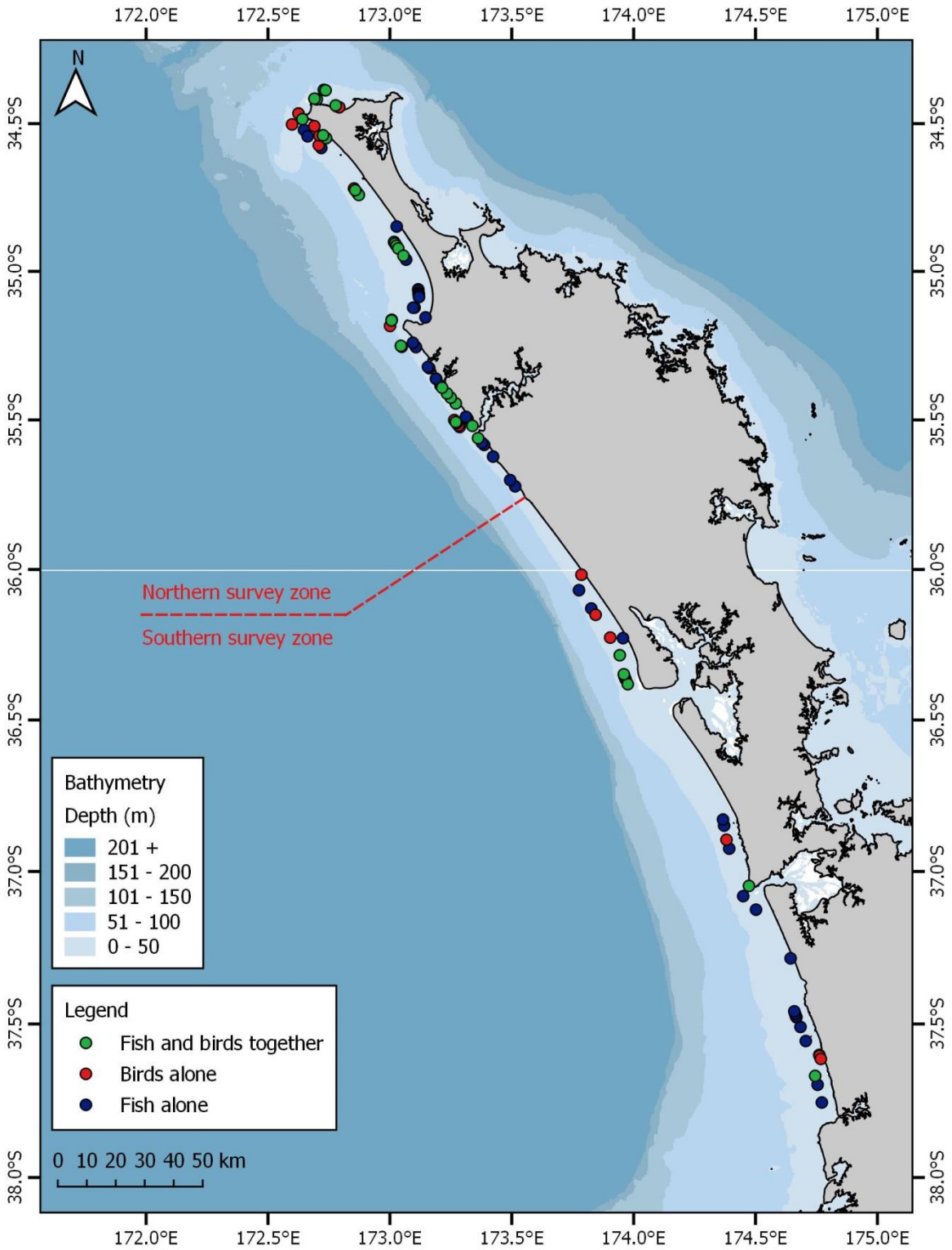


Figure 22. Fish shoals and bird aggregation distribution, West Coast North Island Marine Megafauna surveys (L. Kozmian-Ledward, C. Duffy 2016)



