Indirect effects on seabirds in northern North Island

POP2017-06

Summary of activities carried out to collect samples from fish shoals 2017-2018 (Milestone 2)

30 April 2018

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Cover: *Photos: Northern NZ Seabird Trust*
Figure 1, this page:. Buller's shearwaters. *Photo: Edin Whitehead*

Introduction

This project (POP2017-06 Objective 2) sets out to identify the range of potential seabird prey species within fish work-ups, to:

- Characterise fish work-ups by identifying and estimating abundance of the suite of predator species and record observations of their feeding behaviour, and
- Quantify the composition of the mesozooplankton community associated with fish work-ups.

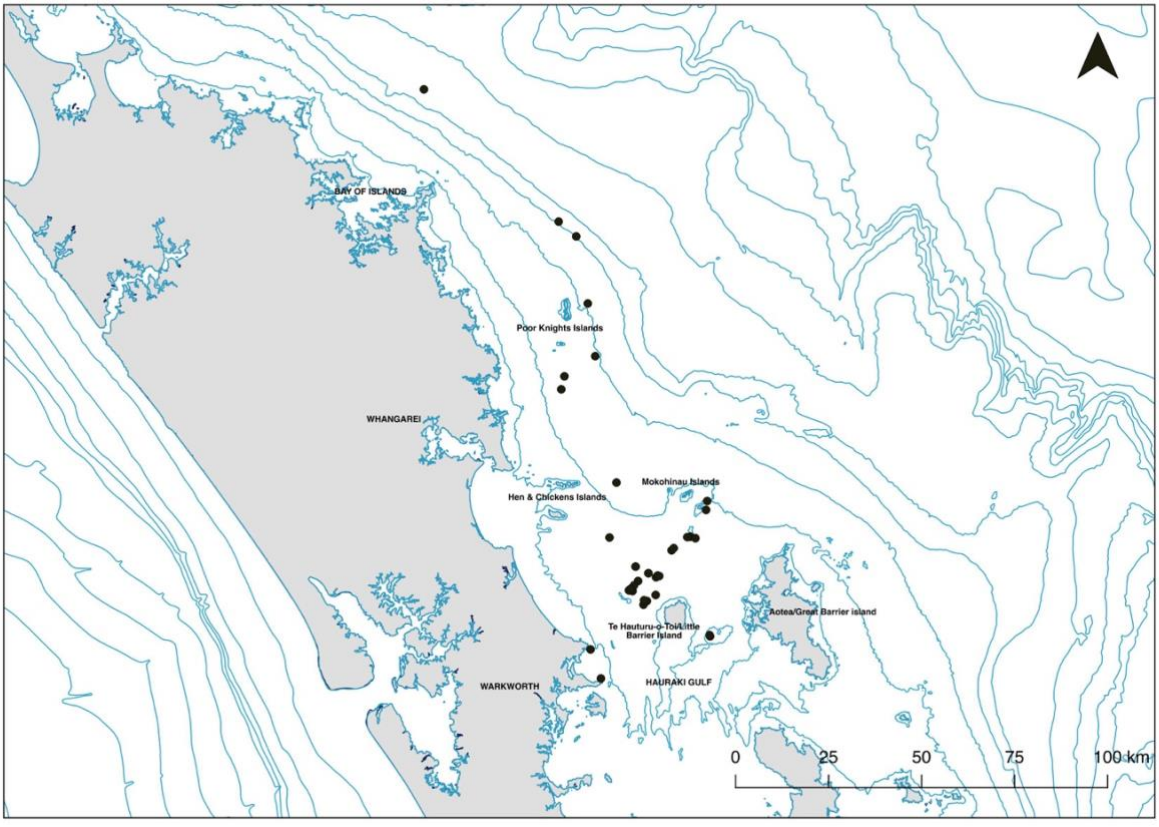
By sampling prey availability within fish work-ups and in the same water surface zones under normal conditions has the potential to provide further information on the range of prey species made available to seabirds by fish work-ups. This report summarises activities from September 2017 to 26 April 2018. The report also includes observations made during the course of the study of other marine activity related to seabird feeding, that is, complementary to their feeding in relation fish work ups, most notably feeding over hydrographic features and in association with cetacean feeding.

