Capture of protected species in New Zealand recreational marine fisheries

Report prepared for Department of Conservation

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1. INTRODUCTION

Marine protected species are caught in a wide range of New Zealand commercial fisheries (e.g., see Abraham & Berkenbusch 2019). To reduce these captures, extensive measures are in place, including restrictions on fishing activity, mitigation measures, video monitoring, and collection of data using fisheries observers (Ministry for Primary Industries 2019).

In New Zealand, there is high participation in recreational fisheries: it was estimated from a recent national survey that there were 1 810 379 recreational fishing trips in this country during the 2017–18 fishing year (from October to September in the following year) (Wynne-Jones et al. 2019). Despite this high activity, little is known about the impacts of recreational fisheries on protected species. Without well-quantified information, it is difficult to assess and manage the potential impacts of recreational fishers on protected species, (which include seabirds, marine mammals, reptiles, some sharks, some corals, and some other fish).

Although there are many reports of the capture of seabirds and marine mammals in New Zealand recreational fisheries (see Abraham et al. 2010), there have been few studies of the recreational catch of these two groups of protected species. Two long-term studies of seabird captures in set nets were conducted in southeastern South Island (Otago), one on the capture of shags (Lalas 1991), and another on the mortality of yellow-eyed penguin (Darby & Dawson 2000). Both of these studies concluded that set netting had a high potential impact on the local populations. At Banks Peninsula, a study of Hector's dolphin estimated that between three and nine dolphins were caught annually in recreational set nets (Dawson 1991), before the introduction of the Banks Peninsula Marine Mammal Sanctuary in 1988.

Boat ramp surveys have been routinely carried out by Fisheries New Zealand, to allow recreational catch to be assessed. The surveys are carried out by interviewing fishers as they return to boat ramps after a fishing trip. These surveys have been carried out consistently over a long period of time, with the most recent available survey being during the 2017–18 fishing year (Hartill et al. 2019). The boat ramp surveys provide

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detailed information on the catch composition of recreational fishing; when combined with an estimate of total boat activity from aerial surveys, they provide an accurate estimate of the recreational take from boat-based fishing. In principle, the boat ramp and aerial surveys allow for detailed mapping of boat-based recreational fishing effort. Nevertheless, this information is not available from the most recent 2017–18 survey. During the 2017–18 fishing year, the boat ramp survey included questions relating to seabird captures for the first time. The responses can be directly linked to the fishers' reported fishing effort, allowing the determining of seabird capture rates.

The National Panel Survey (NPS) of recreational fisheries surveys people from throughout New Zealand over the course of a year (Wynne-Jones et al. 2019). It is a fishing-diary based method, that is balanced geographically and demographically. The NPS provides estimates of fishing effort for all fishing methods used by recreational fishers, by Fisheries Management Area (FMA). During the 2017–18 survey, a question was asked about seabird captures as part of an exit survey at the end of the year.

In this report, data from the 2017–18 boat ramp and NPS surveys were analysed to obtain a national estimate of seabird captures from boat-based line fishing. The report includes a discussion of the limitations of the surveys, and suggestions on how the collection of seabird capture information by those surveys could be improved.

Because of the sparsity of available data, improving the data collection on the interactions between protected species and recreational fisheries is a priority. In this report, I also review the data collection methods that would allow protected species captures in recreatioal fisheries to be assessed. In particular, I discuss what information could be collected using phone app based methods, and how the collection of information by the Department of Conservation could be improved to obtain consistent reporting of protected species captures.

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2. METHODS

2.1 Protected species

Marine protected species in New Zealand include all marine mammals; all marine reptiles; all seabirds, other than black-backed gull (*Larus dominicanus*); some sharks and rays: oceanic whitetip shark (*Carcharhinus longimanus*), basking shark (*Cetorhinus maximus*), deepwater nurse shark (*Odontaspis ferox*), great white shark (*Carcharodon carcharias*), whale shark (*Rhincodon typus*), manta ray (*Manta birostris*), spinetail devil ray (*Mobula japanica*); some other fish: spotted black grouper (*Epinephelus daemelii*), giant grouper (*Epinephelus lanceolatus*); and some corals: black corals (Antipatharia), gorgonian corals (Gorgonacea), stony corals (Scleractinia), hydrocorals (Stylasteridae) (New Zealand Government 1953, 1978, Miskelly 2014, 2016).

Although black-backed gulls are not protected, they were included within the species considered in this report. Often, records of seabird captures in recreational fisheries were not resolved at a species level, and so captures of all seabird species were considered.

2.2 Data sources

Many of the potential sources of information on protected species captures in marine recreational fisheries are from sources that were not primarily designed for collecting bycatch information (Table 1). The only systematic data on protected species captures in recreational fisheries have been records of seabird captures collected during surveys (Abraham et al. 2010, Hartill et al. 2019, Wynne-Jones et al. 2019).

For recreational charter vessels, there is reporting of fishing effort and fish catch (of selected species) to Fisheries New Zealand; however, no information on any seabird or marine mammal captures that occur is reported. The only available information of captures was data collected during 2007 and 2008 in the boat ramp surveys, supporting a fisheries research project (Holdsworth & Boyd 2008, Abraham et al. 2010).

Estimates of national fishing effort are available from the NPS, which is carried out at

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5-yearly intervals (most recentlyin 2017–18; Wynne-Jones et al. 2019). Aerial overflight surveys provide for spatially resolved records of recreational fishing from boats (Hartill et al. 2013, Hartill et al. 2019), and these are supplemented by web-camera monitoring of boat ramps to allow for variations in fishing effort over time to be understood (e.g., Hartill et al. 2015).

An assessment of threats to Māui and Hector's dolphin in 2019 included recreational set-net fishing (Roberts et al. 2019). For this assessment, a distribution of recreational set-net fishing was developed by Fisheries New Zealand, based on records of set-net fishing from the NPS. Although the NPS survey was not designed for this purpose, it may be possible to derive spatial distributions of recreational fishing, other than boat fishing, from these data.

There is little information available on the capture of protected sharks in recreational fisheries, although there is information from reports to the Department of Conservation to suggest that it does occur. Recently, during the 12-month period from March 2019 to February 2020, eight juvenile great white shark recreational fishing captures were reported to DOC in areas including Ninety Mile Beach, Kawhia, Tokerau Beach, Muriwai Beach, Waihi Beach, and Orewa. Five were mortalities, and three were released alive, but post-release survival is unknown and considered unlikely. The nature of the recreational fishing interactions include seven caught on Kontiki beach longlining (both by being hooked and tangled in longline), and one in a recreational set net (K. Middlemiss, pers. comm.) [1]. This kind of anecdotcal information is important in guiding information needs, but does not allow for a quantitive analysis to be made.

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[1] https://www.nzherald.co.nz/the-country/news/article.cfm?c_id=16&objectid=12317462

Table 1: Sources of data, firstly, related to the capture of protected species in marine recreational fisheries, and secondly, related to determining recreational fishing effort. For each source, the table indicates where the data are held (DOC: Department of Conservation; MPI: Fisheries New Zealand; OSNZ: Birds New Zealand; BWM: Bluewater Marine Limited; Fish4All: Fish4All Limited; Fishbrain: Fishbrain AB, Sweden). For capture information, the scope indicates the taxonomic group included in the data, and for fisheries effort the scope indicates which component of the recreational fisheries is covered by the data. The method is either Ad hoc: haphazard reporting; Survey: independent survey with formal data collection procedures; Logbook: fisher self-reported; Statutory: reporting required by regulation; or Monitoring: passive monitoring methods.

Source	Held	Scope	Method	Description
Protected species captures				
DOC hotline	DOC	All wildlife	Ad hoc	Primary contact point for reporting injured wildlife, which may include wildlife caught by fishing (Department of Conservation 2020b).
Bird banding	DOC	Seabirds	Ad hoc	Records sightings of banded birds, including birds caught by fishing (Department of Conservation 2020c).
Shark sightings	DOC	Sharks	Ad hoc	Public reports of sightings, captures, and strandings, which may include captures in recreational fishing (Department of Conservation 2020d).
Beach patrol	OSNZ	Seabirds	Ad hoc	Records of dead birds found on beaches, including birds caught by fishing (Birds New Zealand 2020).
Strandings	DOC	Marine mammals	Ad hoc	Records of marine mammal strandings, includes records of animals that appear to have died as a result of fishing (Department of Conservation 2020a).
Boat ramp survey	MPI	Seabirds	Survey	Survey of boat ramps during 2017–18. Fishers asked if they had caught a seabird (43 669 interviews), and if so, what the outcome was (Hartill et al. 2019).
Diary survey	MPI	Seabirds	Survey	National Panel Survey (NPS) during 2017–18. At the final survey, fishers asked whether a fisher had disrupted their fishing during the year (1203 responses), and if so, what the outcome was (Wynne-Jones et al. 2019).
Charter survey	MPI	Seabirds	Survey	Independent observers on 57 charter vessels during 2007–08 recorded any seabird captures. Data returned to MPI at project end (Abraham et al. 2010).

