Vol. 551: 249–260, 2016
doi: 10.3354/meps11741

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published June 9

Overlap between flesh-footed shearwater *Puffinus carneipes* foraging areas and commercial fisheries in New Zealand waters

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ABSTRACT: Although the flesh-footed shearwater *Puffinus carneipes* is a species with large population sizes (tens of thousands of breeding pairs) and widespread sub-tropical distribution across Australasian water masses, it is among the species most threatened by longline fisheries mortality in this region. While bycatch mitigation measures have been very successful in reducing mortality in some species, bycatch of flesh-footed shearwaters is still high, with captures estimated to exceed the sustainable take of 514 birds yr^{-1} by nearly 200 birds for New Zealand fisheries alone. Management agencies aiming to reduce the impact of fisheries mortality on the populations need to understand which marine areas are being used by flesh-footed shearwaters to better target fishery monitoring and mitigation efforts. Foraging studies of seabirds tell us about their use of resources, i.e. the way species segregate the available habitat and help to identify threats that may affect population viability. Breeding shearwaters were tracked from 2 New Zealand colonies using GPS loggers. Individuals foraged over shelf and deep oceanic waters up to 1200 km from their nesting sites during incubation but were mainly within 370 km during early chick rearing. The intensity of potential interactions increased for trawl and surface longline fishing between the January and February study periods but remained at a similar level for bottom longline fishing. Following the field data collection, changes to fishery monitoring were implemented in the areas where shearwaters foraged.

KEY WORDS: Fisheries interactions · Oceanic · Foraging · Bycatch · Seabird

INTRODUCTION

Fishing mortality is identified globally as a major threat to the conservation of procellariform seabirds, a group which includes all shearwaters, petrels and albatrosses (Croxall et al. 2012). Although shearwaters are very numerous and widespread (Brooke 2004), their ecology is poorly studied, partly due to their small size (150–950 g, Schreiber & Burger 2002), making remote-tracking studies difficult. Species with large populations tend to have a lower conservation threat status than other seabirds and are therefore a lower priority for research and management than threatened species. Shearwaters,

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like many other seabirds, benefit from fishing activity by using fisheries waste for food (Furness et al. 1988, Thompson & Riddy 1995, Garthe et al. 1996, Sullivan et al. 2006a, Thalmann et al. 2010), but they also suffer mortality through accidental capture in fishing gear (Bartle 1991, Gales et al. 1998, Scott et al. 2008, Anderson et al. 2011). The long-lived and low-productivity demographic characteristics of procellariform seabirds result in a particular vulnerability — their populations have a low intrinsic growth rate and are especially sensitive to increases in adult mortality (Stearns 1992, Hunter et al. 2000). The death of one adult will result in the death of any nestling or egg, causing further impact on a species' productivity.

From either fishery- or seabird colony-based research perspectives, assessing the impacts of fishing mortality can be difficult (Barbraud et al. 2008, 2012, Lavers et al. 2013). When seabird bycatch is observed on vessels, it is difficult to assign provenance of captured birds to population or species level; birds caught may be from varying age groups or breeding states, resulting in differential population impacts. Recent research has demonstrated how, using the mineral and stable isotope signatures in feathers, birds recovered from fisheries could be assigned to different ocean basins, regions or colonies (Lavers et al. 2013). Furthermore, it is costly to carry out on-board observation for non-target catch and to collate data across vessels and fleets. Recent New Zealand fishery monitoring has been undertaken at a cost of US\$375 to US\$410 d^{-1} (DOC 2013, 2014). Fishery management agencies aiming to gather statistically robust samples of bycatch occurrence require between 5 and 100% of fishing effort to be observed (DOC 2014, IATTC 2016).