Methods

Finding fish schools

Sampling was conducted in the Hauraki Gulf on 44 occasions spread out between September and April, as and when weather conditions permitted (fig. 2). The sampling voyage generally lasted for an entire day, departing from Whangateau (private launch *Waimania*) or Whangarei Harbours (charter launch *El Pescador*), travelling to inner and outer Hauraki Gulf locations and then returning to start. The search area was generally bounded by Hen & Chickens, Mokohinau and Great Barrier Islands, no further south than Horn Rock and Tokatu Point. Two longer voyages were undertaken from the Bay of Islands using the charter ketch *Manawanui*, working with the Far-Out Ocean Research Collective conducting cetacean surveys along the Northland coast.

Figure 2. Sampling locations



Observations of seabird feeding

A time-stamped GPS track of the vessel movements were kept from each voyage along with regular records of sea state and weather conditions whilst underway. Schools were located by targeting locations where shoaling activity had been seen previously, and, failing this, searching more widely. Whilst underway observers continually scanned using binoculars to spot any fish work-ups based on the presence of seabirds, marine mammals or disturbances to the sea surface by feeding fish. Following a sighting, the work up was approached to allow closer observations, photography and sampling.

Upon approaching a fish-work up the GPS position of the work-up was recorded, as well as observations of the estimated size of the fish work-up and other characteristics, such as horizontal movement of the fish work-up, the extent of fish breaching the surface, and patchiness of the work-up. Observations were also made of the species composition of avian and marine mammal predators, with each species quantified with visual counts or estimates of abundance. The respective feeding/non-feeding behaviour of each species was recorded. including the proportion of each species displaying the behaviour.

Figure 3. Fish work up and shearwaters with Aotea Great Barrier Island in background. *Photo: Edin Whitehead*.

Plankton sampling

Up to three replicate vertical hauls from 30 m depth with a zooplankton net within the fish work-up were used to identify the species of mesozooplankton associated with the work-up and provide an estimate of abundance. The hauls were taken some distance apart but still within the main body of the work-up location. The mesozooplankton net consists has a 750mm diameter opening with 250µm cod end. The net was lowered to 30m depth and then hauled to the surface at a rate of 1 m sec^{-1}, i.e. reaching the surface after 30 seconds. In addition, surface tows were

conducted through some work-ups, or in areas where seabirds were seen feeding (e.g. along current lines).

Figures 3-5. Plankton net on deck with samples in measuring jug (massed small spherical salps with some *Sappharina* copepods (their transparent bodies reflecting blue light) and sieve (likely appendicularians). *Photos: Edin Whitehead*.

The contents of the cod-end were washed into a 250µm sieve and then washed into a sample jar with a minimum amount of seawater and preserved with 90% ethanol and sealed. The containers were all labelled with date, sample number and type of tow. In the work to date, where samples were too large for a single sample container, they were divided across two or three containers. In forthcoming seasons, this method will be changed to the following: the sample will be placed in the plastic measuring jug and the volume made up to a convenient quantity, then stirred vigorously, whereupon half of the sample will be tipped out of the jug. The remaining contents of the jug will be sieved and stored in the sample jar as outlined previously, and a note made on the paper label that the sample has been subsampled (halved).

Field photography

Throughout our sampling programme recorded we what is observed at the surface – fish species, bird species, the nature and extent of the work ups, and conditions. These observations were complemented with high quality, high resolution topside photography to show species composition, foraging behaviour and general activity around fish schools, as well as other situations where birds were seen feeding (fig. 6).

Figure 6. Buller's shearwater over trevally school, fish visible breaking the surface. *Photo: Edin Whitehead*.

Underwater videography

As a result of our previous contract (INT 2016-04) we (NNZST) developed a floating camera-rig for deploying amongst fish school activity (figs. 7 & 8). The resulting videography has allowed us to identify species within the fish schools not always easy to detect above the surface. This was particularly the case for schools with multiple species (e.g. trevally, kahawai and kingfish) (fig 9). Deployment of the rig requires manoeuvring into a position in advance of mobile fish schools and anticipating their movement, which frequently change direction. In some cases, the schools were eruptive, appearing and disappearing across large areas (e.g. slimy (blue) mackerel) (fig. 10), also extremely mobile (e.g. skipjack tuna) (fig. 11). The use of the camera-rig has been extended to filming underwater behaviour of seabirds, with the potential of filming Procellariiform activity around cetacean feeding (fig. 12).

Figures 7-8. Deploying the underwater camera rig from an inflatable. GoPro mount near base end of the 2.2m carbon fibre shaft. *Photos: Tony Whitehead and Abby McBride*

Figure 9. Densely packed trevally and kahawai, Simpson Rock, January 2018. *Photo: Northern NZ Seabird Trust*.