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Table 1 — Continued from previous page

Source	Held	Scope	Method	Description
Boat ramp survey	MPI	Seabirds	Survey	Survey of boat ramps during 2007–08. Fishers asked if they had caught a seabird (763 interviews), and if so, what the outcome was (Abraham et al. 2010).
Recreational fishing effort and captures				
Billfish logbooks	BWM	Gamefish	Logbook	Logbook programme designed to collect catch and effort information from recreational vessels targeting marlin off northern New Zealand. (Holdsworth & Boyd 2017, Blue Water Marine 2020).
Charter	MPI	Boat	Statutory	All recreational charter vessels report fishing effort and catch of selected species to MPI (Fisheries New Zealand 2020).
Aerial	MPI	Boat	Survey	Boat ramp and aerial survey used to estimated fishing effort and catch by recreational fishers using trailer boats. Most recent surveys in FMA 1 in 2017–18. (Hartill et al. 2013, Hartill et al. 2019).
Web camera	MPI	Trailer-boat	Monitoring	Web camera monitoring of boat ramps used to record recreational activity, in FMAs 1, 8, and 9 (Hartill et al. 2015).
Diary survey	MPI	All	Survey	National Panel Survey (NPS) during 2017–18, asked 6975 marine fishers, and 2203 'non-fishers' about fishing catch and effort through 2017–18. All methods recorded. (Wynne-Jones et al. 2019).
Fish4All	Fish4All	All	Logbook	Fish4All is a New Zealand organisation with a mobile app that allows fishers to record their catches, but not bycatch (https://www.fish4all.co.nz).
Fishbrain	Fishbrain	All	Logbook	Fishbrain is a Swedish company with a mobile app that allows fishers to record their catches, but not bycatch (https://fishbrain.com). It operates globally and is used by New Zealand fishers.

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A summary of data available for assessing the capture of protected species captures in recreational fisheries highlights significant information gaps, especially in taxa other

than seabirds (Table 2). There were no datasets of seabird captures by shore-based, set-net, or recreational fishing that would allow estimation of captures in those fisheries; the only record of seabird captures at the species level, was from the limited survey on charter vessels (Abraham et al. 2010); apart from line fishing, spatially-resolved recreational fishing effort data are not available (although it may be possible to generate this information from existing NPS survey data); there were no systematically collected datasets with information on the capture of marine mammals, sharks and rays, or on any potential impacts of recreational fishing on corals.

2.3 Boat ramp surveys

An access point survey was carried out during 2017–18, on boat ramps across New Zealand, for the purpose of estimating the recreational take of key fish species (Hartill et al. 2019). This survey followed a long-established methodology (Hartill et al. 2007), and the data were made available through the Fisheries New Zealand 'rec_data' database (Fisher & Dick 2007).

Table 2: Summary of available data for assessing protected species captures in New Zealand recreational fisheries. For each fishery the availability of systematic data relating to fishing effort, and protected species captures is assessed (anecdotal and haphazard reports, or local studies, are not included). Grey cells: no quantitative data available; orange: either limited data are available, or data may be available if further research was undertaken; green: some quantitative data available. Fishing effort may be available at a Fisheries Management Area scale, or may be spatially resolved (at a scale suitable for risk assessments). Seabird and marine captures may be reported at a group level (such as "seabirds" or "petrels and shearwaters"), or else at a species level. Sources of information are – MPI: statutory reporting to Ministry for Primary Industries (MPI); NPS: National Panel Survey (Wynne-Jones et al. 2019); Aerial.: (Hartill et al. 2013, Hartill et al. 2019); Boat ramp: (Abraham et al. 2010, Hartill et al. 2019); and Charter: (Holdsworth & Boyd 2008, Abraham et al. 2010).

Fishery	Effort		Seabirds		Mammals	Reptiles	Sharks & rays	Other fish	Corals
	FMA	Spatial	Group	Species					
Charter fishing	MPI	MPI	Charter	Charter					
Boat-based recreational line fishing	NPS	NPS/Aerial	Boat ramp						
Recreational shore fishing	NPS	NPS							
Recreational set-net fishing	NPS	NPS							
Other recreational fishing	NPS	NPS							

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On survey days, interviewers were stationed at selected boat ramps for the entire day (from 07:30 or 08:00 h until half an hour after dusk), and they recorded all boats returning to the ramps. Fishers were interviewed, and were asked about their fishing effort (location, target species, fishing gear, start and end of fishing time, hours of fishing), and their catch. Where possible, fish were measured. During 2017–18, the protocol was expanded, with fishers being asked about interactions with seabirds. Specifically, fishers were asked "Did you catch any birds with your fishing gear today?". If the fisher answered "yes", then they were shown a card with a description and photographs of seabirds, and asked to identify the seabird taxon as either:

- gull (A);
- gannet (B);
- shag (C);
- penguin (D);
- tern (E);
- albatross or mollymawk (F);
- petrel or shearwater (G);
- unidentified (U),

where the letter in parentheses was the code recorded by the interviewer. If no bird was caught, the interviewer recorded "N".

If the fisher had caught a bird, then a follow-up question was asked: "How did you catch the bird and what was the outcome?", with the responses recorded in different categories (see Table 3).

The database records an identifier for the interview session (carried out by an interviewer at a boat ramp on a particular day), the boat, and the fisher. A record was made for each combination of fishing location, fishing method, and target species that was used by the fisher. The seabird bycatch questions were asked of each fisher. The response

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Table 3: Details of seabird captures recorded during boat ramp interviews of recreational fishers. The responses were categorised based on the question asked when fishers had caught a bird: "How did you catch the bird and what was the outcome?".

Capture method	Capture location	Outcome	Code
Tangled in line with no hook contact		Released alive	A
		Dead	B
Hooked but hook removed	Hooked in beak or gizzard	Released alive	C
		Dead	D
	Hooked externally	Released alive	E
		Dead	F
Hooked but hook not removed	Hooked in beak or gizzard	Released alive	G
		Dead	H
	Hooked externally	Released alive	I
		Dead	J
Caught in net		Released alive	K
		Dead	L

form allowed an interviewer to record a single seabird capture for each fisher, with the instructions to the interviewers stating "if a fisher catches more than one bird, assign the next bird caught to another fisher's number".

Other information collected during the boat ramp surveys included:

- Session ramp. The boat ramp where the interview was held.
- Session date. The date of the session.
- Session conditions. Typical sea conditions, rain, and wind during the interview session.
- Location. The area of the fishing, using the 'fish_loc' areas defined in the 'rec_data' database (Fisher & Dick 2007).
- Target species. The fish species that was primarily targeted (with the code 'GEN' recorded if no particular species was targeted).
- Fishing method. The method of the fishing, e.g., bait fishing, long line, trolling.
- Start time. The start time of the fishing (lines in the water), to the nearest quarter of an hour.

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- End time. The end time of the fishing (lines out of the water), to the nearest quarter of an hour.
- Time spent on other activity. Any time between the start and end of fishing that was not spent fishing (e.g., time spent for lunch, or other activities such as water skiing).

Data from the 2017–18 recreational boat-ramp survey were provided by Fisheries New Zealand, as an extract from the 'rec_data' database. The data were summarised, with some data preparation carried out:

- Fishing durations were defined from the difference between the start and end time of the fishing, less any non-fishing time (if any non-fishing time was recorded).
- Records were associated with a Fisheries Management Area (FMA), based first on the location of the fishing, and then on the location of the boat ramp where the fishing was carried out from (with the exception of any otherwise unlocated fishing from Mana, Wellington, which was in multiple FMAs).
- Boat-based fishing using a fishing rod, longline, or trolling was marked as methods to be included in the analysis; the fishing-rod methods were classed as either rod and bait, or rod and lure (to test whether birds may be caught more frequently if bait was used). In the estimation, the methods were grouped as either "line" or "longline".
- Target species were restricted to the most commonly targeted fish species (snapper, blue cod, kingfish, kahawai, gurnard, and tarakihi, hāpuku, and bluenose); all tuna and billfish were grouped as "gamefish"; all shellfish were grouped as "shellfish"; all other targets were grouped as "general".
- Records were marked as incomplete if either: the question about seabird captures was not answered, no FMA could be derived for the record; or no fishing duration could be defined.

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- To assist with spatial modelling, an adjacency matrix was prepared, identifying the fishing locations that shared a common boundary (defined by being within two kilometres of each other). There were two disjointed locations in FMA 1: Asteron Reef (AST) and White Island (WHI). Fishing on Asteron Reef was merged with fishing in the close-by location Motiti Island (MII), while entries were added to the adjacency matrix to identify White Island as being adjacent to the NA the Kaikoura area (KAI) was identifed as being adjacent to Port Underwood (POU) (there were no fishing locations between these two locations in the diary survey).

The data preparation included summaries and the development of a statistical model to estimate capture rates in boat-fishing across all FMAs. In addition, a spatial model of seabird capture rates in FMA 1 was developed to represent variation in seabird capture rates throughout this northern region.

