


INT2019-06: Investigation of options for assessing the post-release survival of seabirds that interact with commercial fisheries in New Zealand

WMIL Wildlife Management International




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Executive Summary

Research determining post-release survival of seabirds interacting with New Zealand commercial fisheries has not previously been undertaken. This report reviews methodologies and tracking devices used to study seabird survival and assesses their suitability for development of a future field-based project to determine post-release survival rates.

With recent technological advances the use of miniature satellite tracking devices was determined to be the most effective method to assess the fate of released seabirds following accidental capture by fishing vessels.

A range of operational, biological and environmental factors may constrain a tracking study of injured seabirds. Some of these factors have the potential to significantly impact the likelihood of successfully monitoring the post-release survival, and these are discussed.

Assessment of the health of live seabirds that have interacted with fishing vessels will first need to be carried out to select suitable individuals to track survival and ensure tracking maximises identifying cryptic mortality rates. Individuals with severe injuries that will not survive, and those with no injuries that will likely survive, should not be tracked. Birds with moderate injures where survival probability is uncertain should be tracked, as these provide the best opportunity to understanding true cryptic mortality rates. To achieve this a “Seabird Heath Assessment Tool” has been developed to guide future research.

It is recommended that a review be undertaken of existing seabird injury data, held by Fisheries NZ (FNZ) as recorded by fisheries observers on Observer Protected Species Interaction (PSI) forms, and electronic monitoring (EM) video footage, to categorise (using the health assessment tool presented here) and investigate the number, nature and extent of injuries sustained by seabirds returned alive at-sea, in order to refine the following field-based recommendation.

Considering the above factors, a field-based programme utilising satellite tracking with Teleonics TAV series Platform Transmitter Terminals (PTTs) is recommended as the best method to assess post-release survival of seabirds that interact with commercial fisheries. Although relatively expensive, this method provides the only method which is likely to return sufficient data on behaviour and post-release survival. Target species for tracking should include control groups (healthy seabirds), medium sized seabirds (i.e. black petrel, flesh-footed shearwater, and Buller’s shearwater) in FMA1 and FMA9, and albatross species in FMA5 and FMA6. The study should aim to track ≥30 birds from each group which would likely require a 3-5 year study period.

Section One: Investigate options for assessing the post-release survival of seabirds that interact with commercial fisheries in New Zealand.

1. Background

Internationally, the conservation of seabirds has a large focus on fisheries interactions. The National Plan of Action (NPOA) – Seabirds 2020 (MPI 2020) aims to reduce the incidental mortality of seabirds in New Zealand commercial fisheries towards negligible levels. In the 2015/16 fishing year over 4,500 seabirds were estimated to be captured in the New Zealand trawl and long-line fishery (Abraham & Richard, 2019). However, this estimate did not take into consideration cryptic mortality. Determining post-release survival of seabirds caught in New Zealand commercial fisheries has not previously been undertaken.

There are two principal forms of cryptic mortality:

1. When a seabird dies as a result of an interaction with a fishing vessel/gear, but the carcass falls into the water and is not retained or reported by on-board fishers, observers, or video monitoring. Examples include seabirds becoming hooked on longlines during setting and subsequently drowning, but the carcass falling off during hauling, or birds killed by warp strike and not recovered or reported (by fisher or observer).
2. A seabird is injured by a fisheries interaction (observed or un-observed) and later dies due to sustained injuries.

A recent assessment of the risk posed by commercial fisheries to New Zealand seabirds (Abraham *et al.*, 2017) highlighted that there is no available data on the post-release survival of live captured seabirds which are returned to sea. As such, a uniform beta prior was used in modelling, which assumed average post-release survival rates is 50%. Results showed cryptic mortality had a considerable influence on the risk ratio, and author's called for further research on cryptic mortality to better understand this type of fisheries interaction (Abraham *et al.*, 2017).

Recent technological advances have potentially created the opportunity to use miniature tracking devices to determine the fate of released seabirds following accidental capture on fishing vessels. The current report investigates the options for undertaking such a study.

The report addresses three research aims:

1. Investigate methods available to develop a field-based research project to determine the survival of seabirds post fisheries interaction via a thorough review of seabird tracking practises.
2. Identify operational, biological, and environmental factors which may constrain a field-based research project to determine the survival of seabirds post fisheries interaction.
3. Provide recommendations to develop a baseline field study to quantitatively measure post-release survival rates in protected seabird species captured by New Zealand commercial fisheries.

2. Seabird species interacting with commercial fisheries in New Zealand

A reported 4,517 seabirds were caught in commercial fisheries during the 2015/16 fishing year, with eight species having more than ten capture observations (Table 1; Abraham & Richard, 2019). These species are highly pelagic seabirds, with most foraging well offshore, including in the Southern Ocean. This is a critical factor for consideration in the development of field-based research projects investigating post-release survival.

Table 1. Number of observed seabird captures during the 2015/16 fishing year showing the total number of captures, the number of captures with ID confirmed by experts, and the number of captures that were deceased when brought onboard the vessel (data from Abraham & Richard, 2019).

Species	Captures	Confirmed	Mortalities
White-chinned petrel	239	189	198
New Zealand white-capped albatross	147	102	105
Southern Buller's albatross	115	100	102
Sooty shearwater	62	48	51
Salvin's albatross	40	28	32
Black petrel	20	13	10
Flesh-footed shearwater	14	10	8
Westland petrel	13	10	10

3. Assessment of traditional methods for determining post-release survival of seabirds that interact with commercial fisheries

Most pelagic seabirds form dense breeding colonies (Gaston, 2004) where individuals are relatively easy to capture, mark, and handle as they return to their colonies to breed (Brooke, 2018). Historically, seabird survival studies were predominantly carried out at colonies and involved banding projects. Banding studies of seabird species have been carried out for over 100 years (BTO, 2009; Brooke, 2018). Advances in miniaturisation of tracking and battery technology resulted in a steady increase in seabird tracking to investigate at-sea movements since the early 1990s (Brook, 2018). Currently, the BirdLife International Seabird Tracking Database; Tracking Ocean Wanderers, contains data on 119 seabird species, maintains over 800 datasets, and tracks more than 23,000 individuals (www.seabirdtracking.org accessed 12/09/2019).

A range of methods have been developed to investigate seabird survival rates. Furthermore, a range of tracking technologies have been developed that could be used to determine the short-term survival of seabirds, post interaction with fishing vessels. The below analyses compares the merits of traditional methods of seabird survival and tracking studies including banding, radio telemetry, satellite tracking, Global Location Sensing (GLS), Platform Terminal Transmitters (PTT), and Global Position Systems (GPS) tracking with Telonics Argos Avian Transmitters (TAV) tracking.

Determining post-release survival of seabirds caught by commercial fisheries, and released alive, is important to refining risk assessment models (Abraham *et al.*, 2017). There are many seabird species captured alive, and returned to sea, yet to date there has been no assessment of post-release survival.

As previously stated, Abraham & Richard (2019) estimated that 4,500 seabirds were caught in the 2015-16 fishing year. By species, white-capped mollymawk, Salvin's mollymawk, Buller's

Mollymawk, white-chinned petrel, flesh-footed shearwater and black petrel being the most numerous (Table 1). Any study of post-release survival will likely require determination of a small number of focal species to ensure adequate sample size. The above species are highly pelagic and usually feed well offshore, including in southern fishing grounds.

A principal consideration in developing a method to measure post-release survival will be ensuring a system which returns enough data to get a statistically robust result. All methodologies: banding, radio telemetry, PTT, GLS, and GPS tags, have very different performance characteristics. Trade-offs between the cost vs benefit of each method include temporal resolution, deployment duration, device mass, cost, and the requirement to recapture birds in order to recover data. The suitability of each of the tracking types outlined above are analysed below.

3.1 Banding

Banding to mark individual wild birds has been carried out for over 100 years (BTO, 2009). There have been some significant longitudinal banding projects carried out at seabird colonies, with some studies continuing for 25-50 years (Gaston, 2004). A number of these examples are from New Zealand, including red-billed gull in Kaikoura, Buller's mollymawk on the Snares Islands, and black petrel on Great Barrier Island. For all these studies, banding and significant re-sighting effort at colonies has produced exceptional survival parameters for these species. In New Zealand, banding is coordinated and managed by the Department of Conservation (DOC); and operators must have the relevant qualification to band birds.