Figure 10. Blue (slimy) mackerel school and Euphausiids, 14 October 2018. *Photo: Northern NZ Seabird Trust*.

Figure 11. Skipjack tuna school, Hauraki Gulf, north of Hauturu/ Little Barrier Island, 23 January 2018. *Photo: Northern NZ Seabird Trust*

Figure 12. Black petrel peering through surface watching pilot whales, Ninepin Trench, off Bay of Islands, 26 April 2018. *Photo: Northern NZ Seabird Trust*

Sampling from fish stomachs

Not initially included in the contract, we are investigating two avenues for sampling from fish stomachs, as follows:

1. Catch fish in fish schools where seabirds have been observed feeding,
2. Sample from commercially caught fish species that seabirds frequently associate with.

In the first, captures to date are three skipjack tuna caught recreationally by the crew of *Manawanui* for eating (sashimi). Buller's shearwaters had been seen rafting nearby in two instances. Another was caught in the vicinity where black petrels and flesh-footed shearwaters were foraging over a pod of pilot whales and pelagic bottlenose dolphins (figs. 12-15).

In the second, a request will be made to Observer Services Unit, Fisheries Management, MPI to obtain samples from commercial purse seine fisheries during the 2018-2019 (October to May) season.

Figures 13-16. Skipjack tuna caught off Bay of Islands recreationally. Stomach sample was collected from crew showing dense euphausiids. *Photos: Edin Whitehead*

Archiving and collation of samples

The samples collected are currently in storage at NNZST waiting sorting and collation prior to formal identification by experts, or comparison with voucher samples. Collation and sorting of specimens will be undertaken at the Leigh Marine Laboratory University of Auckland by Lily Kozmian-Ledward through a subcontract to POP2017-06.

Preservation of delicate soft-bodied organisms

Given the prevalence of salps and other soft-bodied organisms in the samples obtained to date, we will be investigating the use of formalin for preserving these delicate organisms next season. Carrying and using both formalin on board vessels will require meeting Health and Safety requirements.

Figures 17 & 18. Salps caught during plankton sampling. *Photos: Tony* (top) *and Edin* (lower) *Whitehead*

Results

Table 1. Seabird species observed feeding in association with fish schools in northern New Zealand waters; also included are species observed in association with feeding cetaceans and in other situations (e.g. along current lines).

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
Australasian gannet	*Morus serrator*	**Not Threatened**	Least Concern
Red-billed gull	*Larus novaeholllandiae scopulinus*	**Nationally Vulnerable**	Least Concern
White-fronted tern	*Strerna striata*	**At Risk - Declining**	Least Concern
Flesh-footed shearwater	*Ardenna carneipes* (= *Puffinus carneipes*)*	**Nationally Vulnerable**	Near Threatened
White-faced storm-petrel	*Pelagodroma marina*	**At Risk - Relict**	Least Concern
Black petrel	*Procellaria parkinsoni*	**Nationally Vulnerable**	Vulnerable
Sooty shearwater	*Ardenna grisea* (= *Puffinus griseus*)*	**At Risk - Declining**	Near Threatened
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
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*.

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

	Fish school/prey type	General description of activity	Species
1	Trevally *Pseudocaranyx dentex* (and mixed	Tightly packed, very active dense schools, sometimes with several schools merging to form very large schools. Birds either forage	Buller's shearwater, fluttering shearwater, fairy prion, sooty shearwater, flesh-footed

	trevally, kahawai *Arripis trutta* & kingfish *Seriola lalandii*)	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. Photos, underwater videography	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. Photos, underwater videography	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. Photos	Australasian gannet, fluttering shearwater, flesh-footed shearwater, Buller's shearwater, white-faced storm-petrel, Cook's petrel (also common dolphins)
5	Skipjack tuna (*Katsuwonus pelamis*)	Fast moving fish sometimes jumping clear of water. Shearwaters following at speed, leap-frogging from one emergent feeding area to next. Photos, underwater videography	Buller's shearwaters, also fluttering shearwaters (with Australasian gannet and red-billed gull and white-fronted tern on occasion)
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. Photos	Buller's shearwater, fluttering shearwater, fairy prion, common diving petrel, white-faced storm-petrel, sooty shearwater.
7	Crustaceans, salps, juvenile fish	Current lines with birds actively feeding without prey being visible at the surface. Photos	Fairy prion, fluttering shearwater, white-faced storm-petrel.

