Diving & foraging behaviour of petrels & shearwaters – initial trials

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by

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DIVING & FORAGING BEHAVIOUR OF PETRELS & SHEARWATERS – INITIAL TRIALS

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SUMMARY

Petrels and shearwaters are known to have an extra-ordinary ability to dive while seeking food - shearwaters for example are capable of diving to the astonishing depth of over 65 metres. This project aims to document the diving and feeding behaviour of petrels and shearwaters in response to fishing baits so as to inform future development of methods of reducing seabird by-catch. As fishing baits are attractive, there is a significant risk of fatal interactions between seabirds and commercial and recreational fishing activities. Black petrel *Procellaria parkinsoni* and flesh-footed shearwater *Ardenna carneipes* have been identified as being at high risk from commercial fisheries in New Zealand waters, particularly longline fisheries that target snapper and bluenose, in addition to interactions with recreational fishers. This threat is most pronounced during the breeding season as these species migrate out of New Zealand waters during winter. The initial two-day trial documented in this report was designed to test a camera rig and underwater diver as methods of recording the diving behaviour of seabirds.

The trial was conducted on two days (31 March and 4 April 2016) in the area between Hauturu and Cape Rodney/Tawharanui using equipment custom-made for this project. An underwater camera rig consisting of an adjustable array of seven GoPro+ cameras was deployed from the stern of an 11m boat. The cameras were angled with overlapping camera sets to provide a wide field of view of both near-surface and underwater activity. This rig was supplemented by video and still photography using a fixed deck camera, a diver and underwater camera, and at one location a snorkeler with a GoPro. Baits of cut pilchard and squid were dropped within two metres of the camera rig. Conditions on both trial days were not ideal with relatively poor visibility, moderate swell and strong winds at times. In addition the timing of the trial at the end of the breeding season for both back petrel and flesh-footed shearwater meant that relatively few birds were present and there was little competition for baits.

During 4.7 hours of filming over the course of the two days we witnessed the interaction of nine seabird species with baits or with other seabirds attracted to bait: fluttering shearwater, flesh-footed shearwater, black petrel, Buller's shearwaters, black-backed gull, red-billed gull, Cook's petrel, Australasian gannet and Arctic skua. A total of 415 individual dives were recorded during the survey period.

Several feeding behaviours were observed. These included flying dives, surface sighting and seizing, duck dives, short dives and prolonged foraging dives. Birds were seen to investigate baits while underwater and, on a number of occasions, reject them. The birds were also highly maneuverable underwater and capable of changing direction with ease.

During this successful initial trial investigating the diving behaviour of at-risk petrels and shearwaters, we made novel discoveries regarding the interactions of these species underwater and their diving capabilities, including: 1) Bait preferences differ between species; 2) Seabird species have different diving inclinations; and 3) Heterospecific interactions around a prey source.

The present study shows that the use of a multi-frame camera apparatus and diver with camera is effective in better understanding the behaviour of petrels and shearwater in interactions with bait and fishing lines. This method can be applied to more in-depth and scientifically controlled studies related to bait preferences, diving and visual acuity, and interactions between seabird species and fishing apparatus. This information is critical in mitigating fisheries by-catch and provides important data for better understanding the at-sea biology of seabirds.

We propose a series of further trials be conducted in November/December 2016 using both recreational and commercial fishing vessels. In addition to using and extending the current methodology, we propose the use of an ROV to film a commercial boat setting and hauling non-hooked baited long-lines. We also propose using the camera rig suspended from a buoy to attempt to film natural seabird feeding activity within an active 'work-up' (ie. birds feeding in association with fish-schools).

Fluttering shearwater. Photo: RR

INTRODUCTION

Petrels and shearwaters have an extremely well-developed ability to find and investigate potential prey sources at sea. It is how they survive, find their food and raise their chicks. Foraging at sea is how species are sustained. Some petrel and shearwater species are attracted to fishing vessels, and within that group, some more than others.

Baits and the smell of fish are attractive to seabirds. These birds can dive in pursuit of prey and sinking baits on hooks on lines are just another potential food source. As a result birds can become hooked, resulting in injury and or death. Some birds also get entangled in lines and drown.

The black petrel *Procellaria parkinsoni* [1], has been identified as the 'most at risk' seabird in New Zealand from commercial fisheries in all three risk assessments undertaken since 2011 (Richard et al 2011; Richard and Abraham 2013). The flesh-footed shearwater *Ardenna carneipes* [2] has ranged from 6th, to 3rd to 4th 'most at risk' in these three assessments. With both these species most fatalities occurred in bottom-longline fisheries targeting snapper and bluenose and trawl fisheries targeting scampi. All of these captures were during the breeding season, as both these species migrate out of New Zealand waters during winter; black petrels to the eastern Pacific and flesh-footed shearwaters to the North Pacific Ocean.

Abraham et al (2010) showed that interactions between recreational fishers and seabirds are commonplace, with nearly half of the fishers interviewed during the study having witnessed a seabird being hooked or tangled at some stage in the past. In many cases, fishers' comments indicate that birds were caught while chasing bait, e.g., "*bird chased bait as line going down*", "*dived after bait was cast & tangled in line*", "*line in water sinking down. Bird seemed to come out of nowhere and chased bait under water, getting caught in the process*". The species caught by recreational fishers included petrels, albatrosses, gannets, gulls, terns and shags. From personal observations (CG, JR) flesh-footed shearwater, Buller's shearwater (*Ardenna bulleri*), sooty shearwater (*A. griseus*) and fluttering shearwater (*Puffinus gavia*) can pursue baits aggressively while line fishing from a boat in northern New Zealand waters.