Similarly, assessing the causes of population changes for seabirds observed at breeding colonies is complex. It requires long-term and detailed datasets for long-lived species, and relationships between population change and environmental and anthropogenic factors are difficult to untangle, as a combination of these factors is often operating (Blaber et al. 1998, Tasker et al. 2000, Baker et al. 2007, Rolland et al. 2009, Barbraud et al. 2012, Lavers 2015). To overcome these issues, modeling of populations and the likelihood of capture of species during encounters with fishing operations has been carried out for many seabird species (e.g. Moloney et al. 1994, Inchausti & Weimerskirch 2002, Lewison & Crowder 2003, Lewison et al. 2004, Francis & Bell 2010, Tuck et al. 2011, Richard & Abraham 2013, 2015). The causes of population changes in relation to fisheries mortality are a key focus for such studies, and their outputs can also be used to understand where to best target mitigation actions in fisheries. A key piece of information to inform these approaches is the foraging distribution of the bird species, as these can be highly variable with strong segregation of zones used between species or colonies within a same species (Ainley et al. 2004, Wakefield et al. 2013).

Seabird bycatch in New Zealand waters has been researched and managed for over 25 yr (Bartle 1991, Murray et al. 1993, MFish & DOC 2004, Waugh et al. 2008, Dillingham & Fletcher 2011, Abraham & Thompson 2011a,b, MPI 2013). In recent years, bycatch numbers have been reduced due to efforts by fishers and by fishery managers in both industry and government (MPI 2013). These efforts include the use of mitigation such as night setting, tori lines, offal reduction and more targeted mitigation efforts in areas or at times of high bycatch risk, facilitated by increased monitoring and reporting (DOC 2012, 2013, 2014, MPI 2013). Recent estimates of bycatch for the main commercial trawl and longline fisheries were ca. 3500 birds annually between 2004–2005 and 2008–2009, a reduction of approximately 50% compared to the previous 5 yr period (Abraham & Thompson 2011a,b). For some species, however, bycatch numbers have remained high, and the flesh-footed shearwater *Puffinus carneipes* is a species for which bycatch reductions have proved difficult to achieve (Baker & Wise 2005, Abraham & Thompson 2011a, Lavers 2015).

The flesh-footed shearwater breeds at over 60 sites in Australia and New Zealand, with one relatively little-studied population at the Île de Saint Paul in the Indian Ocean. A world population of ca. 740 000 pairs was estimated by Lavers (2015) following recent Australian surveys. Around 10 000 to 15 000 pairs nest annually in New Zealand (Waugh et al. 2013). With this Australasian population focus and the difficulty in mitigating bycatch for this species, the focus of information about the species tends to be regional, relying on many government research projects for reporting.

The species has been subject to ecological research efforts in recent years only, despite being one of the more numerous species in the Australasian region and among the most commonly caught species in New Zealand and Australian longline fisheries (Baker & Wise 2005, Abraham & Thompson 2011a, Lavers 2015, Richard & Abraham 2015) and the Australian purse-seine fishery (Dunlop 2007). It is recognized as the fourth most likely species to suffer adverse effects of fishing mortality in New Zealand commercial fisheries (Richard & Abraham 2015). Population decreases reported in the literature at the largest known colony at Lord Howe Island, Australia (ca. 15 000–29 000 pairs), have been linked to bycatch in longline fisheries (Priddel et al. 2006, Reid et al. 2013), with ongoing research assessing the current trend for the population (N. Carlile pers. comm.). Several populations across southern and southwestern Australia are also declining (Lavers 2015). These authors identified the probable causes of population change as fisheries mortality, climate effects, introduced species impacts and contamination. In New Zealand, one large northern colony at Lady Alice Island is likely to be declining, based on count data and demographic modelling, while others are stable or increasing slightly (Barbraud et al. 2012, Jamieson & Waugh 2015). For the New Zealand population, analysis of the incidental catch of this species across a broad group of commercial fisheries has created concern for the sustainability of the populations (MPI 2013). The numbers of birds estimated to potentially incur fatalities (696, 95% CI = 478–995, Richard & Abraham 2015) exceeded the level that is considered sustainable for the population (514, 95% CI = 233–1140, Richard & Abraham 2015), estimated using a potential biological removals approach (Wade 1998, Dillingham & Fletcher 2011). As applied in these analyses, this method assumes that all populations within a species were harvested evenly by the fishery catch. Mortality from recreational fisheries in New Zealand and Australia has been recorded, but the magnitude of this catch is unknown (Abraham et al. 2010, Lavers 2015). Bycatch of New Zealand birds in commercial fisheries in Australia and the North Pacific is also known to occur (Lavers et al. 2013).