Table 3. Other feeding associations recorded during surveys

Cetacean species	Activity	Birds
Common dolphin *Delphinus delphis*	Generally, very active pursuit by dolphins, sometimes herding or rounding baitfish into tightly packed spinning schools; spectacular	Australasian gannet, flesh-footed and fluttering shearwater, red-billed gull and white-fronted tern

	with gannets diving, sometimes in very large numbers, also smaller seabirds active in the midst of the action; shearwaters diving in pursuit of prey. Photos	
Common dolphin	In contrast to the above, more sedate feeding activity by the dolphins (although with occasional surges); attendant birds on the surface peering below, sometimes diving in pursuit of prey, or flying to where new action takes place. Photos	Flesh-footed shearwater, Australian gannet, fluttering and Buller's shearwater
False killer whale *Pseudorca crassidens*, pelagic common bottlenose dolphins *Tursiops truncatus*	The cetaceans feed at or below the surface; petrels and shearwaters diving underwater to pick up discards; birds often scrapping over food. Storm-petrels have been observed feeding on small scraps and the oily slicks generated by the feeding activity. Photos, underwater videography	Black petrel and flesh-footed shearwater with Cook's petrel, Buller's shearwater, fluttering shearwater, white-faced storm-petrel and NZ storm-petrel
Long-finned pilot whales *Globicephala meias* and pelagic common bottlenose dolphins	Mostly seabirds following the pods which for the most part don't appear to be feeding; however, the birds pay close attention to the cetaceans underwater which occasionally bring squid which the birds pick up and fight over. Photos, underwater videography	Black petrel and flesh-footed shearwater with Buller's shearwater, and white-capped and Campbell albatrosses.

Table 4. Samples collected 20 September 2017 to 26 April 2018.

ID	Date	Latitude	Longitude	Depth (<30m)	Surface tow (<1m)	Comments
001	20/09/17	-36.13797	174.94977			NW Reef; Near rafting prions; diving petrels and white-faced storm petrels around; no work ups; sea khaki green; sample full of algae
002	20/09/17	-36.04509	175.06546			SW of Simpsons Rock: Work ups of shearwaters and prions with white-faced storm petrels; fish schools not visible at surface; lots of salps, also algae.
003	20/09/17	-36.03965	175.07169			SW of Simpsons Rock: Work ups of shearwaters and prions with white-faced storm petrels; fish schools not visible at surface; lots of salps, also algae.
004	6/10/17	-36.14564	174.95131			Fish school occasionally surfacing; fluttering shearwaters, white-faced storm petrels around.
005	6/10/17	-36.12109	174.96722			Work up with fluttering shearwaters, white-faced storm petrels (in numbers) and red-billed gulls

006	6/10/17	-36.08624	174.95895			Huge active work with enormous number of birds - shearwaters, prions and red-billed gulls, with one white-capped albatross and a northern giant petrel showing interest but not staying. Photos from Edin W. Underwater video from drop cam.
007	6/10/17	-36.08624	174.95895			Same
008	6/10/17	-36.13171	174.95552			Dispersed birds on active fish schools
009	14/10/17	-36.15395	175.02069			Huge extremely active work up; blue (slimy) mackerel and possibly kahawai; fish schools very mobile, disappearing below the surface for periods before erupting at different place; 1000s of Buller's and fluttering shearwaters, and fairy prions, with a few flesh-footed shearwaters. Very widespread and moving between bust-ups. Underwater video from drop cam.
010	14/10/17	-36.35885	174.86188			Off Tokotu Point at edge of Tawharanui Marine Reserve; red-billed gulls. Masses of salps.
011	1/12/17	-36.14125	174.94461			Rafting birds, dropped net where there had been bird activity; wind got up very strong for a period.
012	1/12/17	-36.01105	175.12025			Big work up of prions, shearwaters and petrels - near Simpsons Rock; fish very active at surface.
013	1/12/17	-36.01105	175.12025			Same
014	1/12/17	-36.01105	175.12025			Same
015	10/01/18	-35.923834	175.168344			Just north of Maori Rocks, trevally and kahawai schools; opportunistic sampling during a birdwatching trip
016	21/01/18	-36.14125	174.94461			NW Reef; few birds, no fish school activity
017	21/01/18	-36.14406	174.94147			NW Reef; few birds, no fish school activity
018	21/01/18	-36.14413	174.94040			NW Reef; few birds, no fish school activity
019	21/01/18	-36.138564,	174.92392			Very active and mobile work up; Buller's, fluttering, sooty, short-tailed and flesh-footed shearwaters fairy prion, white-faced storm petrels with one NZ storm-petrel.
020	21/01/18	-36.16907	174.99483			Same
		-36.17812	174.98482			Underwater videoing: some good footage of mixed species school; two mackerel species plus trevally