Banding is an internationally accepted best practice method to track the survival of injured birds and has been frequently used to determine survival of rehabilitated birds following oil spills. Studies have been carried out on a range of species including penguins, gulls, pelicans, gannets, and auks (Underhill *et al.,* 1999; Goldsworthy *et al.*, 2000; Altwegg *et al.,* 2008). However, these studies generally reported minimum survival rates, because of the inability to record emigration rates. The most robust data is from species where breeding populations are limited to a few sites, and ongoing research projects at these sites enables high recapture rates of seabirds post-release, for example African penguins (Nel & Whittington, 2003).

Due to high levels of breeding site fidelity by seabirds, banding has been routinely used as a method to investigate survival rates. However, such studies require significant inputs, particularly around banding and re-sighting effort. Ensuring robust survival estimates requires large sample sizes (especially chicks to get a known population age) along with a high and consistent re-sighting effort (annual visits to breeding colonies to search for banded birds). Banding of post-release seabirds caught in commercial fisheries is unlikely to result in re-sighting of seabirds from which they can be identified from bands.

Although banding studies have produced robust survival parameters for a range of seabird species, these have all been based on field work at breeding colonies. With their high site-fidelity, banding works exceptionally well to determine annual adult, and to a lesser extent, juvenile survival. The success of this method relies on the ability to routinely recapture birds at the study site and most work involves studies of burrows or nests.

Therefore, banding of injured pelagic seabirds is unlikely to achieve a recovery rate high enough to produce a statistically meaningful result to measure post-release survival. Currently, the most intensely studied seabird species in New Zealand represent just a small proportion of the banded population, or form part of a study population. As such, the chance of recovering banded birds at breeding colonies is extremely low (Table 2).

Recommendation: Banding is <u>not recommended</u> as a method to assess post-release survival of seabirds that interact with commercial fisheries.

3.2 Temporary marking

Using temporary marks to identify seabirds has been widely used in seabird research, primarily using paint or plumage dyes (Thomson and Rothery 1991; Brothers *et al.* 1997). Including in New Zealand where the Hutton's shearwater population has been estimated by marking birds at the breeding colony with enamel spray paint and subsequently re-sighting birds at sea (Rowe *et al.* 2018).

However, such studies require significant inputs, particularly around marking statistically robust numbers of birds (sample size) and re-sighting effort. Further, the longevity of temporary marks on seabirds is variable, and the ability to see paint or plumage dyes on dark seabirds is significantly reduced (Biz Bell pers. comm.). Ensuring robust survival estimates requires large sample sizes along with a high and consistent re-sighting effort. Fisheries observers could mark by-caught seabirds, but as they only have limited time allocated to seabird observations they are unlikely to be able to collect robust re-sighting data.

Therefore, temporary marking of injured pelagic seabirds is unlikely to achieve a re-sighting or recovery rate high enough to produce a statistically meaningful result to measure post-release survival (Table 2).

Recommendation: Temporary marking is not recommended as a method to assess post-release survival of seabirds that interact with commercial fisheries.

3.3 Radio telemetry

Radio telemetry has been used to help locate seabird breeding colonies, including the critically endangered Chatham Island Taiko (Imber *et al.*, 1994*)* and the "re-discovered" New Zealand storm petrel (Gaskin, 2013), which was previously thought to be extinct. This involves the use of handheld receivers, base tracking stations, and aerial tracking (i.e. Sky Ranger technology).

Radio telemetry has been used to measure short-term survival of oiled birds post rehabilitation and release (Anderson *et al.* 1996), usually in combination with aerial surveys to locate individuals over wide areas. Most studies have been limited to inshore foraging species that return to land to roost (e.g. pelicans).

The devices are commonly attached to seabirds by taping the device to dorsal tail feathers located on the centre of the back. The attachment of radio transmitters to protected seabirds requires Wildlife Act Authority (1953) and Animal Ethics Committee (AEC) approval.

Radio telemetry has been used to measure the short-term survival of rehabilitation birds; however, most studies have been limited to inshore foraging species which return to land at night to roost (e.g. pelicans). Protected species of New Zealand pelagic seabirds spend extended periods at sea and therefore, this method would present difficulties in ensuring adequate coverage of likely foraging areas and would require surveying vast areas of ocean.

Recommendation: Radio telemetry is not recommended as a method to assess post-release survival of seabirds that interact with commercial fisheries.

3.4 Satellite tracking

Jouventin & Weimerskrich (1990) pioneered work on satellite tracking for avian species over 30 years ago, and since then there has been increased research effort on the use of PTTs. In particular, seabird studies number >100 peer-reviewed journal papers since 1990 (Burger & Shaffer, 2008). The Birdlife Seabird Tracking Database (BSTD) holds data for 56 species, maintains 238 datasets, and tracks over 7,334 individuals using PTT (www.seabirdtracking.org accessed 12/09/2019).

PTTs use the ARGOS system to transmit location data via satellites to ground receiving stations, allowing animals to be tracked in near real-time without the need to recover the tag. PTTs can provide up to 40 locations per day, however, accuracy and precision of these location is degraded by poor satellite visibility, changes in temperature, and erratic tag movement caused by seabird movement in flight (Wakefield *et al.* 2009).

In recent years, PTT tracking has been used successfully to investigate the first dispersal and survival of fledging seabirds (Crowe *et al.*, 2019; Afan *et al*., 2019). Similarly to the use of radio telemetry, devices are usually attached to seabirds by taping the device to centrally located dorsal feather on the back. The attachment of PTT devices to protected seabirds requires Wildlife Act Authority (1953) and AEC approval.

PTT tracking devices were developed to predominantly determine at-sea foraging ranges of seabirds but could also be used to determine the post-release survival following fishing vessel interaction. PTTs use the ARGOS system to transmit location data via satellites to ground receiving stations, allowing animals to be tracked in near real-time without the need to recover the tag. Tags can be attached to seabirds prior to release from fishing vessels, and the resulting tracks analysed to determine the short-term survival.

PTT tags offer a practical solution to determine survival, however, cost is still a major limitation of satellite tracking and can potentially reduce sample size due to cost restraints. Furthermore, data interpretation requires the researcher to determine which factors need to be programmed into device duty-cycles to assist data analyses, determine bird behaviour, and ultimately post-release survival. For example, a researcher needs to assess whether non-transmission is caused by seabird mortality, tag malfunction, or premature removal from the bird (Table 2).

Recommendation: Satellite tracking is recommended as a method to assess post-release survival of seabirds that interact with commercial fisheries.

3.5 Global Location Sensing (GLS)

Developed as an alternative to satellite-telemetry, GLS geolocators record ambient light, from which sunset and sunrise times are estimated from thresholds in light curves. Latitude is derived from day length, and longitude from the time of local midday with respect to Greenwich Mean Time and Julian Day (Philips *et al.*, 2004).

GLS devices are usually attached to seabirds by fastening the device to a metal or plastic leg band with cable ties. The attachment of GLS devices to protected seabirds requires Wildlife Act Authority (1953) and AEC approval.

Advantages of PTT use for seabird tracking are reduced costs (with no satellite requirements), small size, extended battery life, and, if securely attached, infinite device retention (Philips *et al.*, 2004). The disadvantages are that recapture is necessary before data can be downloaded, only two locations can be recorded per day (local midday and midnight), location accuracy is lower (200 km), and it is impossible to estimate latitude for variable periods around the equinoxes (Philips *et al.,* 2004).

With appropriate processing, GLS logger data can identify foraging ranges during the breeding season, as well as tracking long distance migration and non-breeding grounds (Philips *et al.,* 2004). With GLS devices now widely used to track year round movements of seabirds; the BirdLife Seabird Tracking Database holds GLS data from 79 species, maintains 239 datasets and 5,888 tracks (www.seabirdtracking.org accessed 12/09/2019).

Developed as an alternative to satellite-telemetry, GLS has been widely used on seabird tracking projects. Although the tags have some advantages over PTT, especially reduced costs, lower impacts on birds (due to small size), and extended battery life, the major disadvantage is that recapture is necessary before data can be downloaded. Like the banding method, recovery of birds at breeding colonies, post-release from fishing vessels, is extremely unlikely, therefore, making GLS unsuitable to determine post-release survival of seabirds (Table 2).