Some seabirds have developed specialized sensory mechanisms that allow them to find productive areas, detect prey through the air-water boundary of the ocean surface, and then see amphibiously during extensive underwater foraging. For petrels, shearwaters and other Procellariiformes, locating foraging areas from distances likely incorporates olfactory cues (Nevitt et al. 1995, Nevitt 2000). Having large olfactory bulb to brain size ratios, many Procellariiformes also use smells to locate burrows, mates, and colonies (Bonadonna & Bretagnolle 2002; De León, Mínguez & Belliure 2003; Mardon & Bonadonna 2009). In addition to excellent olfactory sensing, seabirds that catch prey amphibiously have evolved highly specialized visual anatomy for locating and catching prey underwater. Albatross and penguin species have flattened cone cells that allow for a low absolute refraction and exhibit bill positioning; allowing for perception and guidance underwater (Martin & Brooke 1991, Martin

[1] Black petrel *Procellaria parkinsoni* Nationally Vulnerable (NZTCS), Vulnerable (IUCN Red List)
[2] Flesh-footed shearwater Nationally Vulnerable (NZTCS), Least Concern (IUCN Red List)

1998, 1999). These traits are specific to amphibious foraging. In a comparative study of white-chinned petrels (*Procellaria aequinoctialis*, an amphibious foraging species), and Antarctic prions (*Pachyptila desolata*, a surface foraging species), it was found that white-chinned petrels have a visual system similar to that found in penguins and albatross while the Antarctic prion did not exhibit the visual adaptations for foraging underwater (Martin & Prince 2001). The colour spectrum visible to wedge-tailed shearwaters (*Ardenna pacifica*), and likely other seabird species, is also beneficial for seeing prey underwater (Hart 2004). These visual adaptations for amphibious foraging are also reflected in the ecology of many seabird species showing high catch rates during foraging bouts vs. plunge dives (Machovsky-Capuska et al. 2012), and lower activity of foraging at night in some species (Phalan et al. 2007). These specialized senses for locating prey make seabirds particularly vulnerable to interactions with fishing vessels and apparatuses.

Seabirds are endothermic animals that are active in the air and on land, while being equally adept at foraging under the constraints of the ocean. Rapid changes in environmental forces indicate extreme adaptations for changes in pressure, oxygen availability, and metabolic rate (Boyd & Croxall 1996). The physiological ability of seabirds to forage while diving has been shown to be even greater than pinnipeds, when accounting for body size (Boyd & Croxall 1996). While studies have shown that seabirds are able to exceed modelled aerobic dive limits in a large percentage of foraging trips, the processes that allow for these foraging conditions remain unknown (Croll et al. 1992). A recent study comparing the diving effort of grey-faced petrels (*Pterodroma gouldi*), common diving petrels (*Pelecanoides urinatrix urinatrix*) and sooty shearwaters (*Puffinus griseus*), indicate that species that forage at greater depths (in this case, sooty shearwaters) have higher red blood cell and haematorcrit counts, showing evidence for key adaptations in amphibiously foraging in birds (Dunphy et al. 2015). Seabirds have evolved intricate sensory and physiological mechanisms for hunting prey underwater and the effectiveness of these traits is exemplified in their capacity for diving.

The diving capabilities of petrels and shearwaters, in particular the latter, have been well documented with shearwaters capable of diving to astonishing depths. Rayner *et al* (2011) showed that diving activity for flesh-footed shearwaters while on migration during non-breeding were shallower than those recorded during early stages of breeding (2.35 m vs 4.81 m). The maximum dive depth, recorded during the early breeding season, (66.5 m) was similar to that of other shearwaters including the sooty shearwater (breeding: 69.9 m, Shaffer et al. (2009); non-breeding: 68.2 m, Shaffer et al. (2006)), and wedge-tailed shearwater (breeding: 66.0 m, Schreiber & Burger (2001)), indicating a possible biological threshold for diving depth in shearwaters.

During the 2013/2014 breeding season Bell *et al* (2013) found that 80% of black petrel dives were shallow (<5 m) and this pattern was similar for males and females. In this study the deepest dive (-34.3 m) was by a female. In a previous study (Bell *et al* 2013) black petrels were found to dive mostly during the day (93.2%) and over 80% of the dives were shallow (<5 m) and this pattern was similar for males and females. The deepest dive in this earlier study was -27.4 m by a male.

Whether any of these recorded dives were during interactions with fisheries is not known, however black petrels and shearwaters are regularly seen foraging, feeding and diving for natural food (ie. no fishing activity present). This includes feeding in association with fish schools and following feeding cetaceans (e.g. with pseudo orca and bottle-nosed dolphins (RR, pers. obs.)).

Pierre and Goad (2013) note that the characteristics of surface longline gear that exacerbate the risk of seabird by-catch include relatively slow-sinking hooks, which remain within reach of seabirds for significant periods, the use of baits attractive to birds, long snoods, and the very long lengths of lines that are deployed with hooks attached. It should be noted that birds are also caught on the haul. Also, despite the existence of a number of measures to reduce by-catch in surface longline fisheries, on-going captures in these fisheries demonstrate that the available measures do not preclude the existence of significant by-catch risk (Richard et al. 2013, Pierre & Goad 2013).

Long-line sink rates vary depending on the type of sets, weights used and vessel speed. These factors would need to be taken into consideration for trials involving moving vessels, ie. distinct from trials to be conducted on stationary or drifting fishing vessels. For recreational boats anchored in no current, weighted baits will drop close to boats. However, for a drifting or anchored boat with a current flowing (ie. water flowing in relation to the stationary boat) baits will descend away from the vessel. Casting is a popular fishing method especially on a crowded back deck. Baits cast are visible to birds in the air before the reach the water and as they descend through the water column. All these situations have been considered for this trial. Trolling baited lines or lures behind a moving boat is another category which we placed outside this study.