022	21/01/18	-36.16733	174.98624			Very active work up; Buller's, fluttering, sooty, short-tailed and flesh-footed shearwaters fairy prion, white-faced storm petrels
023	21/01/18	-36.25124	175.18607			Horn Rock; white-faced storm petrels feeding along slick lines
024	21/01/18	-36.24830	175.18439			Same
025	23/01/18	-36.10158	174.99769			Cooks petrels, fluttering shearwaters on water active, no fish activity - salps and juvenile fish
026	23/01/18	-36.10158	174.99769			Bird activity stopped, salps
027	23/01/18	-36.01105	175.12025			Simpsons Rock; shearwaters, prions, trevally school
028	23/01/18	-36.01105	175.12025			Same
029	23/01/18	-36.01224	175.11150			Same
030	23/01/18	-35.94538	175.16556			Trevally school off Fanal Island; a few birds (prions, fluttering shearwaters, one short-tailed shearwater, storm-petrels)
031	23/01/18	-36.01447	175.13571			Camera drop; Skipjack school (Buller's shearwaters, prions, Cook's petrels) dispersed quickly
032	23/01/18	-36.11103	175.02069			Skipjack school fast moving - same birds
033	23/01/18	-36.10683	175.02549			Same
034	20/04/18	-36.28900	174.82904			Leigh Reef: kahawai school: fluttering shearwaters (plumage very worn on some birds), white-fronted tern, Australasian gannet (1)
035	20/04/18	-36.01715	174.87939			A few gannets sitting, Buller's shearwater; no fish activity
036	20/04/18	-36.14071	174.94567			NW Reef - boat drifting with the wind; Australasian gannets, Buller's shearwaters, northern diving petrels in vicinity
037	23/04/18	-35.62866	174.73633			Skipjack tuna caught (recreationally); stomach contents collected, dense euphausiids; Buller's shearwaters rafting in large numbers in vicinity
038	23/04/18	-35.66035	174.72773			Flesh-footed shearwaters with numbers of northern diving petrels feeding; salps plus crustaceans (incl. one crab-like organism with reflective blue eyes)
039	24/04/18	-35.88375	174.89698			Common dolphins with very active flesh-footed shearwaters and Australasian gannets; plenty of salps in sample.

040	24/04/18	-35.57851	174.82676		Similar composition (dolphins, shearwaters and gannets); less salps in sample, good diversity of organisms
041	26/04/18	-35.45121	174.80181		Skipjack tuna caught (recreationally); stomach contents collected, dense euphausiids;
042	26/04/18	-35.28926	174.76408		Fairy prions feeding in numbers along a strong (E-W) current line either in groups, or individually, spread out. Juvenile fish plus other organisms
043	26/04/18	-35.25414	174.71123		Fairy prions feeding in numbers along a strong (E-W) current line either in groups, or individually, spread out. More salps. Water colour - markedly khaki compared to further south
044	26/04/18	-34.93867	174.30804		Skipjack tuna caught (recreationally); stomach contents collected, dense euphausiids; pilot whales and bottlenose dolphins with black petrels, flesh-footed shearwater and two species of albatross.

Table 5. Samples collected from fish caught (recreationally) in areas where seabirds were seabird feeding or were rafting.

Date	**Fish species**	**Bird species**
23/04/18	Skipjack tuna	Buller's and flesh-footed shearwaters, common diving petrel
26/04/18	Skipjack tuna	Buller's shearwaters and fairy prions
26/04/18	Skipjack tuna	Black petrels and flesh-footed shearwaters with white-capped and Campbell albatrosses.

Discussion

Seabirds, by definition, find all or most of their food at sea (Taylor 2000). They do this by adopting a range of strategies, using sight, smell, or a combination of both visual and olfactory cues. Some are solitary feeders, others in flocks. Here we focus on food made available to seabirds by the activity of fish schools. We also look at the related foraging associations with cetaceans. A significant number of seabird/fish school observations coincide with major bathymetric features with regular tidal and current flows across or around them. However, seabird and fish school activity also occurs in areas where the relationship with tides, currents, up-welling and bathymetric are less direct and obvious. 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. (Gaskin & Rayner 2013, Gaskin 2017)

The sea off the northern North Island 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).