Managers of protected species and fishery resources are interested in refining their understanding of the foraging areas used by flesh-footed shearwaters from important New Zealand populations. This information would allow a programme of fishery observation and mitigation actions to be implemented that target the areas where there would be most benefit in reducing pressure on the populations of New Zealand flesh-footed shearwaters. In this study, the at-sea movements of breeding flesh-footed shearwaters were documented from 2 New Zealand colonies to examine their foraging distribution and overlap with fisheries. The optimal areas and seasons to monitor and manage fisheries interactions were recommended, and subsequent uptake by management agencies monitoring plans is discussed.

MATERIALS AND METHODS

Study sites and data collection

Flesh-footed shearwaters nest at ca. 20 localities around northern and central New Zealand (Waugh et al. 2013). This study was conducted at 2 of the breeding sites with larger populations: Titi Island (40.95° S, 174.14° E), which is important as the largest of the breeding sites in the Cook Strait area for the species, and Ohinau Island (36.72° S, 175.88° E), which represents the large breeding populations of the Bay of Plenty (approximately 50% of the New Zealand population) (Fig. 1). The sizes of each island population in the study were ca. 160 pairs at Titi Island and ca. 2100 pairs at Ohinau Island in 2012 and 2014, respectively (Jamieson & Waugh 2015). Breeding individuals were captured in their burrows and equipped with IgotU GPS loggers (Mobile Action Technology) in January 2013 at Titi Island (20 loggers) and in January and February 2014 at Ohinau Island (57 loggers). The loggers were removed from their plastic housing, programmed to record location data at 15 min intervals and sealed in heat-shrink tubes before they were attached with waterproof adhesive tape on the back feathers of the birds. The total mass of the attachment was 22 to 25 g, or less than 3% of the

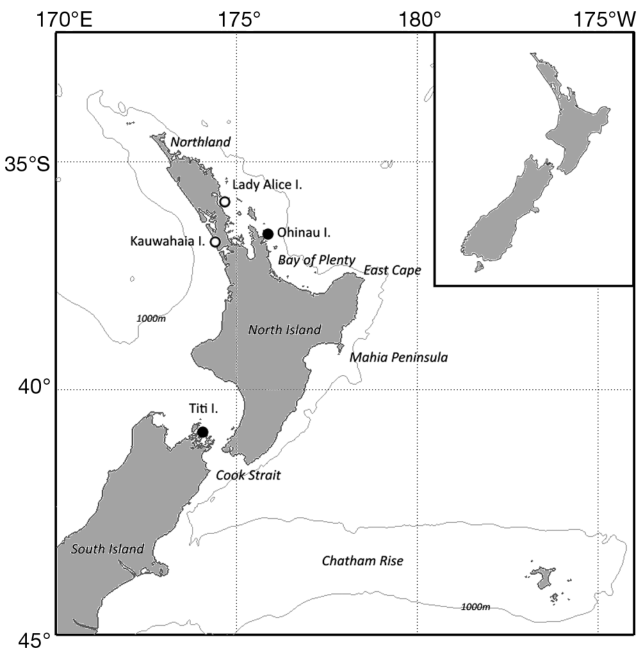

Fig. 1. Shearwater breeding sites around New Zealand discussed in this study (filled circles for sites where tracking studies were conducted; open circles for sites not tracked in this study) and locations of significant marine areas for flesh-footed shearwaters in this study

bird's body mass, thus minimizing the risk of affecting the bird's behavior (Phillips et al. 2003).