PROJECT OBJECTIVES

1. To determine, through specific experimental trials, the diving capabilities and behaviour of black petrels, flesh-footed shearwaters and other species in response to available baits
2. To document the environmental and operational factors which affect this behaviour
3. And to provide recommendations on methods for reducing by-catch risk based on seabird diving behaviour.
4. This initial two-day trial (effectively stage 1 of the overall project) was designed to test the effectiveness of the custom-made camera rig and a diver with camera to record diving behaviour of petrels and shearwaters.

Trial outline & protocol

1. Oversee construction of an underwater camera rig commissioned to record/measure seabird foraging and diving behaviour accurately in relation to the use of different types of baits, gear deployment and fishing vessels
2. Conditions (factors to be recorded): wind direction and speed, overhead conditions, sea state and visibility underwater
3. Attract birds in numbers to boat using berley (chum) and freely dropped bait (pilchards, squid)
4. Move to 'clean' location nearby (ie no chum floating down through water column or oily slick on the surface); anchor or sea-anchor deployed

5. Deploy camera rig – each deployment of cameras to be logged; date/time settings of cameras to be synchronised
6. Activate topside camera(s) to record surface bird activity
7. Drop baits vertically using rod and line (no hooks); cast baits (no hooks); free baits (ie. no line); and loose berley
8. Cameras activated and turned off with the start and finish of each deployment. Three persons – one for baits, one for cameras, one for recording.
9. All deployments logged as 'sessions': camera mount depth (distance below surface), camera activation (start/stop) times, baits used.
10. Download and catalogue video and still images; edit video footage to show different diving behaviours
11. Evaluate the respective filming methods.

TRIAL METHODOLOGY

The trial was conducted on two days (31 March and 4 April 2016) using equipment custom-made for this project.

Custom-built underwater multiple camera rig for stationary or drifting vessel

Seven GoPro+s are mounted on a plate with adjustable neck allowing the array to be moved up and down a 3m length of 25mm diameter stainless steel tubing (ie. array can be locked to various depths). Three of the cameras (Cameras 1, 2 & 3) are angled up towards the surface to capture video of birds breaking the surface, for shallow dives and at the start of deeper dives. A second set of three cameras (Cameras 4, 5 & 6) are fixed to bottom of plate and angled down to capture deeper diving. They are arranged so there is a small overlap between the top and lower camera sets and with overlapping FOV within the same set of three cameras. The six cameras face directly out from the stern of the boat with Cameras 2 and 5 at right angles to the transom. An additional seventh camera (Camera 7) is fixed to the plate to capture any birds diving under the boat's hull. During the trial camera angles and the depth of the rig were changed to optimise recording – this varied according to surface sea state (ie wave action) which could obscure bird activity immediately below the surface.

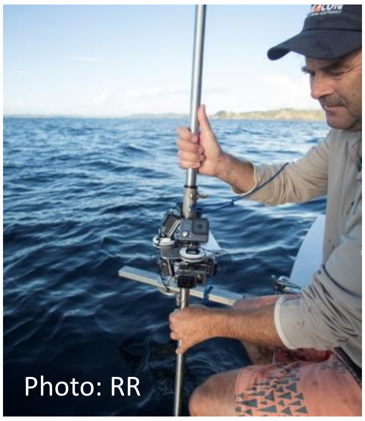


Photo: RR

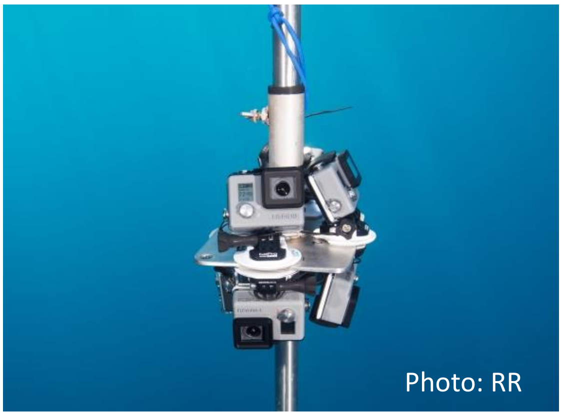


Photo: RR

The rig is positioned vertically, clamped to a box-section stainless steel boom which is bolted to the duck board of the boat. The rig is clamped approximately 1m from the edge of the duckboard (ie. its position on the boom is adjustable). A single GoPro (Camera 8) was fixed to the transom of boat to record surface activity. Baits lowered or dropped were within an area <2m from the camera array.

The rig is suitable for capturing footage of petrels and shearwaters diving for baits around the stern of a stationary or drifting vessel generally, and for analysing petrel behaviour in relation to use of the variety of bait types used by recreational fishers in particular.

GoPro video collating and editing

All the recording sessions were logged (see Appendix 2 for details and conditions encountered during trials). The video from the two days and 19 sessions trial period where downloaded into folders and individually labelled by camera and session for ease of access when sorting through sequences that captured birds moving from one camera to the another. Initially a 'highlights" package was created first – ie. concentrating on single camera footage – then a set of sequences where created using footage from multiple cameras. Our aim – to produce footage that would illustrate different diving behaviour as well as testing the configurations of the rig itself (ie. camera angles, depth of rig) against sea state (ie. wave action, visibility, wind, overhead conditions). Sequences were edited using NCH Video Editor.