Appendix 4

Foraging behaviour – fish school type

Figure 23. Buller's shearwaters feeding with trevally school, Poor Knights Marine Reserve, December 2006. Photo: Karen Baird

Figure 24. Prions and shearwaters feeding with an active fish school, Simpson Rock, Mokohinau Islands, October 2016. Photo: Chris Gaskin

Figure 25. Spreading trevally school leaving an area of disturbed water with feeding birds, Fanal Island, Mokohinau Islands in background, November 2016. Photo: Chris Gaskin

Figure 26. Fairy prions and Buller's shearwaters in association with a trevally school, outer Hauraki Gulf, October 2010. Photo: Jono Irvine

Figure 27. Fairy prions over a mixed trevally, kahawai and kingfish school, Simpsons Rock, Mokohinau Islands, January 2017. Photo: Karen Baird

Figure 28. Fairy prions diving for prey around a fish school, Simpsons Rock, Mokohinau Islands., January 2017. Photo: Karen Baird

Figure 29. Euphausiids with densely packed trevally and kahawai, Simpson Rock, January 2017. Photo: Northern NZ Seabird Trust.

Figure 30. Dense mass of euphausiids spiralling away from a tightly packed fish school, Simpson Rock, January 2017. Photo: Northern NZ Seabird Trust

Figure 31. Unidentified fish larvae in trevally and kahawai school, Simpson Rock, January 2017. Photo: Northern NZ Seabird Trust