Recommendation: GLS is <u>not recommended</u> as a method to assess post-release survival of seabirds that interact with commercial fisheries.

3.6 Archival Global Position System (GPS) tracking

Archival GPS loggers have better location accuracy (usually >95% of locations are within 10 m) and have been increasingly used in preference to PTT (Wakefield *et al.*, 2009). GPS devices have the added advantage of being capable of recording locations every second at accuracies within a few metres of ground truth. They are also relatively inexpensive and small enough (around 20 g) for suitable use on many seabird species. The fine spatial resolution reveals unparalleled details of ground speed, micro-movements and area-restricted searching behaviour (Burger & Shaffer, 2008). The BirdLife Seabird Tracking database has data from 69 species using GPS tracking, maintains 341 datasets and 10,241 tracks (www.seabirdtracking.org accessed 12/09/2019).

Integration with the ARGOS system now allows data to be received via satellite, downloaded to base stations when in range, or via the mobile phone network. However, download via options other than satellite are of limited value when studying pelagic seabirds, as the foraging range of most birds will be out of range of land-based communication networks, and therefore data will be unreliable.

GPS devices are usually attached to seabirds by taping the device to the dorsal feathers in the centre of the back. The attachment of GPS devices to protected seabirds requires Wildlife Act Authority (1953) and AEC approval.

GPS devices have been widely used in seabird tracking studies due to the high levels of accuracy and reduced cost compared to PTT devices. However, again, these devices require the recapturing of birds to recover data. When considering this, alongside banding and GLS devices, the probability of recapture is extremely low making archival GPS tracking an unsuitable option (Table 2).

Recommendation: Archival GPS tracking is <u>not recommended</u> as a method to assess post-release survival of seabirds that interact with commercial fisheries.

4. Recommended method for assessing post-release seabird survival

The highly pelagic nature of protected seabird species, that are known to interact with commercial fishing vessels in New Zealand, has significant implications for development of a methodology to support future projects to investigate post-release survival of seabirds. As previously described, a range of traditional tracking options are available to investigate survival rates, however, the effectiveness of each is variable (Table 2) and makes most methods unsuitable for use in a New Zealand context.

In particular, methods that require recapture of released birds are unlikely to provide adequate (or any) data on the fate of released seabirds. As such, the use of banding, GLS or archival GPS devices is impractical. The attachment of radio transmitters and tracking of seabirds using aerial surveys (i.e. Sky Ranger technology) is possible. Radio transmitters are significantly lower in cost than PTT tags, however, the cost of aerial surveys is high. As such this method is likely to be cost prohibitive comparable to PTT tags, which would provide better quality data, without the risk of birds moving beyond the survey area.

The use of PTT tags offers the most likely opportunity to measure the short-term post-release survival. Devices can be attached to injured birds, and the fate of birds followed for 1-3 weeks post-release. Duration of deployment would be dependent of the number of location fixes per day and because this effects battery consumption, careful consideration would need to be given to the duty-cycle to ensure a robust estimate of survival could be achieved from the data transmitted.

Table 2. Comparative effectiveness of available tracking methods for determining post-release survival of seabirds interacting with commercial fisheries in New Zealand.

Method	Device cost range	Approximate cost per device ($)	Post-release cost	Device deployment duration	Required skill for attachment	Data recovery probability	Device reliability	Impacts on bird	Recommended
Banding	Very Low	0.5	Low[1]	Permanent	Low	Low	High	Very low	No
Temporary marking	Very low	0.25	Low[2]	Short-term	Low	Low	Low	Low	No
Radio telemetry	Medium	300-600	High[3]	Short-term	High	Medium	Medium	Medium	No
PTT	High	2,000	High[4]	Short-term	High	High	High	Medium	Yes
GLS	Low	250	Low[5]	Medium-term	Medium	Low	Medium	Low	No
GPS	Medium	200-600	Low[6]	Short-term	High	Low	High	Medium	No

Notes

[1] Excludes costs associated with visiting colonies to attempt to recapture banded birds. Estimated cost of a single visit to one inshore seabird colony $10,000-15,000.

[2] Excludes placement cost of fisheries observer on vessels.

[2] Excludes costs associated with aerial surveys to attempt to track seabirds. Estimated costs for inshore species $70,000-100,000.

[3] ARGOS download of data cost estimated at between $200-1,000 per PTT

[4] Excludes costs associated with visiting colonies to attempt to recover GLS device. Estimated cost of a single visit to one inshore seabird colony $10,000-15,000.

[6] Excludes costs associated with visiting colonies to attempt to recover GPS device. Estimated cost of a single visit to one inshore seabird colony $10,000-15,000.

5. Telonics TAV Range

Telonics Inc. is a company based in Arizona, United States of America, that specialises in wildlife tracking technologies. The company has developed a range of PTT devices specifically for avian applications; TAV. These transmitters work on the ARGOS system, without GPS, and are user programmable for various fix frequencies. The TAV range has three options in a backpack configuration which would be suitable for deployment on pelagic seabirds. Seabirds captured at sea are fitted with TAV tags, released at sea, and the TAV is used to track their distribution and behaviour. This method has been used to determine foraging location and behaviour of albatross (Copella *et al.,* 2013) and shearwaters (Adams *et al.,* 2012).

The TAV range comes in three sizes (Table 3), which have applications to a wide range of seabird species most commonly recorded interacting with New Zealand commercial fishing vessels.

Table 3*.* Telonics ARGOS Avian Transmitters (TAV) range; model, device dimensions, weight, operational life and suitable species for deployment.

Model	Dimensions L x W x H (mm)	Weight (g)	Operational life (days) with transmissions 24 hours/day	Operational life (days) with transmissions 4 hours/day	Suitable species
TAV-2617	64 x 21 x 10	17	11	66	Medium sized petrels and shearwaters (i.e. black petrel, flesh-footed shearwater, and sooty shearwater)
TAV-2630	63 x 23 x 18	35	51	289	Large petrels, small to medium sized albatross (white-chinned petrel, white-capped, Salvin’s albatross, and Buller’s albatross)
TAV-2664	76 x 33 x 15	70	103	586	Large albatross (royal and wandering)

5.1 Specifications and impacts on determining post-release survival in seabird interactions with commercial fishery vessels.

All TAV models operate through the ARGOS System, where seabird locations are calculated using the Doppler-shift in frequency of the transmitters uplink transmission (these devices do not use GPS to determine location).

All models can also record and transmit additional data, including mortality, activity, temperature, and low-voltage sensors. Data can be collected according to user-defined parameters and schedules and transmitted through ARGOS. This data is likely be useful to interpreting behaviour of released birds to determine survival. Note that mortality functions are unlikely to work on seabirds, as even deceased birds floating on the ocean surface will record movement and, therefore, not trigger mortality thresholds. Also, the ARGOS transmission will not work if the antenna is out of the water.

ARGOS transmissions can be duty-cycled to extend battery life and to schedule transmissions when the best overpasses are predicted. A real-time clock/calendar controls all timing functions. Transmission duty-cycles impact battery consumption and consideration should be given appropriate scheduling to determining post-release survival. In particular, the duration of tracking to determine that the individual has survived the fisheries interaction.

All TAV models can be programmed using TPP. TPP makes it possible for users to program their own systems and simulate performance of the system prior to deployment. As such:

- On-board sensors can be activated/deactivated.
- Data collection regimes and schedules can be altered.
- Sensor data can be added or deleted from ARGOS transmissions.
- ARGOS ID codes, transmission frequencies, transmission power levels, and transmission schedules can all be modified.
- Device power levels are likely to be important in interpreting data, especially in determining mortality when devices stop transmitting.

The data retrieved through ARGOS can be processed using the Telonics Data Converter (TDC). TDC provides complete data decoding of ARGOS DS files, including location and sensor data. This data can then be imported into mapping software, and analyses completed to determine post-release behaviour of birds.

5.2 Data analysis

Determining the fate of tracked seabirds post-release following fisheries interaction will need to influence the duty-cycle of the PTT device, and will determine what other environmental data is collected. Most PTT tracking studies of adult seabirds have not attempted to determine adult mortality.