Unpredictable distribution

Locating fish school and seabird feeding activity during this study required traveling considerable distances (<75nm) during day trips (n=8) and c300nms during multi-day trips (n=2). Several locations where fish school had been seen regularly were visited, however when no activity was detected, further searching over long periods and distances was required. Dense seabird activity above the horizon was generally the visual cue we used, whether for locating fish schools or cetacean feeding.

In order to make better use of our time on water, especially when fish schools were difficult to locate, we looked to other forms of activity to deploy the plankton net. For example, along current lines where prions and shearwaters were seen feeding, or where dolphins, accompanied by seabirds, were observed foraging but where fish activity could not be not detected at the surface. In addition, we will undertake sampling where birds are absent and in random places, not only those associated with underwater features. The aim to find what types of prey occurs in areas away from fish shoals. If there is nothing in the net that is actually a useful result as it shows how important fish shoals and currents/upwelling areas are for the birds.

Experimental aspects of the project to date

To tackle the problems associated with foraging 'behavior' in the open ocean, activity which we did not easily observe from the surface, or through plankton sampling, we have explored additional methods to extract data relevant to the goals of this project.

The importance of videography to identify fish species in schools had been recognised through earlier work with seabird/fish school associations (Gaskin 2017), and we used this method as often as practicable during plankton sampling operations.

Comparing video of fish school activity underwater and the sometimes swarms of krill present (fig. 19) with what was actually captured in the plankton net, we found considerable differences. The mobility and manoeuvrability of the fish schools, and their unpredictability, often changing direction to a range of stimuli (including the vessel we were using) meant it was very difficult to actually tow through the schools themselves. There were exceptions where their direction was

anticipated and the net could be towed immediately in front of them. However, the net itself also disturbed the fish. What was actually captured in the net, while allowing us to detect a much wider range of organisms than could be seen in the videos, was not so successful in helping understand the relative proportions of potential prey that would be made available to seabirds – i.e. shearwaters, prions and petrels.

Figure 19. Dense mass of euphausiids spiralling away from a tightly packed fish school, Simpson Rock, January 2017. Photo: Northern NZ Seabird Trust

Sampling stomach contents of fish caught within fish schools or in areas where seabirds are active, was proposed halfway through the season's work. The notion of sampling fish simultaneously to the plankton net sampling has the potential of establishing direct links between prey available and seabird feeding; also, to see if different zooplankton attract different fish species. In addition, we are proposing investigating sampling from stomachs of fish caught during purse seine operations. Although, in those cases there can be no direct correlation between seabird feeding and fish caught, stomach contents could potentially provide a greater reference collection for comparison with the sampling discussed here (POP2017-06 Objective 1) and regurgitates from seabirds (POP2017-06 Objective 2).

Our aim in recommending broadening the scope of the work we're able to do during this project, is looking towards achieving a better food chain story for the wider Hauraki Gulf and northern inshore waters than we have at present.

Skipjack tuna – a key association for shearwaters?

During this project, a number of seabird species have been observed associating directly with fast-moving skipjack tuna schools. These included fluttering shearwaters, Buller's shearwaters, also flesh-footed and sooty shearwaters, Cook's petrels and white-faced storm-petrels. However, the potential importance of this feeding association for Buller's shearwaters was not recognised until we observed them off the Northland coast, outside the Bay of Islands and Cape Brett in February 2018. Observations made during one multi-day voyage north of the Poor Knights, were further confirmed during a second multi-day voyage from the Bay of Islands and into the outer Hauraki Gulf in April.

In February, we observed large groups of shearwaters, numbering in the thousands, either rafting or aggressively feeding, with birds spread across c.50kms along the 200-250m

Figure 18. Buller's shearwaters, with fluttering shearwaters and Cook's petrels feeding in association with skipjack tuna, 23 January 2018. *Photo: Edin Whitehead*.

Figure 19. Buller's shearwaters feeding with skipjack tuna, one breaking the surface (splash) centre right. *Photo: Edin Whitehead*.

bathymetric contour. It is not clear whether the birds were feeding on krill or small fish. In April, we saw similar numbers of Buller's shearwaters in the Poor Knights/outer Hauraki Gulf region, some actively pursuing skipjack tuna schools, many rafting. Numbers of fairy prions were also seen in the same areas. There is a very strong seasonal aspect to this association with the tuna distribution likely coinciding with the migration of warmer sea temperatures southwards marked by the progressively blue state of the sea and high underwater visibility.