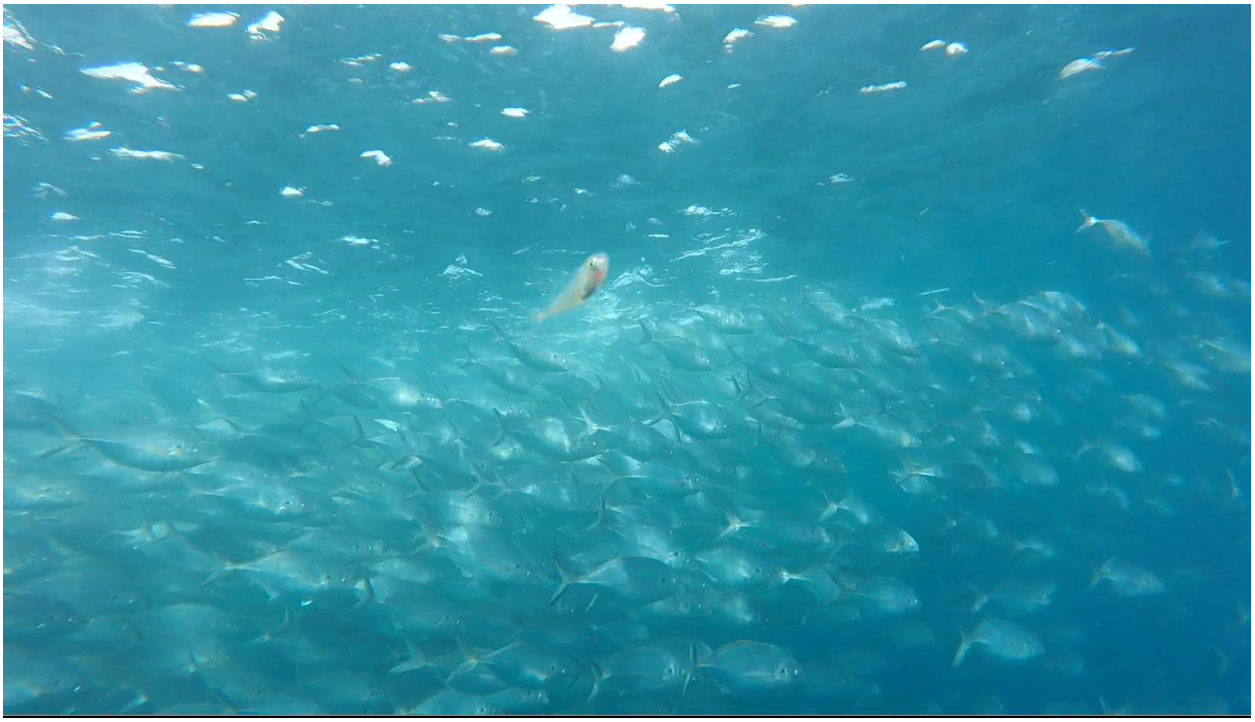


Figure 32. Cloud of what appears to be fish spawn in wake of trevally and kahawai school, Simpson Rock, January 2017. Photo: Northern NZ Seabird Trust

Figure 33. Short-tailed shearwater feeding amid dense trevally activity, November 2016. Photo: Chris Gaskin

Figure 34. White-faced storm-petrels, fairy prions and short-tailed shearwaters feeding in the wake of a trevally school, November 2016. Photo: Chris Gaskin

Figure 35. Fluttering shearwater with a fast-moving kahawai school, Omaha Bay, January 2010. Photo: Karen Baird

Figure 36. Fluttering shearwaters rafting en masse in Kawau Bay in April 2009; typical behaviour following feeding activity, April 2009. Photo: Karen Baird

Figure 37. Australasian gannets and flesh-footed shearwaters feeding on bait fish (unidentified species) with common dolphins (not in screen grab), south east of Hen & Chickens Islands, May 2005. From video: Chris Gaskin

Figure 38. Black petrels feeding in association with false killer whales, off Cape Karikari, Northland, March 2015. Photo: Jochen Zaeschmar.

Figure 39. Mixed species (black and Cook's petrels, Buller's and fluttering shearwaters and white-faced storm-petrels) feeding on discards from false killer whale and bottlenose dolphin feeding, near Horn Rock, Hauraki Gulf, January 2017. Photo: Chris Gaskin

Figure 40. New Zealand storm-petrel and Cook's petrels foraging over an oily slick in wake of feeding false-killer whales and bottlenose dolphins, near Horn Rock, Hauraki Gulf, January 2017. Photo: Chris Gaskin

Appendix 5

Priority list for future island surveys

As outlined above (see **Discussion** and **Recommendation 1**) research is required to determine the distribution, size and status of seabird populations throughout the region. Systematic ground surveying of all islands/breeding sites within region to determine accurate population estimates for all species.

Table 4.

Island / island group	Region	Most recent surveys (year)	Comments	Priority*
Three Kings Islands (Great King)	Northland	1985	Since 1980s surveys have focussed on other fauna (reptiles, invertebrates) and flora (de Lange)	**High**
Three Kings Islands (other islands)	Northland	1985	Since 1980s surveys have focussed on other fauna (reptiles, invertebrates) and flora (de Lange)	**High**
Simmonds Islands	Northland	1990	PNAP survey	**Medium**
Moturoa Islands	Northland	1968	Presence and populations noted in general terms only	**High**
Mahinepua (Stephenson) Island	Northland	1998	PNAP survey	**High**
Cavalli Islands (northern & eastern groups)	Northland	1998	PNAP survey	**High**
Cavalli Islands (other islands)	Northland	1998	PNAP survey (also Hitchmough 1980, Taylor 1988)	**Low**
Motukokako (Piercy or Hole-in-the-rock-island)	Northland	2015-2017	Regular monitoring by Rawhiti iwi (with Massey University and NNZST support)	**Low**
Rimariki (and associated islands)	Northland	1992-1994	PNAP survey	**Medium**
Poor Knights Islands (Tawhiti Rahi and Aorangi)	Northland	2010-2017	CG (acoustic surveys Aorangi 2009-2012); G. Taylor Aorangi; detailed survey Friesen (2016-2017)	**High**
Poor Knights Islands (other islands)	Northland	unknown		**Medium**
Bream Islands	Northland	1990-1991, 2015	PNAP survey, overnight visit / acoustic survey 2015	**High**
North-west Chickens Islands	Northland	2008-2009; 2016-2017	Single species surveys (flesh-footed shearwater); Mauitaha surveyed 2011	**High**