The number of PTT studies tracking fledgling seabirds has increased as device weights have decreased. A range of New Zealand albatross (Weimerskirch *et al.,* 2006), shearwater (Afan *et al.*, 2019; Crowe *et al.*, 2019), and petrel species (WMIL unpublished data) have recently been tracked. Interpreting the end of device transmission to confirm mortality is problematic. Many studies have not adequately used PTT tracking to determine juvenile survival and have instead focused on at sea distribution and the overlap with commercial fisheries (Wakefield *et al.*, 2009; Wood *et al.*, 2000).

Afab *et al.*, (2019) used behaviour models based on bird movement trajectories (velocity and turning angle) to classify behaviours of both adult and fledgling Scopoli's shearwaters (n=10) tracked in the Mediterranean Sea. Eight of ten juvenile shearwater devices stopped transmitting within a week and were recorded as mortalities. The remaining five adults and two juveniles were successfully tracked for between 30 and 103 days.

These studies highlight the importance of determining the duty-cycle, and other data variables to be collected (especially battery levels) in determining post-release survival. A higher fix rate will give finer scale data, which may allow behavioural models to be constructed (assisting survival determination) but will reduce device life. A compromise will be required between-deployment duration and the timeframe for which post-release survival can be measured. A recommended minimum deployment duration for future studies is two weeks, as it is likely that the nature and extent of the fisheries interaction (i.e. type of injury sustained) will have rapid impacts on survival of seabirds. The measure of survival will need to be short-term, to correspond with the ability of the bird to recover from immediate injuries.

6. Tracking/tagging technology recommendation

Satellite tracking using Teleonics TAV series PTTs is recommended as the best method to assess post-release survival of seabirds that interact with commercial fisheries.

Section 2: Identify operational, biological and environmental factors that may constrain the assessment of seabird post-release survival using tracking devices.

To ensure high quality data is produced from any research project investigating the true mortality rate of seabirds, post commercial fisheries interaction, it is important to consider the operational, biological and environmental factors that may impact studies. An at-sea tracking study has been identified as providing the most appropriate research methodology for determining post-release mortality of seabirds by-caught in commercial fisheries and must, therefore, consider how these factors will impact monitoring projects. The following section of the report addresses these issues, and a logic model is provided to help plan and evaluate the implementation of any future field-based research programme (Figure 3).

7. Operational considerations

7.1 Wildlife Act Authority, 1953

Any research project involving protected seabirds in New Zealand will require Wildlife Act Authority (1953) and would include any GPS tracking project of seabirds released post commercial fisheries interactions. The Authority provides specific details on the type and manner in which the research must be carried out, and most Wildlife Act Authorities have specific conditions.

Projects initiated and co-ordinated by DOC (whether carried out by DOC staff or contractors), and which form part of the Departments Conservation Services Plan (CSP), do not require Wildlife Act Authority (1953) as this is granted under the CSP.

7.2 Animal Ethics Committee (AEC) approval

Any project involving the manipulation of a wild animals in New Zealand requires AEC approval. The committee balance the need for research with the impacts on the individual (and population) from the proposed research. Currently all tracking studies of seabirds requires AEC approval. A large number of seabird species have been tracked in New Zealand, with the majority of projects utilising similar methodology involving either back-mounted GPS devices, or leg-mounted GLS devices. Although there is no official Standard Operating Procedure (SOP) for this type of tracking, the AEC has been routinely approving research using these methods and this is not deemed a bottleneck to future studies.

Generally, the AEC stipulates that manipulations are not approved to take place on sick or injured animals. With this in mind, the tracking of injured seabirds caught in fishing gear would be considered differently to other “standard” seabird tracking applications. The threshold for approval for any AEC application is whether the benefits outweigh any potential harm or distress to the animals. Therefore, the research will need to demonstrate an improvement to the population even if individuals are placed under greater stress.

Further, the AEC approval process requires the researcher to demonstrate they have the skills, experience and training to undertake the manipulation. The AEC application must name the personnel who will be undertaking the manipulations.

The AEC committee does not require tracked birds to be banded, but please see discussion below (para 7.3) that the DOC Banding Office recommends all tracked birds are banded.

7.3 DOC Banding Office considerations

The DOC Banding Office does not currently oversee transmitter attachments (including GPS devices), but strongly recommends that birds fitted with temporary tracking loggers are also banded.

Any person banding seabirds requires a New Zealand Bird Banding Certification Level 2 or higher.

7.4 Tracking device life on seabirds

GPS tracking of seabirds is reliant on the device remaining on the bird for an extended period, at least for the duration of the interested study interval.

The period a GPS device will stay on a seabird is related to several factors. As mentioned above a key factor is the skill and experience of the operator, but also the feeding ecology of the bird. As devices are attached to diving seabirds (e.g. petrels and shearwaters) using tape, they tend to remain attached for shorter time periods than species which do not dive (e.g. albatross).

GPS tracking of both black petrel and flesh-footed shearwater fledglings departing colonies had devices remain on birds for 20-60 days (WMIL unpublished data). Recent tracking of flesh-footed shearwater adults had devices remain on birds for 25-37 days (WMIL unpublished data). This highlights a likely expected device life of between 21 and 52 days.

7.5 Operators needed for GPS device attachment

The attachment of GPS devices almost always requires two operators; one to hold the bird securely and the second to physically attach the device to the bird. Both Wildlife Act Authority (1953) and AEC approvals require the attachment method (including the number of operators) to be clearly laid out and conditions adhered too. In most cases both are required specify the name of the operator permitted to handle and attach devices.

7.6 Training for bird handling and device attachment

One potential avenue to enable a tracking study is to train Fisheries NZ (FNZ) observers to attach GPS devices to birds. Fisheries observers are already present onboard boats, and part of their role could be to attach devices to any bycatch protected seabirds that come onboard vessels.

Attaching devices to seabirds is a highly skilled task and improves with experience. The life expectancy of a GPS tag to remain attached to a seabird is almost certainly linked to the skill and experience of the operator attaching the device. There would be a considerable time and cost commitment required by FNZ to train observers to the required level for successful attachment of GPS devices to seabirds.

7.7 Assessing seabird health post fisheries interaction

Seabirds interacting with commercial fisheries in New Zealand sustain a range of injuries, differing in severity (para 8.2). To date, no research has been carried out to assess and categorise seabird injuries received from commercial fishing. Conversely, considerable work has been done assessing the health of seabirds during oil spill events, including assessing condition in relation and factors effecting rehabilitation and post-release survival (Duerr *et al.,* 2016).

With the costs involved in PTT tracking, assessment of seabird injuries and likelihood of survival will need to be determined in order to maximise the effective use of devices. Serious injuries such as broken wings, large open wounds, and significant oiling are likely to be fatal to pelagic seabirds, therefore, these birds should not have tracking devices fitted.

Injuries sustained by seabirds that are categorised as ‘moderate’ in severity are likely to be where most cryptic mortality occurs given that low severity = assumed survival, and high severity = assumed mortality. Therefore, research efforts should be focused on bycatch seabirds which fit the category of moderate injury. Moderate injuries, including broken legs, minor open wounds and light oiling, will have varying impacts on individual birds and will impact survival rates. During research at seabird colonies, some birds are captured with injuries and are either natural or related to commercial and/or recreational fishing. WMIL has collected data on seabird injuries at study sites, and examples are provided below.

Between 1999 and 2020, four adult black petrel at Aotea/Great Barrier Island (from a total of 3,394 banded birds) have been captured with one foot amputated. On Ohinau and Lady Alice Island between 2016 and 2020, there have been two flesh-footed shearwater (from a total of 3,450 banded birds) recorded as having either a missing foot or leg. This provides strong evidence that some birds can survive moderate injuries, however, provides no evidence of survival rates.

Again, on Aotea/Great Barrier Island three adult black petrel have been captured alive with hooks (two in wings and one in the back), and the hooks successfully removed. A further three birds were found at the colony with hooks but were deceased because the trace became tangled around trees. On Ohinau and Lady Alice Island three flesh-footed shearwater were captured alive with a hook imbedded in them; one in a burrow, and two on the surface tangled around trees, but the birds were able to be released (one in very poor condition).