Underwater camera operator

In natural history productions, a key element is the inconspicuousness of the divers. It is therefore impractical to utilize a large contingent of divers. In this case a single operator is required to obtain the necessary footage, with appropriate communications in place, and the dive assistant within viewing distance. We wanted to 1) evaluate the camera rig which would operate at the same time as the diver in the water; 2) get high quality still images of diving shearwaters and petrels for illustration purposes.

Cameras used for the trial were an Underwater Canon 5DSR with lighting rig and a Canon 1DX for additional topside work. Open circuit SCUBA was used to film to a maximum depth of 10m. All dive procedures are outlined in the dive HSE Plan prepared by RR[3]. A heavily weighted line with O_2 bottle attached was attached to one side of the back deck. This served as a safety line, reference point and anchor for RR while in underwater.

RR noted that while in the water the birds appeared reluctant to dive near him. They dove occasionally but more frequently chased baits when they were further away. It was noticeable that the birds appeared less affected by the presence of a snorkeler with a camera at the surface (see below) than by the diver underwater. It could be that the release of bubbles rising to the surface made the birds more wary, or it was the presence of something dark lurking below. One option for the diver in the future will be to: 1) use a re-breather to reduce the discharge of

[3] Robinson R. (March 2016). HSE Plan: Photographing petrel foraging behaviour in the Hauraki Gulf 2016. In accordance of with the Australian/New Zealand Standard Occupational diving operations for Film and photographic diving.

bubbles and see whether this changes the birds' behaviour, and 2) use a smaller 'pony' dive bottle for greater manoeuvrability and possibly with less disturbance to the birds (something we noted with a snorkeler).

Pole-mounted underwater camera

RR's underwater camera mounted on a long pole and controlled from the surface was used later on in Day 2 with great success. Although this required dropping baits right in front of the camera (or in some cases behind because of the current moving the baits) the resulting images were dramatic (see cover photograph).

GoPro footage while snorkelling

During our second trial day Karen Baird, who was on board as the support diver, took one of the GoPros and filmed while snorkelling where birds were foraging. As noted above a snorkeler swimming amongst the birds on the surface did not appear to greatly affect their behaviour. However, the randomness of her swimming meant that while some of video footage obtained includes useful sequences, this method would at best be complementary to that of camera rig or diver, rather than one that could be used consistently over long periods and in waters of varying visibility. The presence of several species of sharks in the Hauraki Gulf could be unsettling and unsafe if visibility was poor.

Bait drops

Bait was dropped directly over the stern of the boat or to one side to take account of direction and speed of drift. Both cut pilchard and squid baits were used. We trialled a method with baits held by alligator clips attached to a line (ie. no hooks) and dropped using a rod. No birds were attracted using this method. However, our view was that this was a result of few birds attracted to the boat when the method was deployed and could be overcome with more birds present around the boat and acting aggressively during different times of the year. This type behaviour could be expected during summer months – ie. November to January.

Recording sessions

Recording sessions were between 5 and 24mins with duration dictated by conditions and the number of birds (ie. forcing a move to a new location). In future we will be standardising these to 20mins as much as possible, taking account of the aforementioned factors.

Battery life of GoPros

During the trial on 4 April the seven camera rig recorded 178mins of video, with some recharging of the cameras while moving between locations. During the last session of the day two of the cameras ran out of battery life. Options for future work would be to have a second set of fully-charged GoPro cameras on hand; or recharge cameras at every opportunity while moving between locations, or during enforced downtime due to no battery life in cameras.

Visibility

Water visibility impacts the ability of cameras and divers to monitor diving behaviour and likely impacts seabirds ability to forage underwater. We used a Secchi disk to test water visibility and found variability in visibility from: 9m, 11m, and 15.5m.

Determining field and depth of vision

To determine the visual field and perspective of videos, we gauged the distance of an object by filming a Secchi disk suspended at 3m and 6m respectively and then moved towards and away from the camera apparatus for 30m in each direction.

RESULTS

Trial 1 – 31 March 2016

This trial was conducted in blustery E-NE conditions which necessitated making our way to lee areas of Te Hauturu-o-Toi Little Barrier Island (hereafter Hauturu). We chose several locations that allowed as much distance from the island as possible at the same time providing conditions suitable for operating the camera rig.

Footage from the upper cameras show glimpses of what could be obtained using the camera rig but because of wave surge and the movement of the boat little diving action was recorded. The lower cameras gave better results. However, the low numbers of birds attracted meant that overall the recordings were disappointing, although we experienced conditions that could be ruled out for further trials to provide meaningful results. While at anchor close to Hauturu we tested the range and field of vision of the camera rig using a Secchi disk suspended from the tender as noted above.

Full results from this trial and species encountered are presented in Appendix 2.

Trial 2 – 4 April 2016

The second trial was conducted in light to medium N-NW conditions until early afternoon when the wind changed and a strong S squall set in. Our first deployments of both the camera rig and diver were made in the vicinity of NW Reef, a regular 'hotspot' area close to the cable zone and shipping channel.

With 11m visibility (vertical) and calm sea conditions were reasonable. However birds were hard to attract initially and meant we moved through four locations to find our target species. The camera rig was set at 700mm and 800mm depths to test for optimum position for capturing action just below the surface and deep diving.

In the afternoon we moved first to a location just outside the Goat Island Cape Rodney Marine Reserve; then across off Tokatu Point at the end of Tawharanui Regional Park and outside the marine reserve. It was at the latter location we had the best results with mainly fluttering shearwaters and some flesh-footed shearwaters.