2.4 National Panel Survey

The 2017–18 National Panel Survey (NPS) was carried out between 1 October 2017 to 30 September 2018 by the National Research Bureau Ltd (NRB). A total of 6975 marine fishers were surveyed throughout the year about their fishing activity, and a further 2203 members of the public screened as "non-fishers" reported their fishing activity over the fishing year. The survey of fishers was carried out through a regular poll (weekly, fortnightly or monthly), which asked whether they had been fishing. They were able to reply with "yes" or "no"; fishers who replied "yes" were telephoned and asked follow-up questions about their fishing activity. The recruitment of people to the panel was balanced demographically and geographically, to allow for scaling from the survey to the New Zealand population. From the survey data, NRB were able to estimate fishing effort and catch by marine recreational fishers during the 2017–18 fishing year.

At the end of the year, the fishers were invited to participate in an exit survey, referred to as the "characterisation survey". During this survey, they were asked questions relating to seabird bycatch. Participants were first asked: "During the last fishing year, have seabirds disrupted your fishing activity?", and were able to respond "yes" or "no". They

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were then asked "How did seabirds disrupt your fishing? (select all that apply)", with the following possible responses:

- By chasing and grabbing your baits (but not getting caught).
- By taking hooked or released fish (but not getting caught).
- By becoming entangled in your lines.
- By taking a baited hook and needing to be unhooked.
- Other (Please specify).

They were asked: "How often did one of those events occur?", with the following possible responses:

- Once or twice, occasionally.
- Several times.
- Most trips.

The final seabird-related question asked them to identify the birds as either:

- large albatrosses;
- smaller petrels or shearwaters, often darkly-coloured;
- shags;
- terns;
- penguins;
- don't know the name;
- other (please specify).

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(Note that, because of the design of the survey, the answers to these questions cannot be related to one another if multiple responses are selected. For example, if someone selected multiple ways in which seabirds disrupted their fishing, and identified multiple seabirds, it is not possible to associate the seabird with the disruption method.)

The data from the characterisation survey were provided by MPI. There was no direct link between the data in the characterisation survey and the main survey data that was available from the rec_data database. Fishers provided an estimate of their activity in the characterisation survey, but there was no available effort measure associated with the records of seabird captures.

2.5 Estimating seabird captures

Two simple models were fitted to the data. The models were generalised linear models (GLMs) fitted using the Bayesian libraries BRMS (Bürkner 2017, 2018), which provides an interface to the Stan modelling software (Stan Development Team 2018). The first model was used to estimate the seabird capture rate in fishing using rod and longline methods, by method. Using the BRMS notation, the first model was specified as

```
capture  ~ offset(log(hours)) + method + fma,
```

where "capture" is the number of seabird captures; the number of captures was assumed to be proportional to the fishing duration (expressed in hundreds of hours), indicated by the "rate(hours)" notation. The linear predictor includes a fishing method fixed-effect ("longline", relative to "line" fishing) and an FMA effect (FMAs relative to FMA 1).

The data were aggregated by method and FMA before modelling, so the input data set were small (with only 12 rows). The seabird captures were assumed to be drawn from a Poisson distribution. The prior for the model intercept was a normal distribution with a mean of -5, and a standard deviation of 2; the prior for the fixed effects was a normal distribution with a mean of 0 and a standard deviation of 1. The Monte-Carlo Markov Chain (MCMC) sampling was carried out for 1000 warm-up iterations, followed by 1000 further iterations, using four chains with no thinning, which resulted in 4000 samples of

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the posterior distribution of each parameter being obtained. The posterior distributions were summarised using the mean and the 95% credible interval, calculated from 2.5% and 97.5% quantiles of the posterior samples. In a Bayesian model, this credible interval can be interpreted as meaning that there is a 95% probability that the true value is within the credible interval, given the model, the data, and priors.

The estimated seabird captures in 2017–18 were assumed to be the product of a seabird capture rate (number of birds captures per 100 hours); the mean number of hours per trip; and the number of trips per FMA during 2017–18. For each of the seven FMAs and two methods, the seabird capture rate was estimated by taking 4000 samples of the estimated mean capture rate from the model; 4000 bootstrap samples of the mean number of hours of fishing per fisher-trip, from the boat ramp data; and 4000 samples from a lognormal distribution, paramaterised to give the number of trips reported by Wynne-Jones et al. 2019. The calculation was made for each of the 4000 sets of samples, allowing for uncertainty to be reported in the final estimate of the seabird captures.

For each FMA, Wynne-Jones et al. 2019 reported fishing effort as the number of trips made during the 2017–18 year, based on the gear used. An extract of the estimated number of trips was provided by FMA, fishing method, and platform. In particular, the number of trips was provided for "Rod or line (not long line)" and for "Long-line including set line, contiki or kite" fishing. These fishing methods were assumed to be equivalent to the "Line" and "Longline" method-groups derived from the boat ramp data. The fishing effort estimates were also provided by platform. Fishing from all vessel-based platforms, including "Trailer motor boat", "Larger motor boat or launch", "Trailer yacht", "Larger yacht or keeler", and "Kayak, canoe, or rowboat" was included in the estimate on the assumption that fishing from these platforms had the same characteristics, with respect to seabird bycatch, as boat-based fishing that was recorded during the boat ramp survey. Fishing that was "Off land, including beach, rocks or jetty" or from "Something else", was not included in the estimation.

Across 'Line' and 'Longline' fishing, 51.1% of trips were a trailer motor boat platform, 31.0% of trips were from shore fishing, 0.5% were from methods marked 'Something

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else', and the remainder (17.4%) were from other vessels.

A second model was fitted to data restricted to FMA 1. The purpose of this model was to explore spatial variation in the seabird capture rate within the FMA 1 region. The model was a Conditional Autoregressive (CAR) model, which assumes that the mean capture rates in adjacent fishing locations are related to one another (Jin et al. 2005, Joseph 2016). In BRMS notation, this aspect is specified as:

```
capture  ~ offset(log(hours)) + method + car(adjacency, gr=location).
```

The adjacency matrix was calculated by identifying fishing location polygons that came within 2 km of each other. As with the national model, a Poisson distribution was assumed. The priors were the same as in the national model, and the standard deviation of the fishing location effects was a student-*t* distribution with mean 0, standard deviation of 2.5, and three degrees of freedom. The MCMC sampling was the same as in the previous model.

2.6 Overlap and the risk assessment methodology

The Spatially Explicit Risk Assessment (SEFRA; e.g., Sharp 2018) provides a method for assessing the impacts of fishing on protected species populations. The method uses the overlap between the spatial distribution of fishing effort and species distributions, to allow extrapolating from observed fishing effort (where there is data on the captures) to all fishing effort. This rests on the assumption that the number of captures is proportional to both the fishing effort and the species density. The risk assessment then derives an estimated mortality (derived from the estimated captures using assumptions about the mortality rate of capture animals, and the number of animals that may be killed, but not recorded by observers). The mortality is then compared with an estimate of population productivity, to derive an estimated risk that the fishing is impacting the population. The SEFRA method has been applied to seabirds (Richard & Abraham 2020, e.g.,) and marine mammals (Abraham et al. 2017, Roberts et al. 2019).

In this report, we calculate the overlap between seabird distributions (Richard &

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Abraham 2020), and a relative intensity of fishing. The fishing intensity was calculated by MPI based on counts of recreational fishing boats, from the 2011–12 aerial survey (Hartill et al. 2013).

Using this methodology, there is the potential to use the captures of 'petrel and shearwater' from the boat ramp survey to estimate the captures of black petrel and flesh-footed shearwater in the FMA 1 region, by making assumptions about the relative vulnerability to capture of the species within that group. To understand the impact of these captures on these species, it would also be necessary to understand the mortality rate (how many captured birds die). There is little information to inform estimation of this rate, either in recreational or commercial fisheries (Bell 2020).

This work is not yet complete. We anticipate that the work will be illustrative, showing what information may be needed to carry out a risk assessment using the recreational fisheries data; rather than directly estimating the species specific captures. It may be that overlap distributions, on their own, are informative.

2.7 Review of data collection methods

In light of the limited available data, we carried out a literature review to investigate the potential of different reporting methods (e.g., fisher self-reporting tools, boat ramp surveys, aerial surveys, diary based surveys) for collecting information on the capture of protected species by marine recreational fisheries.

3. RESULTS

3.1 Boat ramp survey

The boat ramp survey was carried out between October 2017 and September 2018 (Hartill et al. 2019). A total of 51 295 fishers were interviewed. Of this total, 43 669 fishers were asked whether they had caught a seabird. Critical metadata (fishing duration, FMA) could not be derived from 23 interviews, and these interviews were not included in the

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Table 4: Boat ramp interviews of recreational fishers carried out between October 2017 and September 2018, by Fisheries Management Area (FMA) (Hartill et al. 2019). Shown are for each FMA, the number of fishers, the number of boats, the number of interview sessions, the number of distinct ramps surveyed, the total number of hours of fishing, the total number of reported seabird captures, and the seabird capture rate (captures per 100 hours of fishing). Interviews where the fisher was not asked about seabird captures, or that lacked information for deriving fishing duration or FMA were not included.

FMA	Fishers	Boats	Sessions	Ramps	Fishing hours	Captures	Capture rate
1	33 537	14 004	1 558	58	120 566	420	0.35
2	1 818	683	127	5	8 085	8	0.10
3	1 999	702	140	7	6 830	7	0.10
5	574	133	23	1	1 227	3	0.24
7	2 789	854	148	4	8 502	5	0.06
8	1 509	642	94	6	5 190	12	0.23
9	1 420	610	100	3	4 728	0	0.00
All	43 646	17 627	2 170	77	155 130	455	0.29

present analysis. The dataset used for analysing seabird captures included data from 43 646 interviews that had been conducted of fishers from 17 627 fishing groups, during 2 170 distinct interview sessions at 77 boat ramps (Table 4).