The Nest Te Kōhanga is an animal hospital for native wildlife at Wellington Zoo. Between 2015 to 2019 a total of 545 seabirds were treated, including gulls, terns, shags, penguins and more pelagic species such as shearwaters, petrels and albatross. Of these, 210 birds (38.5%) were assessed and then euthanised as it was determined survival prospects were minimal. A further 166 of birds (30.4%) died whilst in care. Only 169 (31.0%) survived treatment and were released back in to the wild. This highlights that seabirds have a high mortality rate from injuries and illness (unpublished data provided by The Nest Te Kōhanga).

There are a significant number of live seabird interactions with commercial fishing vessels that result in the birds sustaining no obvious injury (Table 6). Most of these birds are likely to be nocturnal deck strikes with birds attracted to ships lights at night. These birds, although perhaps disorientated after collision with the vessel, are thought to have no long-term impacts and are likely to survive, however, there is no research to support this assumption. Disorientated birds are likely vulnerable to predation or further injury until they have recovered, therefore, whilst released alive, survival rates may differ for these birds than for those with other 'low' risk injuries.

As previously stated, cryptic mortality is likely to be highest among moderately injured seabirds. Severe injuries should be recorded by observers as mortality events (despite the fact birds are returned to sea), and birds with no obvious injuries recorded as live interactions without causing mortality. Determining the post-release survival rate of moderately injured birds is where tracking studies using PTT should target efforts. In order to assist observers/researchers in assessing which birds to track, a health assessment tool has been developed (Table 4, Figure 1). This describes a ranking system (A-C) as determined by WMILs assessment of above veterinary evidence and based on sustained injuries.

Table 4. Assessment tool to assess survival probability of seabirds that interact with commercial fisheries to determine which individuals to attach PTT devices to.

Ranking	Injuries	Survival prospects	Justification	Track
A	Broken wing bones	Low	Pelagic seabirds with broken wings are unable to fly, and therefore forage so survival prospects are negligible.	No
	Large open wound to any part of body (wound >2cm), and/or broken bill		Large open wounds and significant bill injuries are significant trauma that a pelagic seabird is unlikely to recovery from.	No
	Grease or oil covering >10% of feathering		Grease and oil compromises water proofing and significant oiling is likely to be fatal to pelagic seabird.	No
B	Broken leg	Moderate	Pelagic seabirds are known to survive with missing legs and feet, so some leg injuries may not be fatal.	Yes
	Minor open wound (wound <2cm, i.e. small wound from hook injury)		Pelagic seabirds are known to survive with hook injuries; therefore, some minor wounds are known not to be fatal.	Yes
	Grease or oil covering <10% of feathering		Grease and oil compromises water proofing and minor oiling may not be fatal.	Yes
C	No visible injuries (i.e. nocturnal deck-strikes or "net riding" birds). Note: birds with high levels of disorientation from deck strike should be considered as category 'B' given their vulnerability to predation/further injury upon release.	High	Birds with no visible injuries, mostly birds which are attracted to boats at night due to lights and are classified as deck-strikes or birds which ride nest aboard but are uninjured.	No

Figure 1. Examples of seabird injuries for each health assessment ranking A-C in Table 4. 'A' examples: Live white-capped albatross with broken wing; Live white-capped albatross with broken wing caught in line; dead white-capped albatross with large open wound in neck; dead grey petrel with large open wound in neck. 'B' examples: White-capped mollymawk with minor open wound (hook in wing), royal albatross with minor open wound (hook in bill), White-capped albatross with grease covering <10% of feathering, White-headed petrel with grease covering <10% of feathering. 'C' examples: uninjured Salvin's albatross aboard a vessel after riding net aboard, white-chinned petrel aboard a vessel, white-headed petrel nocturnal deck-strike, grey-backed storm petrel nocturnal deck-strike.

7.8 Health and Safety

Maritime New Zealand is the national maritime regulatory agency whose responsibilities include administering the Health and Safety at Work Act for personnel onboard ships, which are places of work. They have identified commercial fishing of particular concern as this is one of five industries in New Zealand where most harm is occurring https://www.maritimenz.govt.nz/commercial/safety/health-and-safety/documents/HS-guide-for-mariners.pdf).

Maritime New Zealand have specific Safety Management Systems for commercial operators to ensure vessel and crew safety that take into account international laws. Any DOC research carried out onboard commercial fishing vessels will need to develop a specific Health and Safety plan incorporating maritime safety management systems.

7.9 Vessel considerations

As discussed above, the number of personnel required to effectively fit seabird GPS devices is two. Therefore, vessel capability to enable two operators to travel during fishing trips will need to be considered. Most commercial fishing vessels have limited space, and this is likely to impact on the ability to include two trained observers on vessels. It is possible, with assistance from crew, that one observer could potentially be used.

8. Biological Factors

8.1 At-sea seabird behaviour

The at-sea foraging behaviour of a wide range of seabirds has been tracked in New Zealand and all research has involved tracking birds directly from breeding colonies. Generally, these studies report that the tracking of seabirds had no impacts on individual bird behaviour, although typically impacts of devices are under-reported in tracking studies (Heggøy *et al.,* 2015; Passos *et al.*, 2010; Vandenabeele *et al.,* 2011). Some studies have reported impacts; the GPS tracking of adult flesh-footed shearwater during incubation appears to have impacted birds and may have led to them undertaking longer foraging trips (WMIL unpublished data).

No known tracking studies have used seabirds captured at sea, and as such there is no information on the behaviour of birds caught and released at-sea. To determine the fate and behaviour of birds injured by commercial fishing, by-caught birds would be tracked following release from fishing vessels. In order to determine the behaviour of “healthy” birds vs injured bycaught seabirds, consideration should be given to tracking a subset of “healthy” control birds to understand the comparative behaviour between these two subsets.

8.2 Sample sizes

A total of 1,117 seabird interactions involving fishing gear and released alive were reported by fisheries observers during the 2016/17, 2017/18 and 2018/19 reporting period (DOC/WMIL seabird ID database). For records with supporting location data (n=1003), the majority of seabirds were caught in southern ocean fisheries (Fisheries Management Area (FMA5 and FMA6). Although the combined totals of FMA1 and FMA9 show northern seabirds were also caught in significant numbers (Figure 2 and Table 5). These overlap consistently with seabird mortalities recorded by observers for the same period (Figure 3).

The number of seabird interactions will have a profound impact on potential sample sizes of species (or species groups) being tracked and, therefore, on the design of a field-based research programme to monitor post-release mortality rates.