Species response

Over the course of the two trials, we witnessed the interaction of 9 seabird species with baits (or parasitically attracted to other seabirds attracted to baits) over the course of 4.7 hours (282 mins) of active surveying, including fluttering shearwater, flesh-footed shearwater, black petrel, Buller's shearwater, black-backed gull (*Larus dominicanus antipodus*), red-billed gull (*L. scopulinus*), Cook's petrel (*Pterodroma cookii*), Australasian gannet (*Morus serrator*) and Arctic skua (*Stercorarius parasiticus*). Of these, several species landed on the water at different locations: black petrel (n= 3), flesh-footed shearwater (n=70), Buller's shearwater (n= 6), fluttering shearwater (n= 15) and red-billed gull (n=2). Several species dove under the surface in efforts to capture prey amphibiously: black petrel (n= 19 dives), flesh-footed shearwater (n = 36), Buller's shearwater (n= 6), fluttering shearwater (n= 353) and black-backed gull (n= 1).

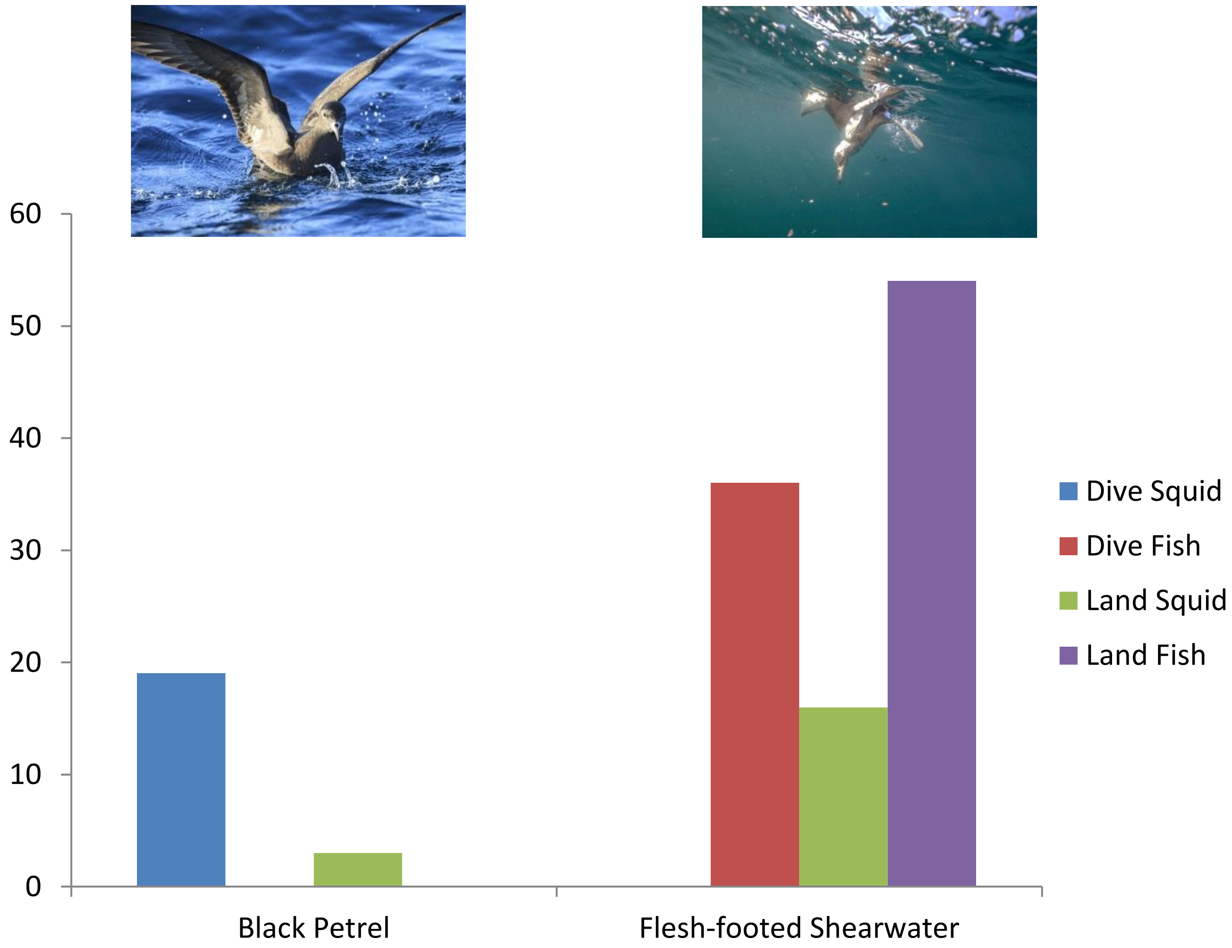


Figure 1. The number of dives and lands on water surface to squid and fish for major target species for both trial days. It should be noted that there was not equal effort for both squid and fish baits.

Feeding strategies for petrels and shearwaters observed during trial

1 Flying dive

Bird sees bait below the surface from the air and either plunges smoothly through the water's surface with barely a splash or 'belly-flops' and continues 'flying (ie. swimming) underwater to investigate the bait (ie. no alighting on the surface).

Flesh-footed shearwater (both images). Photos: RR

2 Surface seizing

Bird on surface snatching food from just underwater.