Marotere (Chickens Islands)	Northland	2008-2009; 2016-2017	Single species surveys (flesh-footed shearwater); previous Pycroft's and little shearwater research	**Medium-high**
Taranga (Hen Island)	Northland	2010;	Acoustic survey 2010 (western end); detailed survey by Buxton (parts of island only)	**High**
Mokohinau Islands (excluding Burgess Island)	Auckland	2004, 2009-2010	Island visits (excl. Fanal Island) in April 2004. Acoustic surveys (incl. Fanal Island) 2009-2010	**High**
Mokohinau Islands (Burgess Island)	Auckland	2009-2017	Ongoing research allows for regular monitoring of populations	**Low**
Te Hauturu-o-Toi (Little Barrier Island)	Auckland	2006-2017	Comprehensive acoustic surveys (black petrel and NZ storm-petrel); previous detailed surveys for Cook's petrel (Rayner)	**Medium**
Aotea (Great Barrier Island) – Hirakimata	Auckland	1998-2017	Ongoing research for black petrel (Bell)	**Low**
Tataweka (northern main island Aotea/Great Barrier Island)	Auckland	Unknown		**High**
The Noises	Auckland	2016	Island visits (part-day only) in 2013 and 2016. Acoustic survey 2016	**Medium**
Motukawao Group	Waikato	unknown	Australasian gannets have been the focus of visits; seabird presence noted in botanical surveys (Gilham, Newhook)	**Medium**
Channel Island	Waikato	unknown		**High**
Squaretop Island	Waikato	unknown		**Medium**
Repanga (Cuvier Island)	Waikato	2008	Visits to island during Pycroft's petrel translocations (Taylor)	**Medium**
Great Mercury Island	Waikato	2015-2017	Ground searches before and after eradication programme	**Low**
Mercury Island Group	Waikato	1980s; 2008-2009; 2016-2017	Island visits with ground searches (Taylor); single species surveys (flesh-footed shearwater) on Green I.; habitat surveys on Korapuki and Green I. (Borrelle)	**Medium-high**

Ohinau & Ohinauiti Islands	Waikato	2008-2009; 2016-2017	Single species surveys (flesh-footed shearwater) on Ohinau	**Low**
Ruamaahua (Aldermen Islands)	Waikato	1998	Most islands visited (*in* Tennyson)	**High**
Karewa	Bay of Plenty	2008-2009	Single species surveys (flesh-footed shearwater)	**High**
Motiti Islets	Bay of Plenty	unknown		**Medium**
Motunau (Plate Island)	Bay of Plenty	1988	Island visit with ground searches	**Medium**
Moutohora (Whale Island)	Bay of Plenty	2014	DOC with local iwi conduct regular surveys; mostly focussed on grey-faced petrel	**High**
Rurima Island	Bay of Plenty	unknown		**Low**
Whangaokeno (East Island)	East Coast		DOC with local iwi conduct regular surveys	**Medium**
Motuopoa	Northland	1993, 1999	Island visit and ground searches (Pierce); PNAP survey	**High**
Matapia (Motupia) Island	Northland	1993	PNAP survey	**Medium**
Karewa (Gannet Island)	Waikato	1993	Only recent landing parties have been for fur seal counts and botanical survey (de Lange)	**Low**
Nga Motu (Sugar Loaf Islands)	Taranaki	1998	'Opportunistic sampling of petrels' during island visit (Taylor)	**High**

***** Priority ranking applies to future surveys, ie. not ongoing current surveys.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