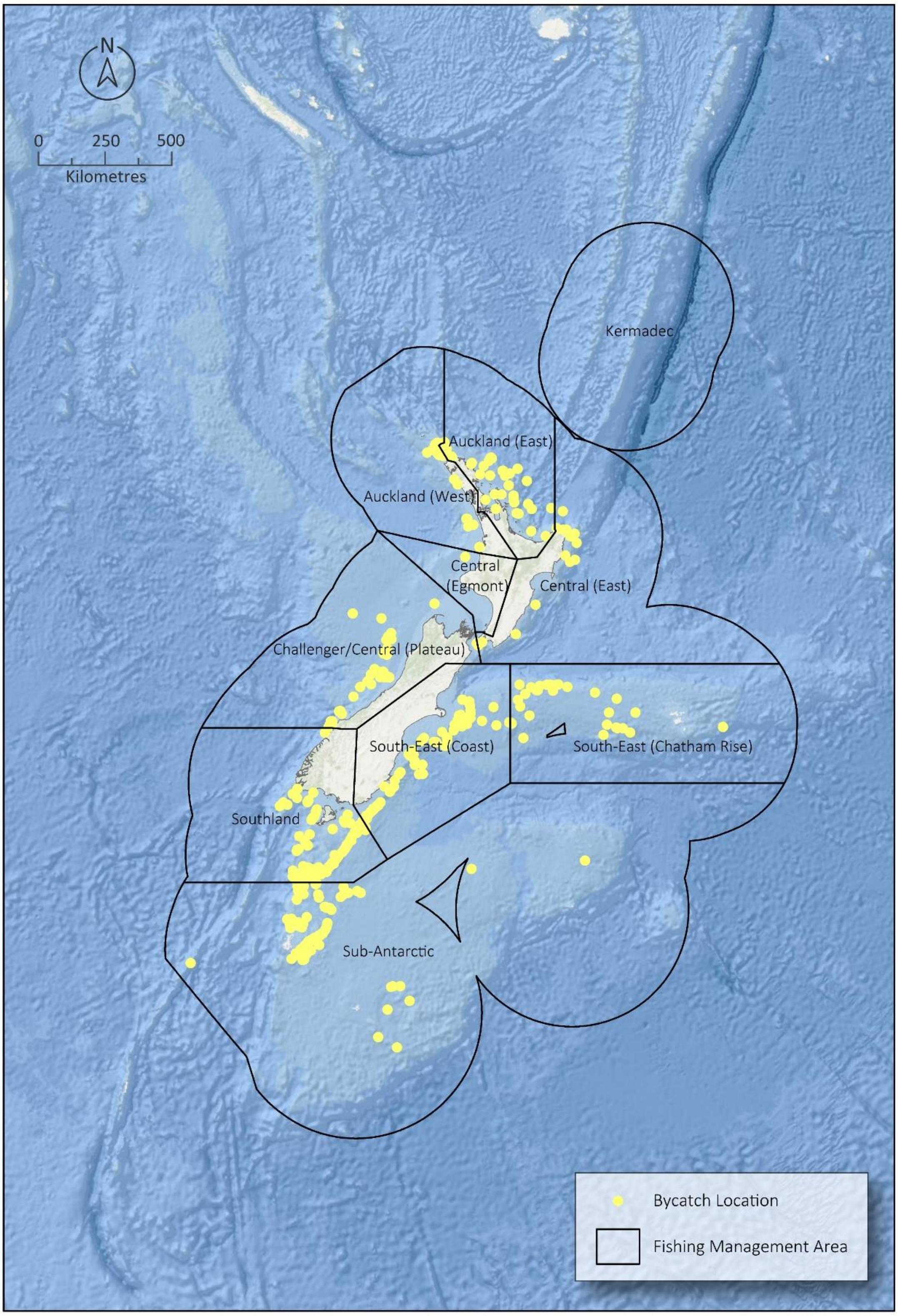

Figure 2. Location of seabird interactions involving seabirds caught in commercial fishing gear and returned to sea alive as reported by fisheries observers during the 2016/17, 2017/18 and 2018/19 reporting period (FNZ).

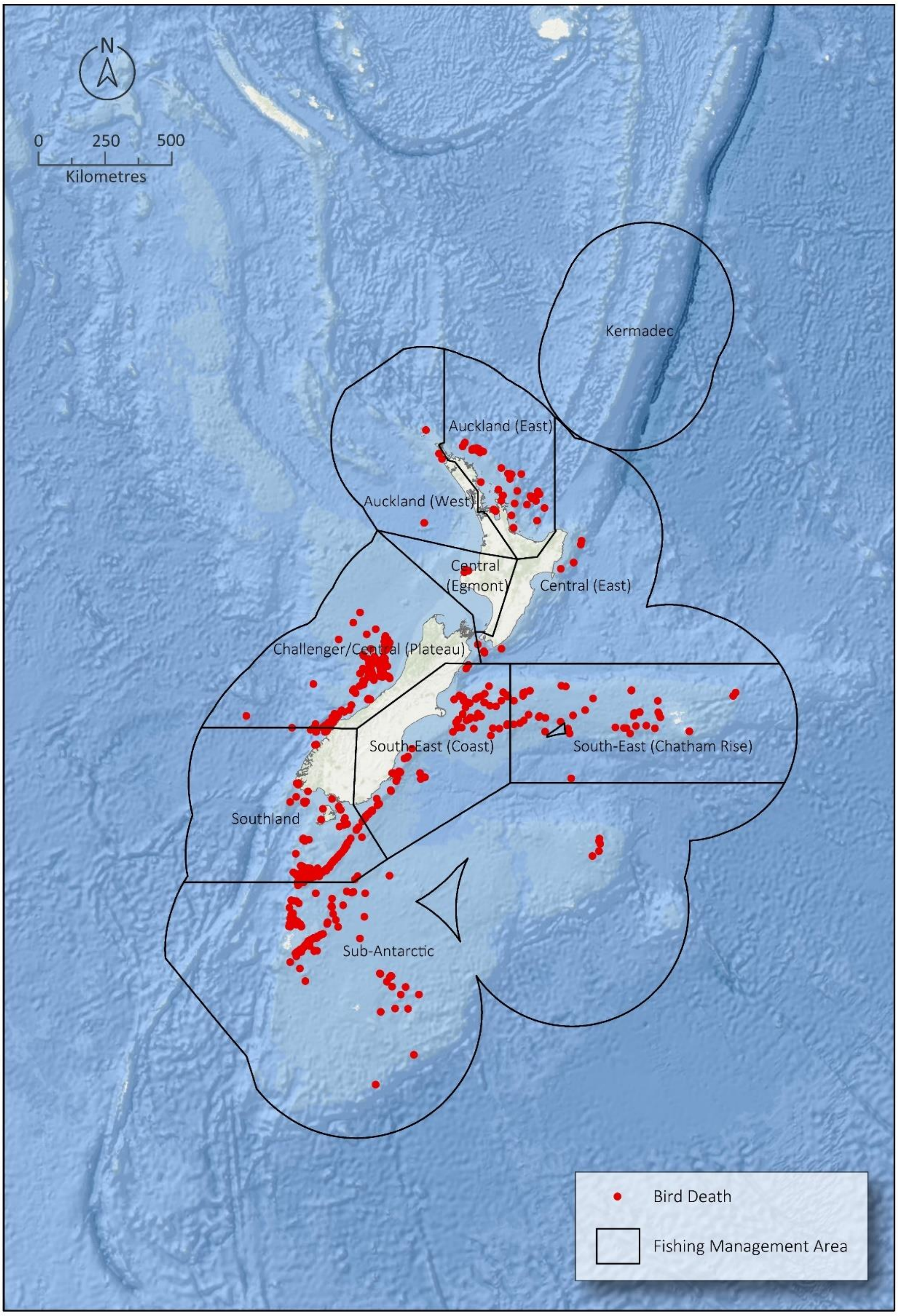

Figure 3. Location of commercial fishing seabird mortalities reported by fisheries observers during the 2016/17, 2017/18 and 2018/19 reporting period (FNZ).

Table 5. The number, FMA, and species richness of seabirds returned to sea as reported by fisheries observers during the 2016/17, 2017/18, and 2018/19 reporting period (FNZ).

FMA Name	FMA ID	Total birds	Birds caught (%)	Species richness
Auckland (East)	FMA1	43	4.3	13
Central (East)	FMA2	20	2	15
South-East (Coast)	FMA3	110	11	19
South-East (Chatham Rise)	FMA4	32	3.2	15
Southland	FMA5	523	52.1	30
Subantarctic	FMA6	158	15.8	25
Challenger/Central (Plateau)	FMA7	48	4.8	17
Central (Egmont)	FMA8	1	0.1	1
Auckland (West)	FMA9	68	6.8	14
Kermadec	FMA10	0	0	0

For seabird interactions with supporting location data (n=1003) interactions involving live seabirds returned to sea were dominated by trawl fisheries (63.3%) and longline fisheries (35.9%) (Table 6). The impacts of fishery type vary per FMA and is likely a factor of the predominant fishery occurring within each FMA (Table 6). Fishery type, and vessel type will have implications on the ability for two operators to be accommodated on fishing trips to be able to fit PTT tags to birds.

Table 6. The proportion of seabird interactions with various fishing methods involving live birds returned to sea as reported by fisheries observers during the 2016/17, 2017/18 and 2018/19 reporting period (FNZ).

FMA NAME	FMA ID	Total birds	FISHING METHOD %				
			Bottom longline	Setnet	Longline (bottom/surface)	Surface longline	Trawl (bottom/midwater)
Auckland (East)	FMA1	43	39.5	0	2.3	23.3	34.9
Central (East)	FMA2	20	10	0	0	25	65
South-East (Coast)	FMA3	110	18.2	6.4	0	3.6	71.8
South-East (Chatham Rise)	FMA4	32	9.4	0	0	0	90.6
Southland	FMA5	523	54.3	0.8	0	0.2	44.7
Sub-Antarctic	FMA6	158	0.6	0	0	0	99.4
Challenger/Central (Plateau)	FMA7	48	0	0	0	56.3	43.8
Central (Egmont)	FMA8	1	0	0	0	0	100
Auckland (West)	FMA9	68	14.7	0	66.2	0	19.1
Kermadec	FMA10	0	0	0	0	0	0

Fishery observers recorded injuries to seabirds captured alive, and birds returned to sea. For birds with injury data (n=1,115) most birds were reported to have no visible injuries. However, it should be noted that observers do not do a thorough examination of each bird, and under-reporting of injuries is likely to be occurring. Less than 0.5% of birds are reported to have physical injuries (broken bones or open wounds). It is also unlikely that the figure of less than 0.5% of birds reported to have their plumage covered with some degree of greasing is accurate. This is an important consideration which is likely to compromise the birds waterproofness and could increase the risk of post-release mortality (Table 7).