Fluttering shearwater. Photo: RR

3 Surface sighting

Bird on surface peering underwater while swimming, searching for food underwater

Fluttering shearwater. Photo: RR

4 Duck dive

Upended grab below the surface with bird head and shoulders underwater and wings part-opened

Black petrel. Photo: Karen Baird

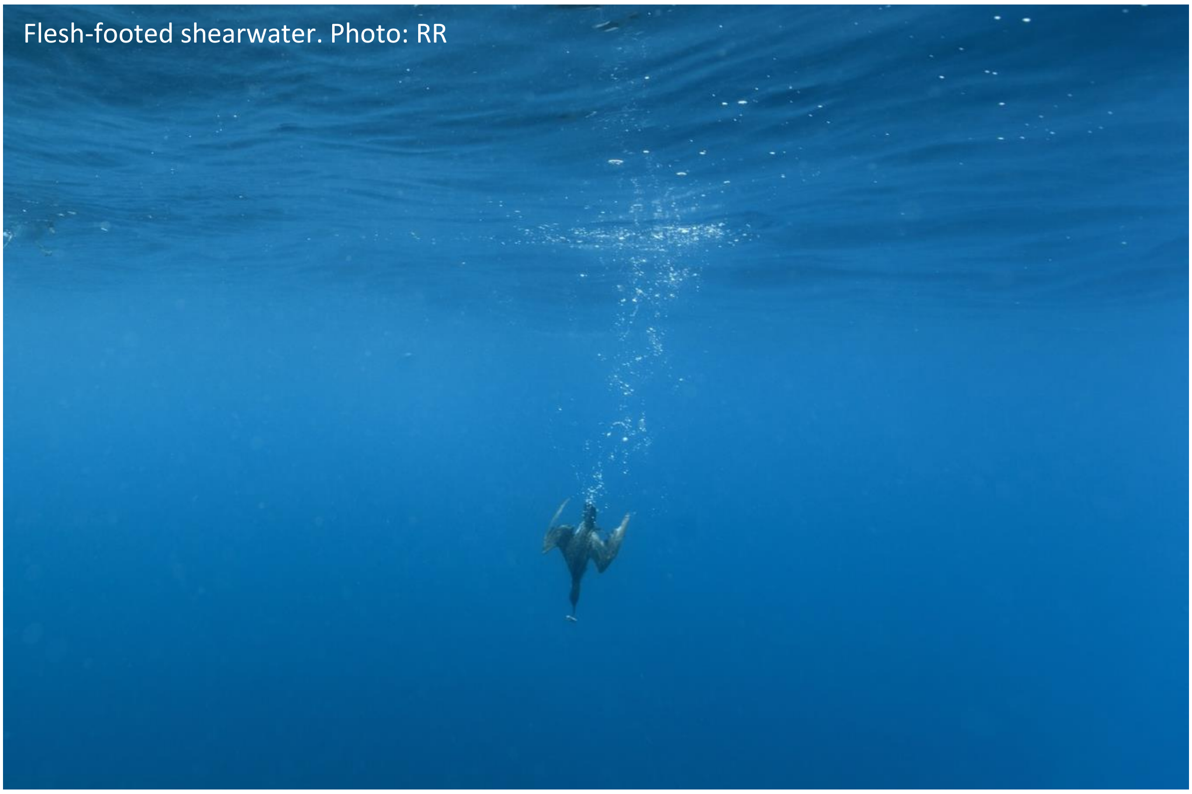
5 Short dives

Whole body disappears briefly to retrieve food and return to surface with it, also in response to sighting bait underwater.

Black petrel. Photo: RR

6 Prolonged foraging dive

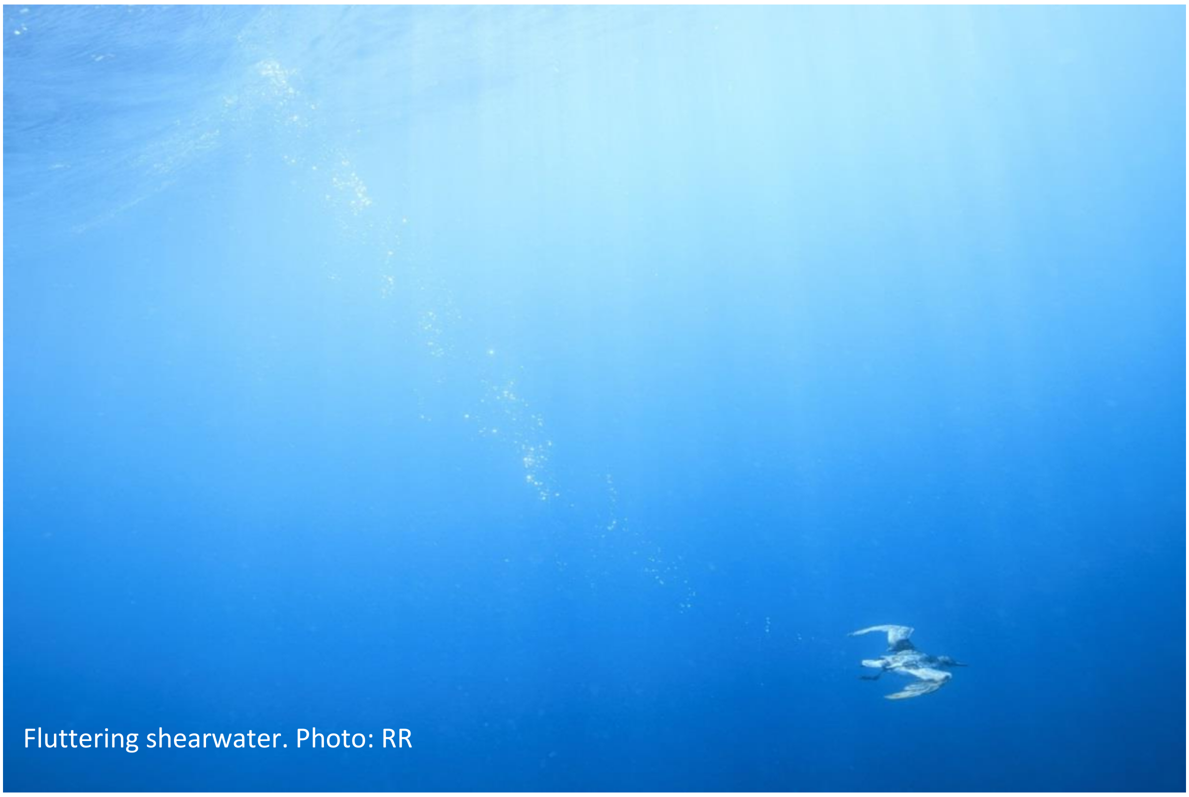
Bird dives deep up to 15m sometimes going straight to bait or searching for baits, often changing direction, at times sharply. Bird may swallow bait underwater if small enough and continue foraging.