Salps and other soft-bodied marine organisms as prey

The prevalence of salps and other soft-bodied marine organisms in plankton net sampling, especially in areas where seabirds are observed feeding, including in association with fish schools, raises the question whether some seabirds are feeding on them. There are examples of predation by seabirds on gelatinous zooplankton, for example Harrison (1984) and Spear et al (2007) for the Bering Sea and Eastern Tropical Pacific Ocean. Scyphozoan jellyfish and other organisms were found in the stomachs of a number of seabird species, including sooty and short-tailed shearwaters and some storm-petrels. Here in New Zealand, James and Stahl (2000) found, from the regurgitations of chicks, that salps were the most abundant prey items and second most by frequency of occurrence in the diet of Buller's albatross (*Thalassarche bulleri bulleri*).

Soft bodied organisms have probably been overlooked in the analysis of avian stomach contents because of the rapid breakdown of their tissue. Also, salps and associates are approximately 90% water so are not considered a very rich food source (Anderson 2007). Zeldis & Willis (2014) reported that recent work by E. Carroll (University of Auckland/University of Aberdeen) on the diet of Bryde's whales (*Balaenoptera brydei*), based on genomic sequencing, showed that Chordata (probably appendicularians and salps) are important components, along with fish, euphausiids and amphipods.

Seabird scavenging

Procellariiforms and other seabirds (e.g. gulls) will scavenge carrion floating at the surface ranging in size from tiny fishes to large squids and whales, bits thereof, including fisheries discards (figs 25 & 26) and even refuse from ships. This behaviour, while not directly connected to fish schools, in most cases, highlights other relationships within marine ecosystems where top predators make food, including commercially caught species, available to seabirds that they might not be able to obtain themselves.

Feeding in association with cetaceans

During the course of this study, seabirds have been observed feeding in association with cetaceans on a number of occasions. This follows previous observations made in 2016-2017 as described in Gaskin (2017) and highlights a reliance on this association for some species - most notably, Australasian gannet, black petrel, flesh-footed shearwater and fluttering shearwater.

With gannets, and some Procellariiforms, this activity relates to their feeding on bait fish and mackerel that common dolphins (*Delphinus delphis*) pursue, often in frenzied activity (fig. 20). This is not scavenging, rather actively feeding on the fish the dolphins are chasing. In contrast, with Procellariiforms, and in particular black petrels and flesh-footed shearwaters, their feeding in association with cetaceans is generally when the latter's feeding generates discards (i.e. uneaten parts of prey) that the birds then feed on. This behaviour has been observed with mixed pods of false killer whales (*Pseudorca crassidens*) (fig. 23), pelagic common bottlenose dolphins (*Tursiops truncatus*) and long-finned pilot whales (*Globicephala meias*) (figs 21-22) (Gaskin 2017, and during this study). On other occasions, common dolphin activity attracts both gannets, shearwaters and petrels, where the latter appear to be feeding more on planktonic prey, rather than fish (fig 24).

Figure 20. Australasian gannets and fluttering and flesh-footed shearwaters feeding in association with common dolphins, Hauraki Gulf. *Photo: Clinton Duffy*

Figure 21. Black petrel and pilot whales, Ninepin Trench, off Bay of Islands 26 April 2018. *Photo: Edin Whitehead*

Figure 22. Flesh-footed shearwaters scrapping over squid discarded by pilot whales. *Photo: Edin Whitehead*