The interview effort was primarily in FMA 1 (on the North Island east coast, see Figure 1 for FMA boundaries), with 76.8% of all interviews being carried out in this northern area (Table 4). This spatial bias reflected a goal of the survey during the 2017–18 fishing year, which was to provide estimates of recreational take of fish species in FMA 1, by carrying out boat ramp surveys in conjunction with aerial overflight surveys (used to count the number of boats fishing). Across all interviews, a total of 455 seabird captures were reported, with 92.3% of these captures reported from fishing in FMA 1. Within FMA 1, the seabird capture rate was 0.35 captures per 100 hours of fishing. Across all of the interviews, the average seabird capture rate was 0.29 captures per 100 hours of fishing.

Across all data, 76.8% of the fishers used a rod with baited hooks (this category also included fishers that used mixed methods, such as bait fishing and jigging, or a combination of bait fishing and use of plastic lures); 85.7% of the reported seabird captures were associated with this fishing method (Table 5). In comparison, 9% of fishers used a rod with a lure (such as fishing with plastic soft baits, jigging, and fly-fishing), and 9% of seabird captures were associated with this method. The seabird capture rates were

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Table 5: Seabird captures reported in boat ramp interviews of recreational fishers, by fishing method (Hartill et al. 2019). Shown are for each method the number of fishers interviewed, the number of boats that used it, the total number of hours of fishing, the total number of reported seabird captures, and the seabird capture rate (captures per 100 hours of fishing). The methods summarise the following methods reported by the interviewers: Rod and bait – baitfishing, baitfishing and plasic soft baits, baitfishing and jigging, live baiting (not balloon fishing); Rod and lure – jigging, plasic soft baits, poppers, fly casting, spinning; Longline – longlining, kite fishing (long-line); Diving – snorkel diving, scuba diving, spear fishing; Net – set net, drag netting; Bottom gear – dredging, potting (i.e., for crayfish); Trolling – trolling with lure, trolling (lure and bait), trolling with a bait; Bottom line – drop/dahn line, bottom longline; Gathering – hand gathering (eg pipi); Shore fishing – wharf (or jetty) fishing, surfcasting (off the rocks), surfcasting (rocks and sand); Mixed – 2+ expert methods.

Method	Fishers	Boats	Fishing hours	Captures	Capture rate
Rod and bait	33 536	14 122	122 041	390	0.32
Rod and lure	3 937	1 883	12 946	41	0.32
Trolling	2 121	991	9 340	23	0.25
Longline	802	394	2 000	1	0.05
Diving	2 225	1 017	4 156	0	0.00
Bottom gear	684	346	3 838	0	0.00
Net	186	99	524	0	0.00
Bottom line	29	16	124	0	0.00
Gathering	103	46	102	0	0.00
Mixed	10	3	36	0	0.00
Shore fishing	13	12	22	0	0.00
All	43 646	17 627	155 130	455	0.29

the same (0.32 seabirds per 100 fishing hours) for both rod-fishing methods, irrespective of whether bait or lures were used. The other methods that reported seabird captures were trolling and longlining. Of the methods with no reported seabird captures, diving and the use of bottom-gear (pots or dredges) had around 4000 hours of fishing effort reported, while the other methods had around 500 hours or less of fishing effort reported.

When restricted to boat-based rod, longline and trolling fishing methods, the seabird capture rates were highest within FMA 1, in the Hauraki Gulf area (Figure 1). In this area, the capture rates were over 1 seabird capture per 100 hours of fishing in some of the fishing locations. The FMA 1 area was also the region with the highest number of interviews. High seabird capture rates (over 0.5 seabirds per 100 hours of fishing) were also reported from fishing close to New Plymouth, in FMA 8, and at locations close to Dunedin, in FMA 3. Within FMA 7, fishing was surveyed in the Marlborough Sounds, Tasman Bay, and Golden Bay regions, at the north of South Island. There were no interviews carried out on the South Island west coast. In FMA 5, all of the survey

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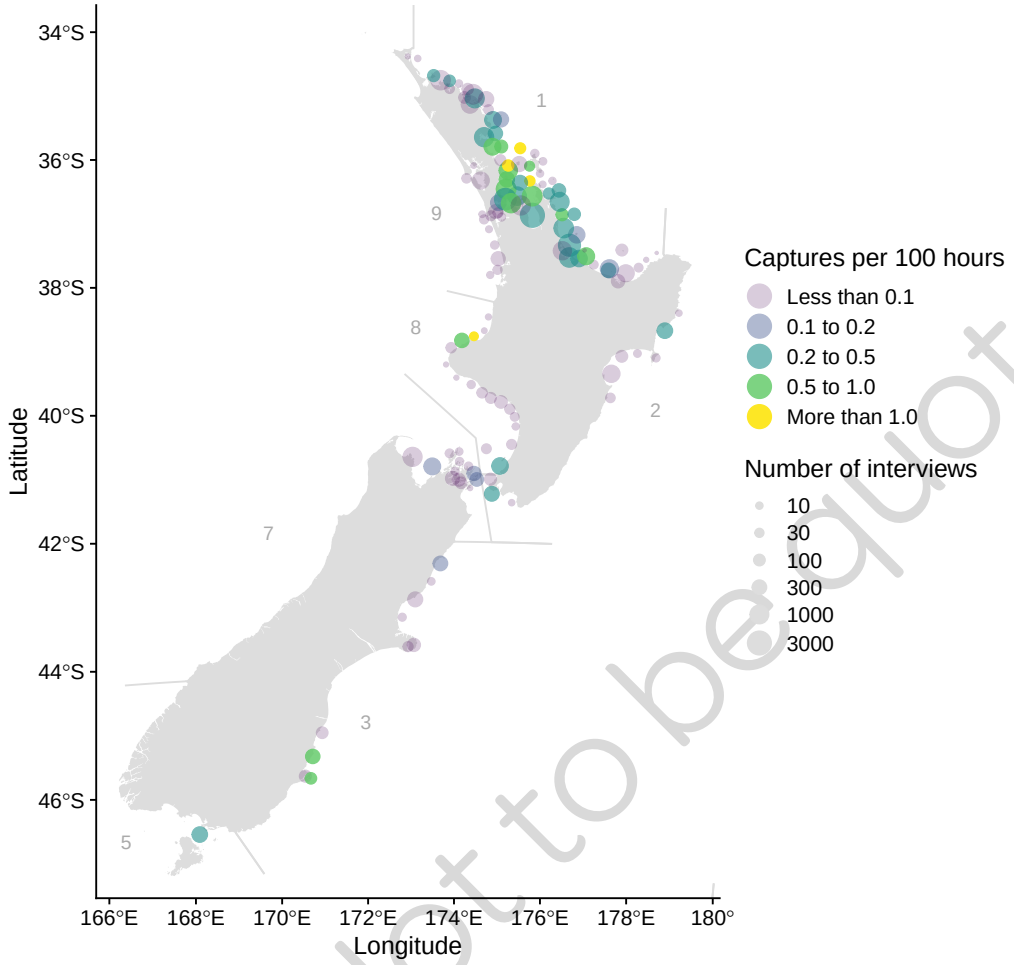

Figure 1: Seabird capture rate by recreational fishers by fishing location (Hartill et al. 2019). For each reported fishing location, the colour of the circle indicates the capture rate (number of seabird captures per 100 hours of fishing), while the size of the circle indicates the number of fishers interviewed. Data were restricted to boat fishing by rod, longline or troll (the methods that had recorded captures). There were 106 interviews that reported a general fishing location, which are not shown on the map. Inshore boundaries of Fisheries Management Areas 1, 2, 3, 5, 7, 8, and 9 are indicated.

effort was of fishers using the boat ramp in Bluff, and there were no surveys of fishers in Fiordland, at the south of the South Island west coast.

The most frequently targeted species was snapper, which was targeted by 62.7% of all fishers (Table 6).The highest seabird capture rate was for recreational fishing targeting kahawai (0.87 captures per 100 fishing hours), while seabird capture rates for target species with a more southern distribution (gurnard and blue cod) were low (0.03 and

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Table 6: Target species reported by recreational fishers during boat ramp interviews (Hartill et al. 2019). Shown are for each target species the number of fishers, the number of boats that targeted those species, the total number of hours of fishing, the total number of reported seabird captures, and the seabird capture rate (captures per 100 hours of fishing). The target "general" includes fishers that did not report a specific target species, and also species that were targeted for less than 1000 hours of fishing. The target "gamefish" included tuna, marlin and swordfish species.