Table 7. Injuries to seabirds interacting with New Zealand commercial fisheries and returned to sea alive as recorded by fisheries observers in 2016/17, 2017/18 and 2018/19 (FNZ).

	2016/17		2017/18		2018/19		
	Photograph	**Interaction**	**Photograph**	**Interaction**	**Photograph**	**Interaction**	**Total**
No visible injuries	38	425	51	212	30	154	910
Disorientated	3	8	7	14	2	5	39
Waterlogged			2	2	2		6
Broken wing		2	1	4	1		8
Broken leg						1	1
Hook in bill or throat	2	5	1	2			10
Hook in wing		4		3	1		8
Hook in body		2		1			3
Open wound		2	2	2			6
Greased	1	1	4	29		1	36
Unknown (unable to assess)		45		24		19	88
TOTAL	**44**	**494**	**68**	**293**	**36**	**180**	**1115**

A wide range of seabird species have been recorded by fisheries observers as live interactions with commercial fishing vessels and birds returned to sea (Table 8). Those involving diving petrel, storm petrel, and prion species are almost always likely to be from nocturnal deck strikes as these birds are readily attracted to light sources (Rodriguez *et al.,* 2017).

Significant numbers of white-chinned petrel, white-capped albatross, sooty shearwater, Salvin's albatross, Buller's albatross, black petrel, Buller's shearwater and flesh-footed shearwater have been recorded as live release from fisheries interactions (Table 8). These species should be targeted for tracking in a field-based programme.

Further, due to differing foraging behaviours between albatross and medium sized petrels and shearwaters, WMIL believe this is likely to result in differing post-release survival rates between species. To ensure adequate sample sizes, a field-based research programme should work on two seabird groups: *albatross species and medium sized petrels and shearwaters*.

Table 8. Seabird species and fishing method for live seabird interactions recorded in New Zealand commercial fisheries for 2016/17, 2017/18, and 2018/19 (FNZ).

Species	Total count	% of total birds	Fishing method (%)				
			Bottom longline	Setnet	Longline (bottom/surface)	Surface longline	Trawl (bottom/midwater)
Common diving petrel	286	28.6	94.1	0	1.7	0	4.2
White-chinned petrel	141	14.1	0.7	1.4	0	1.4	96.5
New Zealand white-capped albatross	120	12	0	5	0	8.3	86.7
Sooty shearwater	61	6.1	3.3	1.6	0	0	95.1
White-faced storm petrel	44	4.4	70.5	0	15.9	0	13.6
Salvin's albatross	37	3.7	0	0	0	0	100
Buller's albatross	30	3	0	0	0	23.3	76.7
Petrels, prion and shearwaters (unidentified)	30	3	0	0	63.3	0	36.7
Albatross (unidentified)	23	2.3	0	0	0	0	100
Prion (unidentified)	23	2.3	43.5	0	8.7	8.7	39.1
Black (Parkinson's) petrel	18	1.8	55.6	0	0	22.2	22.2
Petrel (unidentified)	18	1.8	0	0	0	0	100
Procellaria petrel (unidentified)	18	1.8	0	0	0	0	100
Buller's shearwater	15	1.5	0	0	60	0	40
Fairy prion	14	1.4	0	7.1	0	7.1	85.7
Buller's and Pacific albatross	13	1.3	0	0	0	7.7	92.3
Storm petrel (unidentified)	10	1	10	0	0	10	80
Westland petrel	10	1	0	0	0	40	60
Flesh-footed shearwater	8	0.8	37.5	0	0	12.5	50
Grey-backed storm petrel	8	0.8	0	0	0	25	75
Shearwater (unidentified)	7	0.7	0	0	0	28.6	71.4
Cape petrels	6	0.6	16.7	16.7	0	0	66.7

Great-winged (Grey-faced) petrel	6	0.6	0	0	33.3	33.3	33.3
Mottled petrel	5	0.5	80	0	0	0	20
Great albatross (unidentified)	4	0.4	0	0	0	25	75
Royal albatross (unidentified)	4	0.4	0	0	0	25	75
Shy albatross	4	0.4	0	0	0	25	75
Southern royal albatross	4	0.4	0	0	0	50	50
Grey petrel	3	0.3	0	0	0	33.3	66.7
Small albatross (unidentified)	3	0.3	0	0	0	0	100
Black-backed gull	2	0.2	100	0	0	0	0
Fluttering shearwater	2	0.2	0	0	100	0	0
Gibson's albatross	2	0.2	50	0	0	50	0
Mid-sized petrel & shearwater (unidentified)	2	0.2	0	0	0	0	100
Penguin (unidentified)	2	0.2	0	0	0	0	100
Seabird (small)	2	0.2	0	0	0	0	100
Spotted shag	2	0.2	0	0	0	0	100
Wandering albatross (unidentified)	2	0.2	0	0	0	0	100
White-headed petrel	2	0.2	0	0	0	0	100
Antipodean and Gibson's albatross	1	0.1	0	0	0	100	0
Black-bellied storm petrel	1	0.1	0	0	0	0	100
Cape petrel	1	0.1	100	0	0	0	0
Little blue penguin	1	0.1	100	0	0	0	0
Northern giant petrel	1	0.1	0	0	0	0	100
Pterodroma petrel (unidentified)	1	0.1	0	0	0	0	100
Southern giant petrel	1	0.1	0	0	0	0	100
Wandering (Snowy) albatross	1	0.1	0	0	0	0	100

9. Environmental factors

9.1 At-sea influences

A wide range of seabird survival studies have highlighted how climate and marine variables (e.g. sea surface temperature) influence adult and juvenile survival on seabirds (Sandvik *et al.,* 2005). These variables likely impact food availability, which influences survival and breeding success.

Marine environmental conditions vary spatially and temporally, therefore, impacts on seabird survival are variable. Seabird populations have good years and bad years, and this inter-annual variability will need to be considered when designing a project assessing post-release survival of seabirds interacting with commercial fisheries. If sampling size means that tracking of bycaught seabirds will extend beyond one season, it is recommended that tracking of a control group of healthy seabirds will also need to be carried out concurrently each season in order to identify any seasonal effects on results.

10. Logic model

To help evaluate the operational, biological and environmental factors which may constrain a field-based programme to assess post-release survival of seabirds interacting with commercial fisheries, a logic model is presented (Figure 4).

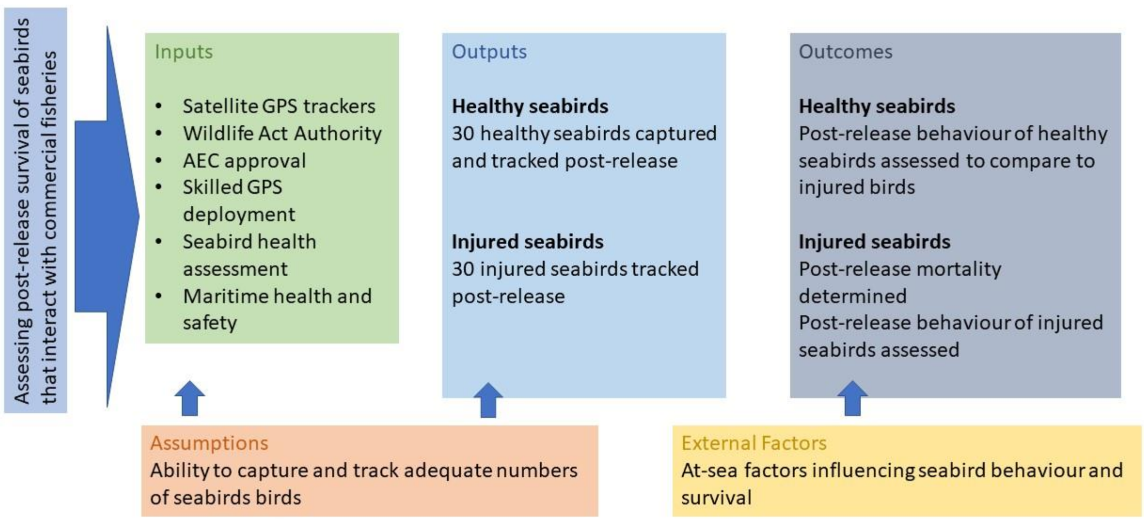

Figure 4. Logic model planning and evaluation tool for assessing factors likely to impact a field-based programme to assess post-release survival of seabirds interacting with commercial fisheries.