Flesh-footed shearwater. Photo: RR

Buller’s shearwater. Photo: RR

Fluttering shearwater. Photo: RR



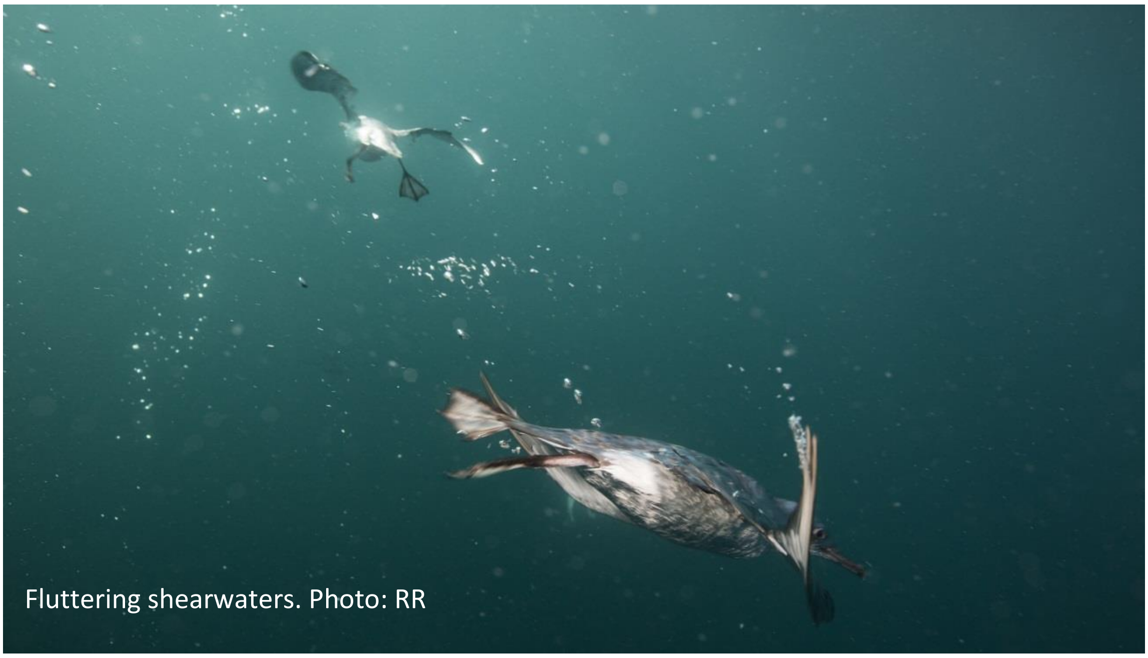
Fluttering shearwater. Photo: RR

7 Other observed behaviour

Birds on the water around the boat were observed to watch activity on the back deck very closely, anticipating actions such as throwing baits, and would, in response, move very quickly to where the bait landed and, if other birds were close by, very agressively.

When moving underwater birds were seen to investigate baits and on a good number of occasions reject them. The behaviour was observed mostly with fluttering shearwaters. The impression gained was that flesh-footed shearwaters were very much grab first, then either reject or take to the surface to eat. In contrast to the fluttering shearwaters which appeared to be much more 'discerning'. Birds were also highly manoeuvrable underwater and capable of changing direction with ease; but it was the extreme agility of the fluttering shearwaters which impressed most.

Flesh-footed shearwater. Photo: RR



Fluttering shearwaters. Photo: RR

8 Kleptoparasitic interactions

Intraspecific competition (flesh-footed shearwater on flesh-footed shearwater) or interspecific competition (flesh-footed shearwater on black petrel, occasionally black petrel on flesh-footed shearwater, also black-backed gull and Arctic skua on flesh-footed, Buller's and fluttering shearwaters

Juvenile black-backed gull chasing a Buller's shearwater. Photo: Karen Baird

DISCUSSION – EVALUATION OF METHODS USED DURING TRIALS

The timing of the trial, 31 March and 4 April, was towards the end of the breeding season for both target species (ie. black petrel and flesh-footed shearwater) and also Buller's shearwaters. This means that low numbers were present in the Gulf as non-breeders and many adults would have already begun migrations to the Eastern and North Pacific. The low density of birds made it difficult to attract them within range of the camera rig and diver. On the positive side, the numbers of fluttering shearwaters were high, easily attracted close to the boat and proved to be excellent performers for assessing the rig's capabilities, although fluttering shearwaters' main risk from fisheries interactions are likely to be from set nets. Conducting further filming in November and December would mean there would be a greater numbers of target species around, more birds attracted close to the boat, and more observable data regarding diving behaviour, especially as birds overcome shyness and are likely to be more aggressive in chasing baits.

While further tweaking of camera angles and depth of the rig is required, the overall effectiveness is high. In this short trial, we have observed never-before-noted behaviours of petrels and shearwaters regarding bait acquisition, diving inclinations, and heterospecific species interactions. This information is critical in advising fisheries by-catch mitigation, and also provides important data for better understanding the at-sea biology of seabirds, an area that remains primarily unknown.