Method	Fishers	Boats	Fishing hours	Captures	Capture rate
Snapper	27 380	11 606	97 891	328	0.34
General	5 440	2 315	18 861	47	0.25
Kingfish	2 042	932	7 716	33	0.43
Kahawai	905	421	2 183	19	0.87
Tarakihi	729	326	2 989	13	0.43
Blue cod	2 330	782	6 593	10	0.15
Gamefish	1 166	539	6 995	4	0.06
Gurnard	744	345	3 090	1	0.03
Rock lobster	1 026	536	4 492	0	0.00
Shellfish and kina	1 406	625	1 843	0	0.00
Hāpuku	303	125	1 444	0	0.00
Bluenose	175	75	1 032	0	0.00
All	43 646	17 627	155 130	455	0.29

0.15 captures per 100 fishing hours, respectively). Fishing targeting gamefish also had a low seabird capture rate (0.06 captures per 100 fishing hours). No captures were recorded from fishing targeting species that were fished using diving, bottom gear or hand gathering (rock lobster, shellfish and kina), or from fishing targeting either hāpuku or bluenose.

For seabirds, the most frequently caught taxa were petrels and shearwaters (Table 7), with 50.8% of all reported captures in this group. Captures were reported for all the taxa that were included in the form used by interviewers; however, 14.7% of captures were not identified. For all taxa, the highest number of captures was recorded in FMA 1, reflecting the higher interview effort (Table 4). The group with the highest proportion of captures outside of FMA 1 were albatrosses, which had over half of reported captures in other areas.

Birds were most frequently reported as tangled in the line, with no hook contact (Table 8): 58.7% of birds were reported to have been caught in this way; 18.9% of birds were reported as being hooked in the beak or gizzard, and 16.7% were reported as being hooked externally, or foul-hooked. The remaining captures were either caught in a net

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Table 7: Seabird captures, by species group and area, reported by recreational fishers during boat ramp interviews (Hartill et al. 2019). Shown are for each species group the number of captures recorded in each Fisheries Management Area (FMA). (Interviews were carried out in FMA 9, but no captures were reported.)

Taxon	FMA						
	1	2	3	5	7	8	All
Albatross	7		5	1		2	15
Gannet	32						32
Gull	31	1	2	1	1	6	42
Penguin	3						3
Petrel	225	4			2		231
Shag	38	2			2	3	45
Tern	19	1					20
Unidentified	65			1		1	67
All	420	8	7	3	5	12	455

(these two net captures occurred during fishing with a rod and bait), or did not have the capture method recorded. Of the birds that were hooked, the hook was reported as being removed 90.7% of the time.

The captured birds were reported as released alive in 98.4% of the records. Across all of the survey, there were only seven birds that were reported as dead. One bird was a gannet, caught during bait-fishing targeting snapper, that was hooked in the beak or gizzard. The other six records of dead birds were all from a single fishing group, also bait-fishing targeting snapper. The captures were all recorded as unidentified birds that had been tangled in the line.

These records illustrate a potential limitation of the data: all of the six fishers in the group that reported six dead captures had an identical seabird capture record reported for them. Across all the data, there were captures reported from interviews with fishers from 340 groups. Of these groups, 264 reported a single capture, while 76 reported more than one seabird capture (between two and six captures). Of the groups with multiple seabird captures, 46 reported the same number of captures as number of fishers in the group, with each capture being of the same seabird taxon, and with the same reported capture characteristics. Because of the structure of the form (allowing up to one seabird capture to be reported for each fisher), the number of reported captures could not be greater than

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Table 8: Seabird captures reported in boat ramp interviews of recreational fishers, by species group and outcome (Hartill et al. 2019). For each capture, the interviews recorded how the bird was caught (caught in a net, hooked externally, i.e., foul-hooked; hooked in the beak or gizzard; or tangled in the line without being hooked). For birds that were hooked, the interviewer recorded whether the hook was removed. For all captures, the outcome was recorded: whether the bird was dead, or was released alive.

Capture	Hook	Outcome	Albatross	Gannet	Gull	Penguin	Petrel	Shag	Tern	Unidentified	All
Caught in net		Alive	0	0	0	0	1	0	0	1	2
Hooked externally	Not removed	Alive	0	1	1	0	0	0	0	2	4
	Removed	Alive	3	7	4	1	39	7	4	7	72
Hooked in beak or gizzard	Not removed	Alive	1	0	0	0	2	2	0	6	11
	Removed	Alive	2	8	6	0	28	16	1	13	74
	Removed	Dead	0	1	0	0	0	0	0	0	1
Tangled		Alive	9	15	29	2	160	16	14	16	261
		Dead	0	0	0	0	0	0	0	6	6
Unknown			0	0	2	0	1	4	1	16	24
All			15	32	42	3	231	45	20	67	455

the number of fishers in the group.

3.2 National Panel Survey (NPS)

There were 1847 responses to the NPS characterisation survey, and 1203 fishers answered the question relating to seabirds ("During the last fishing year have seabirds disrupted your fishing activity?"), with 295 (24.5%) fishers answering "yes".

There were 52 respondents who reported that a bird took a baited hook and needed to be unhooked at some stage during the fishing year (Table 9). There were also 33 respondents who reported a bird becoming entangled in their lines. Respondents were able to select multiple responses, and some respondents reported both of these interactions. (Note that respondents were not able to report more than one interaction of the same kind.) There were 212 respondents who answered that the types of incidents disrupting their fishing (described in Table 9) occurred "once or twice, occasionally". In comparison, 62 respondents answered that that the incidents occurred "several times", and 20 answered

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Table 9: Responses to the National Panel Survey question, "How did seabirds disrupt your fishing?". Shown are for each response the number of people who selected it; the two unique responses where from people who selected "other (please specify)". Respondents were able to select multiple responses, and so the number of responses is higher than the number of people who answered "yes" to the question "During the last fishing year have seabirds disrupted your fishing activity?".

Response	Number
By chasing and grabbing your baits (but not getting caught)	225
By taking hooked or released fish (but not getting caught)	92
By becoming entangled in your lines	33
By taking a baited hook and needing to be unhooked	52
Attacking fish on my float line while spearfishing	1
Kept trying to take our mussels	1
Total responses	404

Table 10: Responses to the National Panel Survey question, "What types of birds were involved?" (in captures). Shown are for each response the number of people who selected it. Two responses where "other" was selected and the bird group was described as "mollyhawks" were recoded as "large albatrosses". One response where the bird was described as "gannet grabbed a lewer on the surface" was recoded as "gannets".

Response	Number
Gulls	146
Shags	125
Smaller petrels or shearwaters, often darkly-coloured	74
Large albatrosses	32
Don't know the name	17
Terns	5
Gannets	2
Penguins	1

that incidents occurred on "most trips". Respondents were not able to report how often entanglement or hooking occurred, compared with apparently more frequent incidents such as "…chasing and grabbing your baits (but not getting caught)".

3.3 Estimated seabird captures

The national model of seabird captures converged (all Gelman-Rubin $\hat{R}$ diagnostics were less than 1.00, and there were no divergent transitions), and traces of the Monte Carlo Markov Chains (MCMCs) were stable and overlapping (Figure 2). Seabird capture rates were lower in "longline" than in "line" fishing. Relative to FMA 1, mean capture rates

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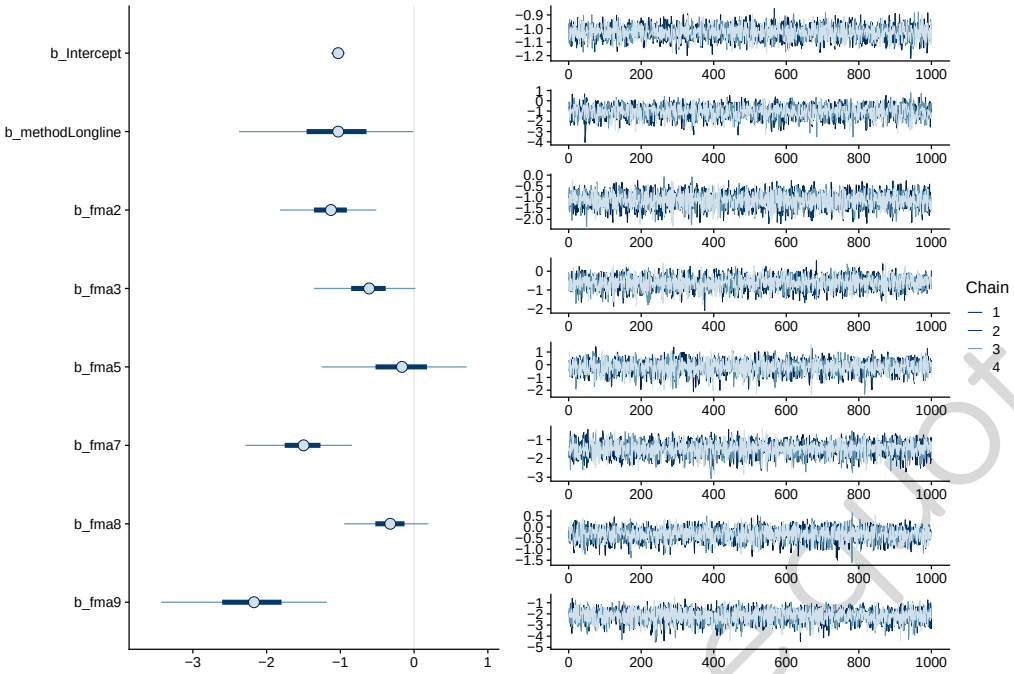

Figure 2: Credible intervals and traces of the parameters of the model of seabird capture rates by Fisheries Management Areas (FMA). The parameters are the model intercept, a method fixed (longline relative to a line effect), and FMA effects relative to FMA 1. The credible intervals shown are the 50% and 95% intervals (thick and thin lines), with the mean indicated by a point. The traces show the traces for each of the four chains, overlaid on one another.

were lower in all other FMAs. The FMAs with capture rates most similar to FMA 1 were FMA 5 and FMA 8.