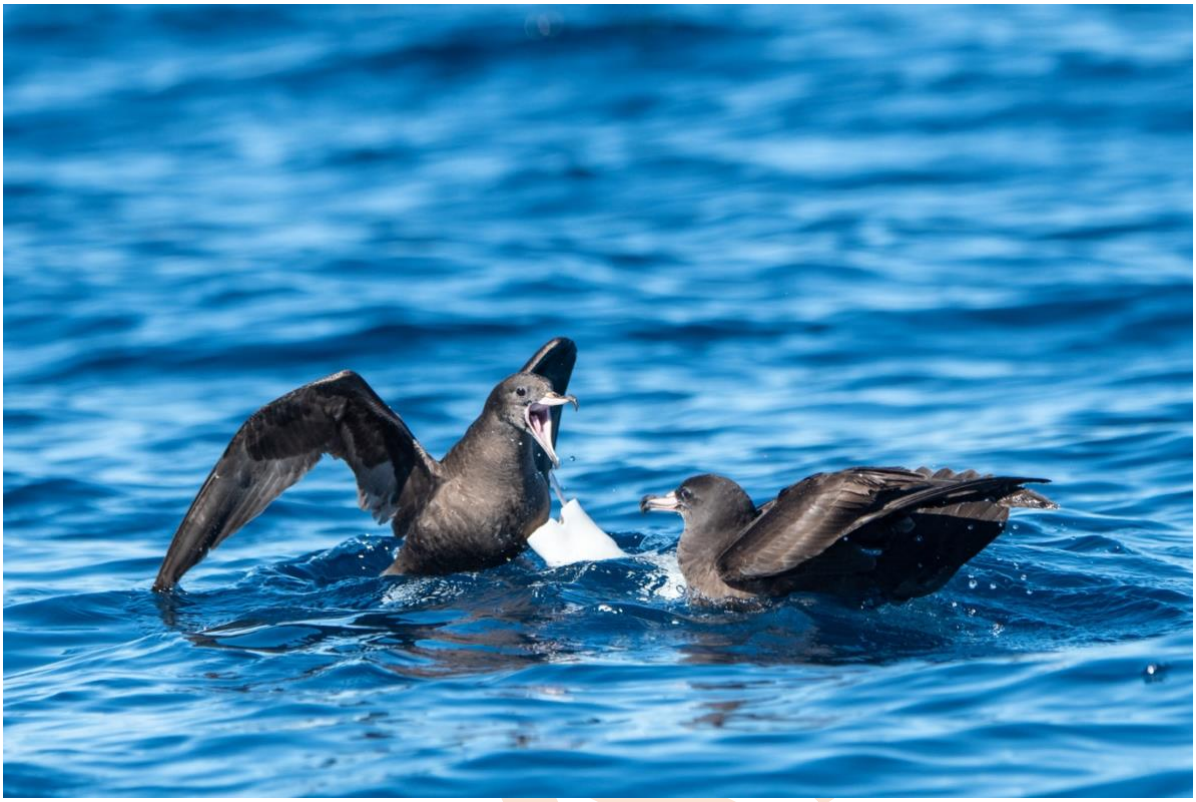


Figure 23. Black petrels and flesh-footed shearwaters feeding on discards from false killer whale daytime-feeding. *Photo: Jochen Zaeschmar*

Common dolphins and false killer whales feed during the daytime whereas pilot whales are nocturnal (J. Zaeschmar pers. comm.), although the latter have been seen in what has been interpreted as 'play feeding', where squid is caught during the day possibly for training young (fig 22). The numbers of petrels and shearwaters that follow these pods during the day would indicate that they anticipate that food is likely from that source. What is unknown is whether the petrels and shearwaters will obtain discards at night when the pilot whales do most their feeding. But more importantly, we don't know whether the food obtained from these associations forms a significant part of what is fed to chicks.

Figure 24. Flesh-footed shearwaters foraging around a mobile pod of common dolphins, outer Hauraki Gulf., 24 April 2018. *Photo: Edin Whitehead*

Figures 25 & 26. Flesh-footed shearwaters feeding on what appears to be fish discards in an area where 75 recreational fishing boats were concentrated, halfway between Poor Knights and Hen and Chickens Islands, 23 April 2018. *Photo: Edin Whitehead*

Recommendations for sampling in 2018-2019

This project has had quite a steep learning curve to sort out the best approach to get the most from our days on the water. We would like to extend this work into next season now that we have the techniques developed – this will mean a sampling regime for all months September 2018 to May 2019. A final report will be submitted following completion on 20 June 2019.

Our sampling programme for 2018-2019 will be as follows:

1. Regular monthly voyages from Whangateau Harbour, also Bay of Islands as opportunities arise in conjunction with cetacean surveying. Departure from Whangarei Harbour to be used depending on boat availability.
2. Fixed sampling sites to be determined, although some flexibility will be required during each voyage to ensure we encounter fish shoals.
3. Methodology for plankton sampling to be tightened with an even balance between deep 30m drops and surface tows at fish schools, and sampling from random places where seabirds are not feeding.
4. Catch fish from fish schools where seabirds are observed actively feeding to obtain stomach samples.
5. Obtain stomach samples from commercially caught fish (i.e. purse seine fishery) through fisheries observer programme.
6. Underwater videography to be undertaken simultaneously with plankton sampling.
7. Topside photography to be undertaken simultaneously with plankton sampling.
8. Soft-bodied organisms to be preserved in formalin on board provided health and safety requirements can be met.
9. Determine what calorific value or nutrient value is derived from salps.
10. Continue to record other seabird feeding activity

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