Future work with this method needs to address the ability to accurately gauge the coverage of what the camera rig is actually recording, ie. both depth of field (distance from camera) and also vertical depth (ie. below surface) to be able to provide an accurate analysis of the birds' diving behaviour. We did several trials using the tender and the Secchi disk while at anchor in behind Little Barrier Island/Te Hauturu-o-Toi on 31 March, but further work needs to be done to set parameters around what is actually captured using the respective methods.

The ability to quantify the output of these results is important as our observations of diving behaviour of these species are novel. To accomplish this, we aim to increase the effort during the critical time in the Hauraki Gulf for the target petrel and shearwater species. Additionally, controls for the time of videos, bait types, and randomization of treatments will be added when more birds are in the area

During these initial trials, water visibility impacted camera quality and the diver's ability to obtain images (with potential safety issues). While water visibility affects the methods used, it may also influence the way that seabirds dive under water. Gaining a better understanding of the role of water visibility in diving birds' interactions with baits will likely influence management efforts.

Some experiments to reduce the interactions of seabirds with fisheries have targeted the unique visual acuity of seabirds to see underwater. For example, an attempt to camouflage bait through dying was tested in wedge-tailed shearwaters. Researchers found that squid dyed blue was taken 3-8% of the time, compared to 75-89% of the time with control squid. This same study found dyed fish to be less effective (Cocking et al. 2008). Another study that trialled camouflaging bait in other seabird taxa was less conclusive (Lydon & Starr 2005), and practical application was logistically complicated (ACAP 2014). However, an understanding of the target species sensory acuity is likely important for the future of seabird conservation efforts.

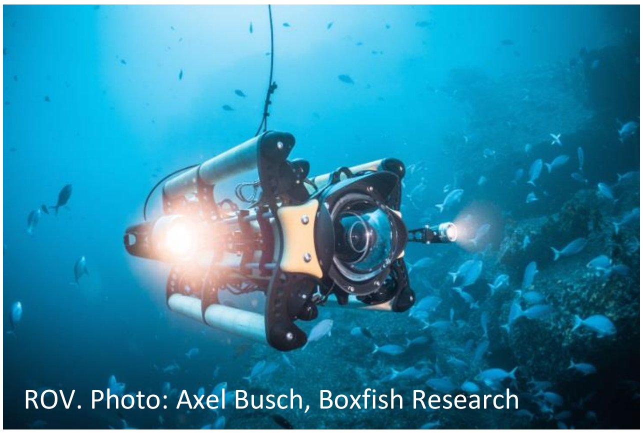
The ability of conservation efforts may also be influenced by the types of prey that target species are most interested in. One novel result of this study is a potential dichotomy in the types of baits that were taken by flesh-footed shearwaters and black petrels. Black petrels were interested in and ate squid, while flesh-footed shearwaters were less interested in squid baits and ate pilchard. While this observation seemed to be relevant, more controlled experimentation is required to investigate what prey types are most attractive to particular species.

The present study shows that the combined use of a multi-frame camera apparatus and diver with camera is effective in better understanding the behaviour of petrels and shearwater in interactions with bait and fishing lines. This trial has uncovered that distinct behaviours in foraging behaviour may be critical in conclusions related to bycatch mitigation. This method can be applied to more in depth and scientifically controlled studies related to bait preferences, diving and visual acuity in amphibious movements, and how interactions with heterospecific seabird species impact contact with fishing apparatus.

FUTURE WORK

We recommend the following tasks in order to address the overall project objectives:

1. Conduct a further series of trials using camera rigs operated from recreational boats (at least 2) and a commercial long-liner (at least 2)
2. For stationary and drifting vessels (recreational fishery):
   - Timing –November/December 2016.
   - Location – use a network of fishing skippers/vessels (through Lee Fishery) to inform the team on the project boat of the presence and location of numbers of target species; move project boat to area
   - Recording and deployment to be the same as outlined in this report.
   - Drop baits vertically using rod and line (no hooks); cast baits (no hooks); free baits (ie. no line); loose berley
   - Variety of baits and line weighting to be used.
   - Progress through a sequence of trials using different baits. Cameras activated and turned off with the start and finish of each trial. Three persons – one for baits, one for cameras, one for recording.
   - Employ cameraman for underwater camera images/video of diving behaviour to provide additional visual material and for the purposes of advocacy. Could be undertaken separately from camera rig deployment.
   - Downloading, cataloguing, editing and analysis of video and still images.
3. For moving vessel (long-line fishery)
   - Timing – conduct trials in November/December 2016.
   - Our recommendation is for a day trial to assess the method
   - Location – Outer Hauraki Gulf location
   - Conditions (factors to be recorded): wind direction and speed, overhead conditions, sea state and visibility underwater
   - Crew to prepare a set of non-hooked snoods (baits tied)
   - Attract birds in numbers using berley then start moving through clean water with birds following
   - Deploy ROV using two operators
   - Deploy line (no mitigation methods to be used – ie. do everything 'wrong' to encourage birds in close)
   - Activate topside camera(s) to record surface bird activity along the line set
   - Use ROV to film along the line set as it sinks – out to 100m and down to 10m (bird activity will determine this)
   - Downloading, cataloguing, editing and analysis of video and still image files.



ROV. Photo: Axel Busch, Boxfish Research

We also envisage further uses beyond this current project for the camera rig. These could include filming Procellariiform feeding activity where the rig would be suspended from buoy and dropped into work-up activity (ie. birds feeding in association with fish schools) or amongst feeding birds (ie. birds feeding on zooplankton – e.g. Euphausiids).

Seabird and fish action. Photo: Chris Gaskin

Euphausiids and mackerel. Photo: Kim Westerskov

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