From the fitted model, the number of seabird captures was estimated by FMA and by method (Table 11). The highest number of trips were in FMA 1 (987 387; coefficient of variation, CV: 0.06), and the mean capture rate was also highest in this area (0.36 birds captures per 100 hours of fishing; CV: 0.05). These estimates used a mean number of hours of fishing per trip that was derived from the boat ramp survey data as 3.79 (CV: 0.008) for line fishing and 2.53 (CV: 0.01) for longline fishing.

The number of estimated seabird captures during 2017–18 was highest in FMA 1, in "line" fishing with a mean of 10 568 captures (95% c.i.: 9 043 to 12 202) (Table 11). This combination was the only FMA-method stratum with a mean estimate of over 1000 captures. The high estimate reflected both the high estimated fishing effort and the high estimated capture rate within FMA 1. The total estimated captures by line fishing,

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Table 11: Estimated captures of seabirds by recreational fishers using boat-based line and longline methods, during 2017–18. The number of trips is from the National Panel Survey from 2017–18, the capture rate (birds caught per 100 hundred hours of fishing) is from statistical modelling of the boat ramp survey data, and the estimated seabird captures are derived by applying the estimated rate to the trip data. Shown are for each parameter the mean and coefficient of variation (CV), for the estimated captures, and also the 2.5% and 95% quantiles of the distribution.

Method	FMA	Trips		Capture rate		Seabird captures			
		Mean	CV	Mean	CV	Mean	CV	2.5%	97.5%
Line	1	779 521	0.06	0.36	0.05	10 568	0.07	9 043	12 202
	2	71 838	0.12	0.12	0.32	327	0.34	149	583
	3	37 993	0.11	0.20	0.34	294	0.36	130	550
	5	21 222	0.15	0.33	0.49	269	0.53	77	631
	7	121 366	0.09	0.08	0.38	381	0.39	151	721
	8	56 164	0.12	0.27	0.28	571	0.31	285	960
	9	92 779	0.12	0.05	0.57	162	0.59	40	396
Longline	1	17 087	0.16	0.14	0.58	62	0.62	13	158
	2	2 829	0.36	0.05	0.69	3	0.97	0	12
	3	1 141	0.79	0.08	0.69	2	1.40	0	10
	5	587	0.71	0.13	0.83	2	1.44	0	9
	7	9 771	0.33	0.03	0.69	8	0.85	0	26
	8	2 911	0.30	0.11	0.67	8	0.83	1	25
	9	151	0.98	0.02	0.88	0	4.21	0	1
Line	All					12 571	0.07	10 944	14 356
Longline	All					86	0.60	18	214
Both	All					12 656	0.07	11 037	14 438

across all FMAs, had a mean of 12 571 (95% c.i.: 10 944 to 14 356) captures. Captures by "longline" fishing were considerably lower, with a total of 86 (95% c.i.: 18 to 214) captures across all FMAs. The total estimated captures, across all the estimated fishing were 12 656 (95% c.i.: 11 037 to 14 438). These estimates are based on capture rates from the boat ramp survey, which were applied to 'Line' and 'Longline' fishing effort from all vessels.

The spatial model of seabird captures within FMA 1 converged (all Gelman-Rubin $\hat{R}$ diagnostics were all equal to 1.00, and there were no divergent transitions). The traces of all chains overlapped (although there was high correlation in the intercept chain) (Figure 3). The CAR parameter was broadly distributed within the zero to one range (this parameter relates to the independence of adjacent zero, with a value of zero indicating independence of adjacent areas). The mean value of "longline" fishing was lower than "line" fishing, but the 95% credible interval overlapped zero.

From this model, seabird capture rates in FMA 1 were estimated, reflecting different

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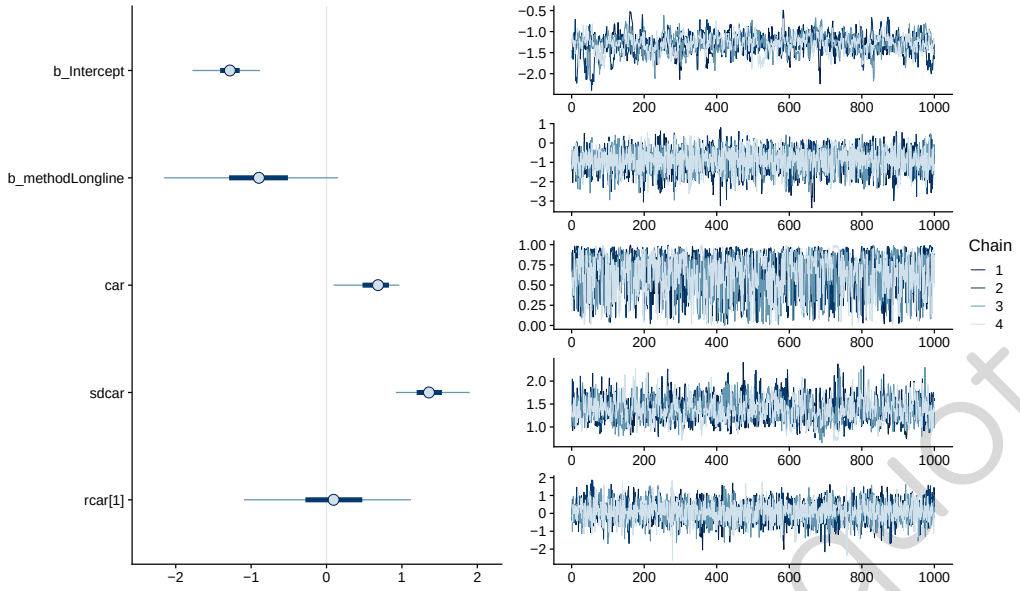

Figure 3: Credible intervals and traces of the model parameters. The parameters are the model intercept, the 'Longline' fixed effect (which is relative to a 'Line' method), the CAR parameter, the standard deviation of the CAR random effects, and an example of one of the CAR random effects (there are 63 of these effects, one for each location with data in Fisheries Management Area 1). The credible intervals shown are the 50% and 95% intervals (thick and thin lines), with the mean indicated by a point. The traces show the traces for each of the four chains, overlaid on one another.

rates throughout this northern region (Figure 4). Consistent with the use of a CAR model, the capture rate was smoothed, relative to the raw data (see Figure 1). There was high uncertainty in areas with low sampling effort and which were only adjacent to a single other area. The smoothing was apparent when compared with the seabird capture rate derived directly from the survey data (Figure 5). The highest values were reduced, although their credible intervals still included the original values (the credible intervals include the one-to-one line, which indicates equality between the observed and estimated rates). There was a high uncertainty associated with fishing locations that had no observed captures and few fishing hours of observation.

3.4 Overlap and the risk assessment methodology

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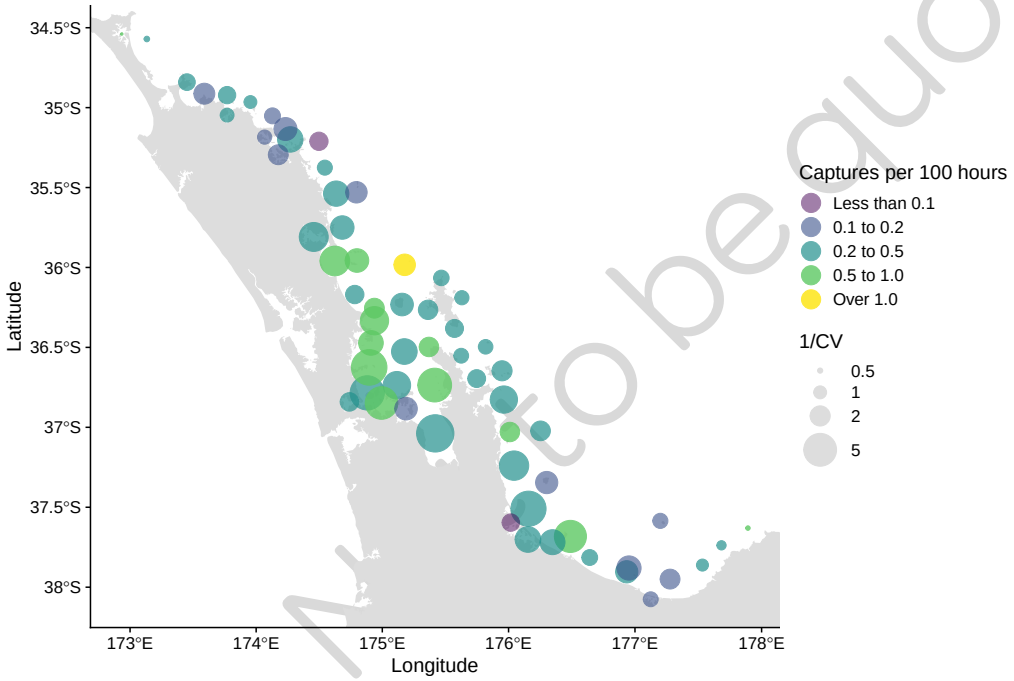

Figure 4: Estimated seabird capture rates in recreational fisheries within Fisheries Management Area 1. The capture rate (number of seabirds per 100 hours of fishing) was estimated for "line" fishing in the fishing locations. The colour indicates the mean of the posterior distribution, and the size of the circle is related to the inverse of the coefficient of variation (CV), with a larger circle having a lower uncertainty.