Median hatching date was 3 February at Ohinau Island in 2014 (n = 20, range 27 January to 18 February). Hatching of chicks at Titi Island was more sporadically checked, with 4 daily inspections of nests with logger-equipped birds only. On 29 January 2013, 50% of eggs were confirmed hatched (n = 4 nests with confirmed contents); by 2 February, 80% were hatched, and 20% were unhatched (n = 5).

Trip duration, distance travelled and maximum range are expressed as means (SE; sample size). To assess overlap with fisheries by period, we used month of the year rather than breeding stage, as calendar date is more likely to be used in fishery monitoring and management contexts.

Assessing fisheries overlap

Fine-resolution GPS tracking data were used to quantify the distribution range and habitat use of the shearwaters during mid to late incubation in January and early chick rearing in February.

To investigate the potential for overlap with commercial fisheries during the shearwater's breeding season, catch per unit effort data from fisheries for the 5 yr period 2009–2010 to 2013–2014 (December to May) were extracted from Ministry for Primary Industries (New Zealand) databases. This 5 yr dataset enabled a robust representation of vessel usage of the areas in question, whereas data from a single year could be subject to short-term changes in effort. In 2014, data were available to March only. Data for bottom longline, surface longline and trawl (combining midwater, bottom and paired trawls) fishing events were used. Date and start latitude and longitude were used to plot the location of events. Latitude and longitude were analyzed at a resolution of 0.1 decimal degree. Density plots were generated using the sum of fishing effort (using a grid of 0.1 decimal degrees) for each month and fishing method.

Fisheries overlap maps were produced using a combination of ecological data from bird tracking and fishing effort data for the relevant periods and areas. Effort data were analysed for January and February corresponding to mid- to late-incubation and early chick-rearing parts of the shearwater breeding cycle. Bottom and surface longline effort densities were expressed as hooks d^{-1}, and trawl effort was expressed as h d^{-1}. Spatial overlap maps were generated by multiplying the monthly fishing effort maps with the corresponding spatially normalized seabird density maps produced by kernelling at a resolution of 0.1° × 0.1°. Spatial normalization was performed on the whole range of the species including its range outside the New Zealand Exclusive Economic Zone (NZEEZ). This created a density distribution for the range of the species during its breeding period that summed to 1. This matrix was created for each month of the study. This was then clipped to the area within the NZEEZ, as fishing data were available from within the NZEEZ only. Fishery overlap indices were obtained by summing the overlap map for each month and each fishing method. Data were plotted on graphics with a square-root transformation to enable high-intensity overlap areas to be more readily identifiable. These methodologies were developed and implemented for multiple species risk comparisons in ecological risk assessments for New Zealand and South Pacific fisheries (Waugh et al. 2011, 2012) and differ from these examples in that the overlap metrics in this study were applied to a single bird species, and the levels of overlap between different periods for the same fishery compared, for several fisheries. Previous studies compared several species' overlap for 1 fishery only. Seabirds are known to interact with fishing vessels with variation in the intensity and outcome of interactions varying significantly between fleets, depending on factors such as the vessel discard regime, target fish species, fishing gear type, mitigation methods used and timing of fishing in the day (Ryan & Watkins 2002, Sullivan et al. 2006b, Pierre et al. 2012). Within-fleet characteristics are most comparable, while those between fleets and fishing methods are less comparable. For this reason, comparing overlap scores between fishing methods was not considered appropriate.

RESULTS

GPS data were retrieved from 4 and 54 individuals from Titi Island and Ohinau Island, respectively. Data for each site were analysed separately to generate density distributions for the species by site but were combined when overlap with fishery was analysed (Fig. 2A,B). The size of each population was taken into account when generating the overall shearwater density matrix for the overlap map, with the contribution of each tracking dataset weighted by the size of the corresponding population.