Section 3: Recommendation on the most effective method to assess post-release survival of seabirds interacting with commercial fisheries.

Utilising satellite tracking using Teleonics TAV series PTTs is recommended as the best method to assess post-release survival of seabirds that interact with commercial fisheries. Although relatively expensive, this method provides the only method which is likely to return data on the behaviour and survival of seabirds post-release (Section One).

A range of operational, biological and environmental factors may constrain a tracking study of injured seabirds. Some of these factors have the potential to significantly impact the likelihood of successfully monitoring post-release survival (Table 9). Some factors are likely to have a high impact on the project but are more easily managed – such as granting of Wildlife Act Authority (1953) and AEC approvals following the development of science-based applications which have the relevant supporting information.

Other factors with a higher impact on the likelihood of project success are moderately difficult to manage. These are categorised in to two main areas. Firstly, the need for skilled experienced operators to attach PPT devices to birds. This will be required in order to gain Wildlife Act Authority (1953) and AEC approval, but also strongly influences the attachment period of PTT devices to seabirds. To ensure PTTs remain on birds for the proposed assessment period of two weeks, it is vital to have skilled and experienced operators attaching them.

Assessment of the health of live seabirds interacting with commercial fisheries will need to occur to ensure PTT tracking maximises identifying cryptic mortality rates. Individuals with severe injuries that will not survive, and those with no injuries that will survive, should not be tracked. Birds with moderate injures where survival probability is uncertain should be tracked, as these provide the best opportunity to understanding true cryptic mortality rates. To achieve this a “Seabird Heath Assessment Tool” has been developed to guide future research.

The health assessment tool developed in the current project could be refined further by reviewing current bycatch data held by Fisheries New Zealand (FNZ). There are two data sets which could be assessed to further investigate the nature and extent of injuries sustained by seabirds in commercial fisheries. FNZ hold data on seabird injuries recorded on Observer Protected Species Interaction Forms (PSI form); and data could be made available from the Electronic Monitoring (EM) trials currently underway from the inshore fisheries. Injury codes could be data mined from the PSI forms and categorised using the health assessment tool presented in this report (i.e. low, medium and high likelihood of survival). This data should be reviewed to further refine both the health assessment tool, and the recommended field-based tracking project, and to initially develop a better understanding of the problem using historical findings not previously investigated.

Secondly, biological and environmental impacts which differ spatially and temporally will influence seabird survival. To account for this risk factor, PTT tracking of a control group of “healthy” uninjured birds should be done during the same study period. This way there will be the ability for comparative studies between injured and uninjured birds. For such a study, seabirds could be attracted to a charter boat using burley and birds caught with a scoop net or neck crook. Birds can be carefully brought aboard, processed, a PTT attached and released back to sea. The entire device attachment process should be able to be completed in under 15 minutes.

The most severe and difficult to manage factors which will impact on the project is that it requires two operators to attach a PTT to a seabird. This will impact on the ability for two trained operators to be present on a commercial fishing vessel for an extended period. Only one of these operators needs to be skilled and experienced in PTT attachment, with the second operator required to securely hold the bird. Experience or training for the second operator would be desirable here, and this is likely a role which could be filled by a fisheries observer.

Table 9. Risk assessment of operational, biological and environmental factors which may constrain a tracking study of moderately injured seabirds post interaction with commercial fisheries.

Factor	Impact severity	Factor manageability	Controls	Risk
Wildlife Act Authority (1953)	High	Easy	Appropriate applications submitted with documented evidence to support application	Low
AEC approval	High	Easy	Appropriate applications submitted with documented evidence to support application	Low
Banding Office considerations	Low	Easy	At least one qualified bander (Level 2 or greater seabird bander) present during field-based programme	Low
Device life on a seabird	High	Moderate	At least one skilled and experienced operator present during field-based programme to attach device to bird	Low
Operators required for GPS device attachment	High	Difficult	Two operators needed, including at least one skilled and experienced operator presents during field-based programme to attach device to bird	High
Training	High	Moderate	Fisheries observer time committed to training in GPS attachment methodology; and/or at least one skilled and experienced operator presents during field-based programme to attach device to bird or use experience operators	Medium
Health and Safety	High	Easy	Develop appropriate Health and Safety plans in co-operation with commercial fishing vessels	Low
Vessel considerations	High	Difficult	Appropriate vessel selection for project ensure ability for two operators to be onboard	High
At-sea behaviour	Medium	Moderate	Track a similar sample control group of “healthy” birds in all seasons for which injured birds are tracked	Medium
Sample size	High	Moderate	Carry out a multi-year project to ensure adequate sample size for accurate assessment of survival rates (≥30 birds)	Medium
At-sea influences	Medium	Moderate	Track a similar sample control group of “healthy” birds in all seasons for which injured birds are tracked	Medium

In the three fishing seasons 2016/17, 2017/18, and 2018/19, fisheries observers recorded a total of 1,117 seabird interactions with commercial fisheries that were released alive. This number represents a range of species, including 248 albatross species (24.8% of all seabird interactions) and 199 medium sized petrel or shearwater species (19.9% of all seabird interactions).

It is likely that survival rates between albatross, and medium sized petrel and shearwaters is different, and a post-release survival tracking study will need to investigate both groups of birds.

Southern ocean fisheries FMA5 and FMA6 dominated live seabird interactions with 67.9% of interactions reported from these two FMAs. This is likely to be strongly influenced by the large number of deck-strikes of diving petrel, storm petrels and prions attracted to fishing vessels at night in the Southern ocean. Although these fishing areas are also likely the principal location of albatross captures.

In Northern New Zealand FMA1 and FMA 9 combined account for 11% of live captures. These fisheries are likely impacting medium sized petrels and shearwaters, and especially black petrel, flesh-footed shearwater and Buller's shearwater.

11. Recommended field-based programme.

It is recommended to undertake a PTT tracking study using TAV Avian series tags on two groups of seabirds – albatross species and medium sized petrels and shearwaters. Prior to a field-based study being initiated a review should be conducted of existing seabird injury data held by FNZ, recorded by fisheries observers on PSI forms, and EM video footage, to investigate and categorise (using the health assessment tool presented here) the number, nature and extent of injuries sustained by seabirds returned alive to sea. This will help to refine the following field-based recommendations.

This field-based programme should include:

- Tracking medium size seabirds (black petrel, flesh-footed shearwater and Buller's shearwater) interacting with commercial fisheries in FMA1 and FMA9.
- Tracking albatross species interacting with commercial fisheries in FMA5 and FMA6.
- Track ≥30 birds from each group (≥30 medium sized seabirds and ≥30 albatross species). In order to achieve this sample size, the project should be carried out across 3-5 years.
- The "Seabird Heath Assessment Tool" should be used to determine the appropriate individuals to be selected for tracking categorised as health status 'B'; moderate injuries.
- A tracking period of ≥14 days should be used. PTT devices should be programmed to maximise locational fixes for a 14-day period to allow determination of seabird behaviour.
- A control group of "healthy" seabirds should be captured unharmed using scoop nets or neck crooks (i.e. in a manner not connected to commercial fishing interaction) and tracked each season. This will ensure variation of environmental conditions is accounted for in the experimental design for analysing seabird survival and behaviour.
- Two operators should be used to attach PTT tags to seabirds, at least one of these operators should be a skilled and experienced seabird biologist with PTT and/or GPS tag attachment experience. Training should be provided to the second operator, who could be a fisheries observer.

12. Acknowledgements

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