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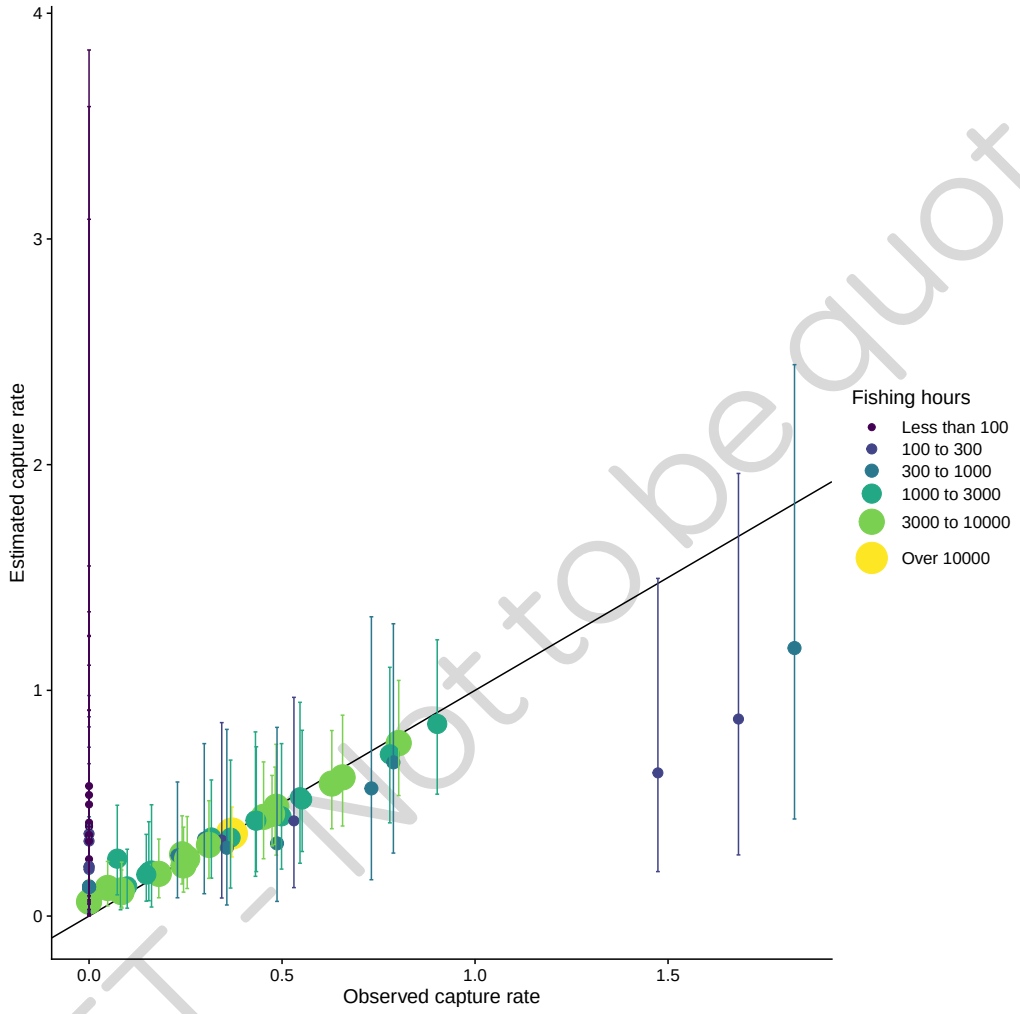

Figure 5: Estimated seabird capture rate (number of seabirds per 100 hours of fishing) in recreational fisheries within Fisheries Management Area 1 (FMA 1), compared with the observed capture rate taken directly from survey responses of fishers. Each circle corresponds to a fishing location within FMA 1, with the colour indicating the number of fishing hours in that area by fishers that were surveyed in the 2017–18 boat ramp survey. On the y-axis, the circle indicates the mean value of the posterior distribution, and the line indicates the 95% credible interval.

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3.5 Review of data collection methods

This review is yet to be completed.

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4. DISCUSSION

Discussion points:

- Development of spatial distributions of recreational fishing effort is required to carry out a risk assessment approach, from both the boat ramp and aerial survey data and from the NPS data. The development of fishing effort distributions will be critical to making progress in understanding the impacts of recreational fishing. Work reported in the Māui and Hector risk assessment showed that it may be possible to use the NPS data for developing effort distributions for fishing methods with limited data (i.e., set net), and this aspect should be investigated further.
- Species-specific estimates of seabird bycatch (such as black petrel or flesh-footed shearwater), could be made by making assumptions about the relative vulnerability of particular species to capture.
- Attendance and interaction data collected in small-scale studies could be used to help clarify, for example, the relative likelihood of larger shearwater species (e.g., flesh-footed, sooty shearwaters) and smaller shearwaters (e.g., Buller's shearwater) of getting caught in recreational fisheries.
- Reporting of seabird captures across all reporting mechanisms (including the prompt question, the prompt and recording of taxon, the recording of how the capture occurred, and of the outcome), should be standardised to ensure that consistent information is collected.
- The seabird capture rates from the boat ramp survey was similar to the previous study, suggesting that the bycatch of seabirds in recreational fisheries is a consistent and ongoing issue.
- The use of the NPS data in this study was limited, because the data extract did not allow linking to the effort data. This limitation could be easily addressed, so that the capture rates from NPS and the boat ramp survey could be compared.

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- The NPS questions should be restructured to allow the collection of information about specific incidents.

- The estimate of total captures derived here was based on scaling across all platforms, but would preferably be applied across effort with similar characteristics as the effort surveyed in the boat ramp surveys (this aspect may be investigated before the final report).

- Within the limitations of the study, the analysis suggests that most captures of seabirds in boat-based fishing are occurring within FMA 1, and the highest capture rates were in Hauraki Gulf. This finding does not preclude bycatch impacts in other parts of New Zealand that may affect specific populations (such as yellow-eyed penguin in Otago, or king shag in Marlborough Sounds).

- The direct response to the boat ramp survey suggest that the mortality rate was low (1.5% of captures were recorded as dead). The dead birds were from only two groups of fishers. This mortality rate does not include any birds that were released alive and that died subsequently. Furthermore, there may be reluctance on the part of fishers to report mortalities to boat ramp interviewers. Understanding the mortality that results from capture in recreational fisheries is a key uncertainty. Following the Rena oil spill in northeastern New Zealand (Bay of Plenty) in 2011, flesh-footed shearwater were recovered that showed signs of having been killed following capture in recreational fisheries (Miskelly et al. 2012). This indicates that seabird capture in recreational fisheries should not be dismissed as harmless.

- Would it be posssible to adopt the health assessment system used for observed captures in commercial fisheries (Bell 2020), to allow people reporting captures to categorise injuries to the birds, and obtain better estimation of post-release survival?

- The estimated captures need to be understood within a risk framework that allows the estimated captures to be combined with assumptions about mortality rate, to determine potential population impacts. This framework can help guide future research.

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- Even without capture rate information, an overlap analysis of species distributions and recreational fishing effort could be used to guide management interventions (such as focusing attention on areas where the provision of educational material to recreational fishers would be beneficial).
- There are only *ad hoc* records or historic research, so that there is no quantitative information on marine mammal, shark, reptile, or other protected species captures (other than seabrds) in recreational fisheries.

The collection of data on protected species captures could be expanded through the use of mobile apps or other crowd-sourced information. Specific discussion points about this aspect:

- The government's digital strategy recommends that government develop open standards and APIs (application programming interfaces). This goal is broadly aligned with the recommendations by Hartill and Thompson (2016) for the government to focus on developing an interface that allows the collection of information on protected species captures to be collected in a consistent way.
- This approach allows for existing applications (such as Fish4All) to contribute data, and supports a range of data collection mechanisms without fragmenting the data.
- Data are most valuable when associated effort (such as hours of fishing) is recorded. For this reason, the recording of protected species captures could be combined with fishing diary applications that are recording fishing trips and effort. If broad-scale data collection is a goal, then working with a provider of a fishing diary application may be the most effective approach to collect the required protected species capture information.
- The consistent recording of zero captures (i.e., fishing trips with no protected species captures) will be a key challenge for the design of any data collection.
- Reporting that does not include zero captures (i.e., incident reporting) is of less value, but may help with determining the relative catch rates of different species.

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The reporting of this information could be combined with the reporting of sighting information (as is reported on platforms like eBird and iNaturalist).