During the first GPS deployment on this species in New Zealand at Titi island in 2013, many equipped birds or their partners undertook trips in excess of 10 d, which was longer than the planned period of

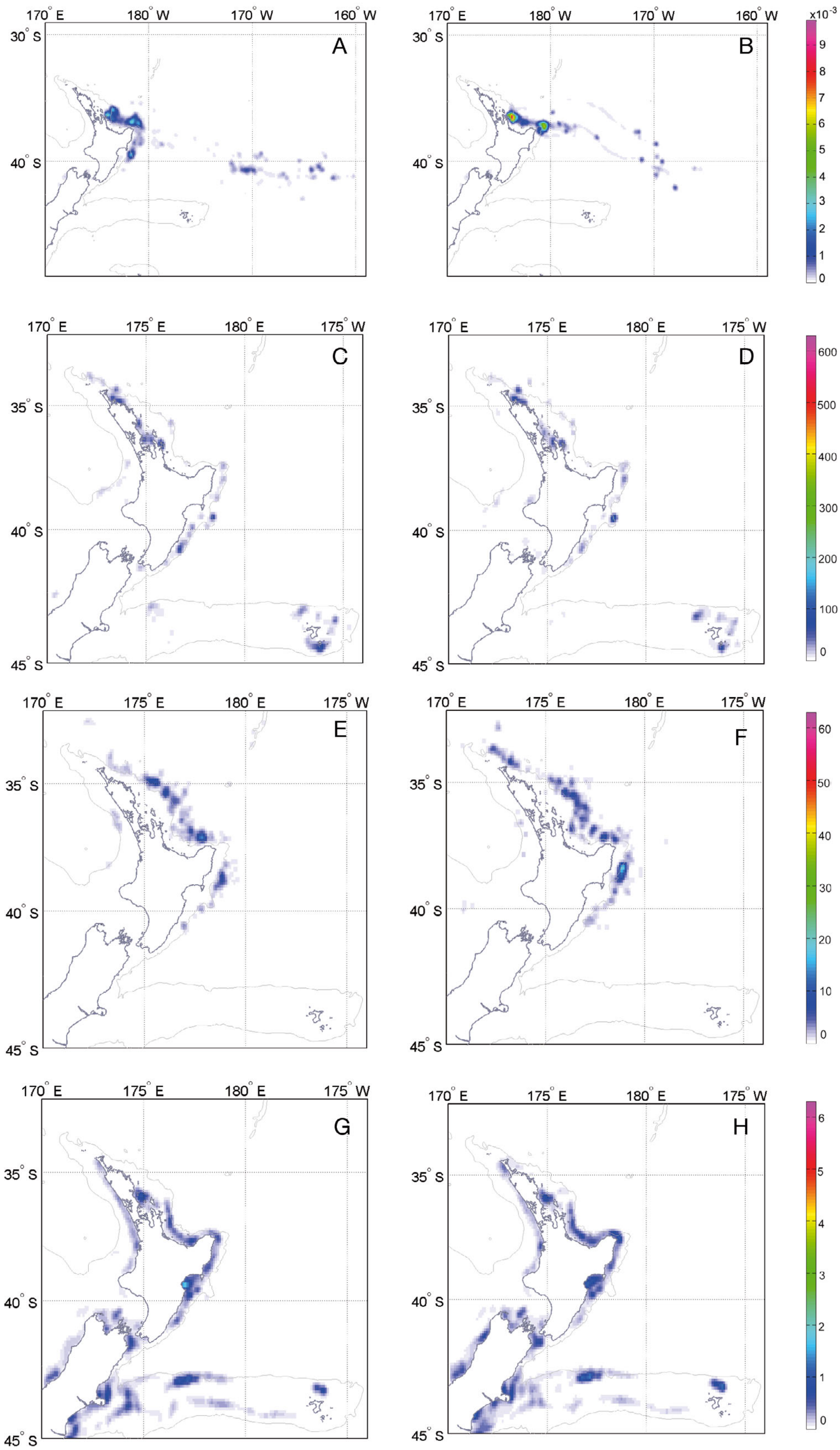

Fig. 2. (A) GPS tracking distribution for flesh-footed shearwaters in the incubation period and (B) chick-rearing period. Normalised fishery distribution effort plots for (C,D) bottom longline for the corresponding months (C) January and (D) February; and the same months for (E,F) surface longline; and (G,H) trawl. Scale bar (A,B): density of birds; (C–H): fishing effort per 0.1 degree of longitude and latitude. Note that the scale bar for each row of plots differs

study, leading to incomplete information for this site. Few devices were retrieved, and those that were not would be retained by the bird until the post-breeding molting period (4 mo) at a maximum or for a shorter period (e.g. 1 mo) as the adhesive tape lost its waterproofness and fell off the bird. For 6 birds from Titi Island, devices were retrieved after the bird had incubated for >9 d, and no data were recovered.

During incubation and early chick-rearing periods (Fig. 3), GPS tracking showed that birds from Ohinau

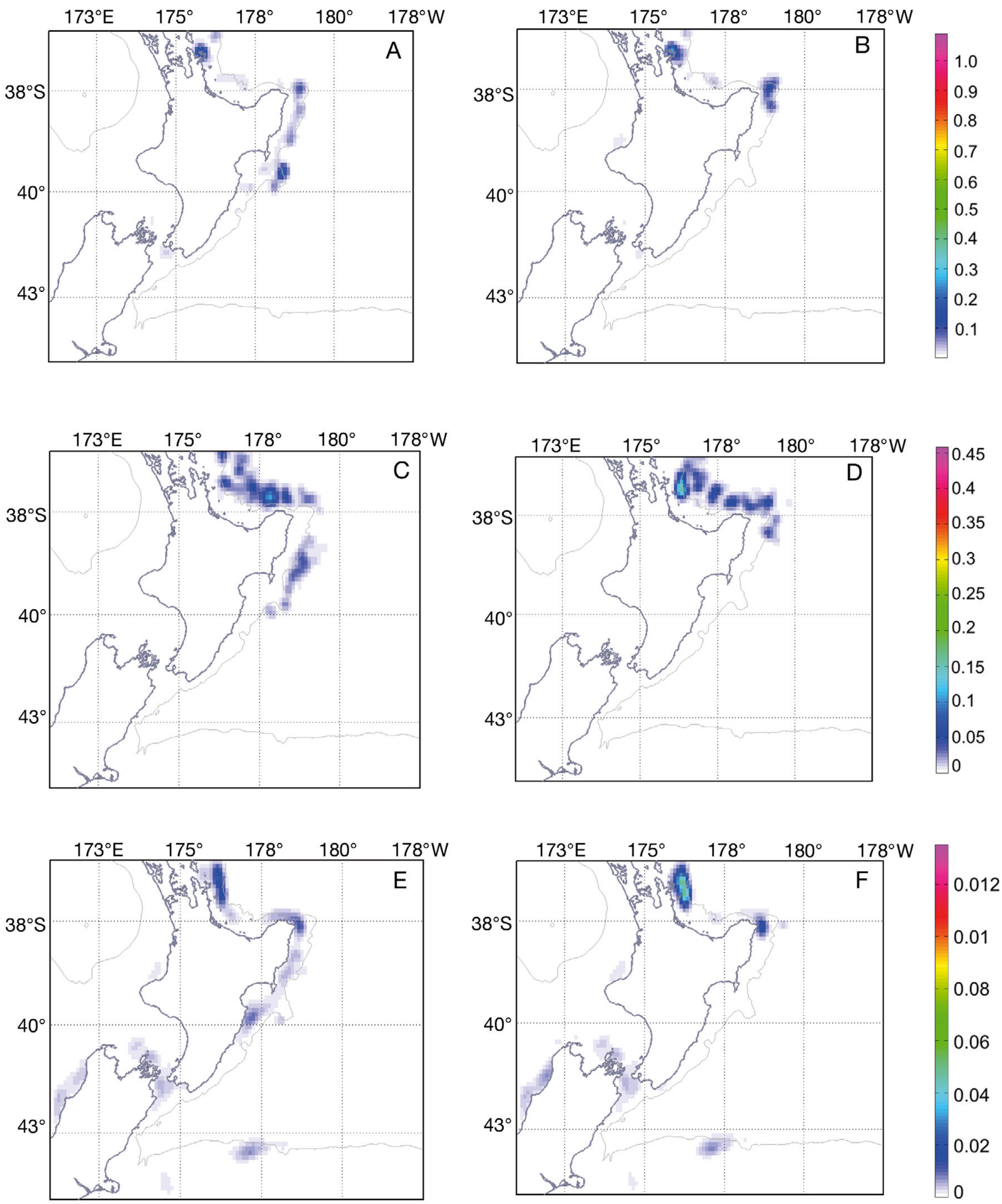

Fig. 3. Normalised intensity of overlap between shearwater and fisheries activity for (A,C,E) January incubation period and (B,D,F) February early chick-rearing period. (A,B) Bottom longline fishing; (C,D) surface longline fishing; (E,F) trawl fishing. Note that the scale bar for each row of plots differs

Island spent large amounts of time along the North Island coastline to the east of the breeding site, with regular trips to the region to the east of New Zealand over deep water. Trips averaged 3.6 d in duration (0.52; 56), with birds travelling 1223 km (202.92; 56) and with a maximum range from the breeding sites of 368.70 km (74; 56). Birds from Titi Island (average trip duration 10.9 d [1.6; 3], note that data for 1 trip were incomplete) remained mainly in the waters of Cook Strait and immediately to the east and west during incubation, with some longer trips out towards the deeper waters to the north of the Chatham Rise.

The intensity of overlap of bird activity in different parts of the breeding cycle and fishing effort was calculated. The overlap metric relates to the degree of overlap between bird distribution and fishing activity and is a relative index of overlap within a fishing method. The overlap index decreased between January and February by 0.08% (from 1.68 to 1.55) for bottom longline fishing. For surface longline fishing, it increased by 25% between the 2 months (January metric was 0.89, and February metric was 1.13). For trawl fishing, the increase between months was 92% (from 0.40 to 0.77).