- Accurate identification of species is missing from the data collection to date; for this reason, any application should encourage the taking of photographs. A small amount of information on relative capture rates between species in groups (such as 'petrels and shearwaters') would help with a risk assessment. This information could be provided without needing fishing effort.
- Similarly, a targeted programme that collects a small amount of data from methods other than those represented in the boat ramp survey could help with the development of a risk assessment. Other methods include shore-based kontiki or longline fishing, and also set netting.
- To keep fishers engaged with a reporting platform, it is recommended that the latter provides as incentive for fishers to report information. For example, fishing diary applications could also maintain information about the fishing history. Related platforms, like inaturalist, which allow the recording and identification of species sightings rely on social aspects (visible participation in the platform) to engage users.

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6. REFERENCES

Abraham, E. R. & Berkenbusch, K. (2019). Preparation of data for protected species capture estimation, updated to 2017–18. *New Zealand Aquatic Environment and Biodiversity Report No. 234*. 49 p. Retrieved from https://fs.fish.govt.nz/Page.aspx?pk=113&dk=24767

Abraham, E. R.; Berkenbusch, K. N., & Richard, Y. (2010). The capture of seabirds and marine mammals in New Zealand non-commercial fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 64*. 52 p.

Abraham, E. R.; Neubauer, P.; Berkenbusch, K., & Richard, Y. (2017). Assessment of the risk to New Zealand marine mammals from commercial fisheries. *New Zealand Aquatic Environment and Biodiversity Report No. 189*. 123 p. Retrieved from http://fs.fish.govt.nz/Page.aspx?pk=113&dk=24554

Bell, M. (2020). *Investigate options for assessing the post-release survival of seabirds that interact with commercial fisheries in New Zealand*. Unpublished Technical Report to the Department of Conservation. Retrieved from https://www.doc.govt.nz/globalassets/documents/conservation/marine-and-coastal/marine-conservation-services/reports/draft-reports/int2019-06-post-release-survival-of-seabirds-draft-report.pdf

Birds New Zealand (2020). *Birds New Zealand beach patrol*. Retrieved from https://beach-patrol.dragonfly.co.nz/

Blue Water Marine (2020). Bilfish logbooks. Retrieved from https://bluewatermarine.co.nz/project/billfish-logbooks/

Bürkner, P.-C. (2017). brms: An R package for Bayesian multilevel models using Stan. *Journal of Statistical Software*, *80*, 1–28. doi:10.18637/jss.v080.i01

Bürkner, P.-C. (2018). Advanced Bayesian multilevel modeling with the r package brms. *The R Journal*, *10*(1), 395–411. doi:10.32614/RJ-2018-017

Darby, J. T. & Dawson, S. M. (2000). Bycatch of yellow-eyed penguin (*Megadyptes antipodes*) in gillnets in New Zealand waters 1979–1997. *Biological Conservation*, *93*, 327–332.

DRAFT - Not to be quoted

Dawson, S. M. (1991). Incidental catch of Hector's dolphin in inshore gillnets. *Marine Mammal Science*, *7*, 283–295.

Department of Conservation (2020a). *New Zealand whale and dolphin stranding database, Wellington, New Zealand*. Retrieved from https://www.doc.govt.nz/nature/native-animals/marine-mammals/marine-mammal-sightings/marine-mammal-sighting-form/

Department of Conservation (2020b). *Report sick, injured or dead wildlife*. Retrieved from https://www.doc.govt.nz/nature/native-animals/sick-injured-and-dead-wildlife/

Department of Conservation (2020c). *What to do if you find a banded bird*. Retrieved from https://www.doc.govt.nz/our-work/bird-banding/finding-a-banded-bird/

Department of Conservation (2020d). *You can help sharks/mangō*. Retrieved from https://www.doc.govt.nz/nature/native-animals/marine-fish-and-reptiles/sharks-mango/you-can-help/

Fisher, D. O. & Dick, C. (2007). Database documentation: rec_data. *NIWA Fisheries Data Management Database Documentation Series*. Retrieved from https://www.fisheries.govt.nz/dmsdocument/15583-database-documentation-rec-data

Fisheries New Zealand (2020). Charter fishing vessel operators. Retrieved from https://www.mpi.govt.nz/travel-and-recreation/fishing/charter-fishing-vessel-operators/

Hartill, B.; Bian, R.; Rush, N., & Armiger, H. (2013). Aerial-access recreational harvest estimates fornsnapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2011–12. *New Zealand Fisheries Assessment Report 2013/70*. 44 p.

Hartill, B.; Rush, N.; Armiger, H., & Bian, R. (2019). Aerial-access recreational harvest estimates for snapper, kahawai, red gurnard, tarakihi and trevally in FMA 1 in 2017–18. *New Zealand Fisheries Assessment Report 2019/23*. 39 p.

Hartill, B.; Rush, N.; Bian, R.; Millar, A.; Payne, G., & Armiger, H. (2015). Web camera and creel survey monitoring of recreational fisheries in FMAs 1, 8, and 9. *New Zealand Fisheries Assessment Report 2015/52*. 32 p.

Hartill, B. & Thompson, F. (2016). Review of self-reporting tools for recreational fishers. *New Zealand Fisheries Assessment Report 2016/06*. 35 p. Retrieved from http://fs.fish.govt.nz/Page.aspx?pk=113&dk=23998

DRAFT - Not to be quoted

Hartill, B.; Watson, T.; Cryer, M., & Armiger, H. (2007). Recreational marine harvest estimates of snapper and kahawai in the hauraki gulf in 2003–04. *New Zealand Fisheries Assessment Report 2007/25*. 55 p.

Holdsworth, J. C. & Boyd, R. O. (2008). Size, condition, and estimated release mortality of snapper (*Pagrus auratus*) caught in the SNA 1 recreational fishery, 2006–07. *New Zealand Fisheries Assessment Report 2008/53*. 37 p.

Holdsworth, J. C. & Boyd, R. O. (2017). Striped marlin catch and CPUE in the New Zealand sport fishery 2013–14 to 2015–16. *New Zealand Fisheries Assessment Report 2017/18*. 27 p.

Jin, X.; Carlin, B. P., & Banerjee, S. (2005). Generalized hierarchical multivariate CAR models for areal data. *Biometrics*, *61*(4), 950–961.

Joseph, M. (2016). *Exact sparse CAR models in Stan*. Retrieved from http://mc-stan.org/documentation/case-studies/mbjoseph-CARStan.html

Lalas, C. (1991). *Assessment of bird kills in set nets in otago harbour over a period of eight years (1977–1985)*. Unpublished report held by Department of Conservation, Dunedin.

Ministry for Primary Industries (2019). *Aquatic Environment and Biodiversity Annual Review 2018*. Wellington, New Zealand: Compiled by the Fisheries Science Team, Ministry for Primary Industries. 704 p.

Miskelly, C. M. (2014). Legal protection of new zealand's indigenous terrestrial fauna–an historical review. *Tuhinga*, *25*, 25–101.

Miskelly, C. M. (2016). Legal protection of new zealand's indigenous aquatic fauna–an historical review. *Tuhinga*, 81.

Miskelly, C.; Baylis, S.; Tennyson, A.; Waugh, S.; Bartle, S.; Hunter, S.; Gartrell, B., & Morgan, K. (2012). *Impacts of the Rena oil spill on New Zealand seabirds*. Unpublished poster held by Te Papa, Wellington. Retrieved from http://collections.tepapa.govt.nz/publication/3818

New Zealand Government (1953). Wildlife Act 1953. Parliamentary Counsel Office, New Zealand Legislation. Retrieved from %7Bhttp://www.legislation.govt.nz/act/public/1953/0031/latest/DLM276814.html%7D

DRAFT - Not to be quoted

New Zealand Government (1978). Marine Mammals Protection Act 1953. Parliamentary Counsel Office, New Zealand Legislation. Retrieved from %7Bhttp : / / www . legislation.govt.nz/act/public/1978/0080/latest/DLM25111.html%7D

Richard, Y. & Abraham, E. R. (2020). Assessment of the risk of commercial fisheries to New Zealand seabirds, 2006–07 to 2016–17. *New Zealand Aquatic Environment and Biodiversity Report 237*. 61 p. Retrieved from https : / / www . mpi . govt . nz / dmsdocument/39407/direct

Roberts, J.; Webber, D.; Roe, W.; Edwards, C., & Doonan, I. (2019). Spatial risk assessment of threats to Hector's and Māui dolphins (*Cephalorhynchus hectori)*. *New Zealand Aquatic Environment and Biodiversity Report No. 214*. 168 p.

Sharp, B. R. (2018). Spatially Explicit Fisheries Risk Assessment (SEFRA): A framework for quantifying and managing incidental commercial fisheries impacts on non-target species and habitats. Chapter 3. In *Aquatic Environment and Biodiversity Annual Review 2018*. 38 p. Wellington, New Zealand: Compiled by the Fisheries Management Science Team, Ministry for Primary Industries.

Stan Development Team (2018). RStan: the R interface to Stan. R package version 2.17.3. Retrieved from http://mc-stan.org/

Wynne-Jones, J.; Gray, A.; Heinemann, A.; Hill, L., & Walton, L. (2019). National panel survey of marine recreational fishers 2017–18. *New Zealand Fisheries Assessment Report*, *2019/24*. 104 p.

DRAFT - Not to be quoted