Spatial overlap of each fishing method during different periods of the breeding season varied in relation to the concentration of fishing effort by season and area. The areas in which overlap was most intensive between flesh-footed shearwaters and all fisheries considered were (1) immediately to the east of Ohinau Island and the nearby continental shelf break (approximated by the 1000 m depth contour), (2) from Ohinau Island to East Cape, and (3) around the shelf break to the south of Mahia Peninsula (Fig. 3).

For bottom longline fisheries, areas of highest overlap were near to Ohinau Island, off East Cape and Mahia Peninsula (Fig. 3). The zone of overlap extended in both periods between Ohinau Island and the western end of the Chatham Rise. Most overlap for bottom longline fishing was at or near the continental shelf break (in waters of ca. 200–1000 m depth).

For surface longline fisheries, overlap was most intense offshore from the shelf break and over deep waters across the Bay of Plenty from Ohinau Island to East Cape, with some areas of stronger interactions occurring from East Cape to Mahia Peninsula when birds were doing longer foraging trips in the incubation and late chick-rearing periods (Fig. 3). This fishery operates further offshore than the other fisheries examined, so there was little overlap over the shelf waters. The main area of overlap extends from the shelf slope and continues seaward from there. In January, areas of more intense overlap are evident near East Cape, where deep water is close to shore. In February, some intensity of overlap is apparent in the East Cape region, but it is especially intense near Ohinau Island where deep water is closest to shore.

For trawl fisheries, the zone of overlap with flesh-footed shearwaters was over a large area, covering most continental shelf areas within the bird's range described by the GPS tracking dataset. Overlap was more intense in February than January and was particularly strong along the shelf break near Ohinau Island and East Cape.

DISCUSSION

Our study describes the foraging characteristics of flesh-footed shearwaters from 2 important breeding populations in New Zealand, albeit with a small sample size from 1 site. It investigates the use of combined fishing and bird tracking data to identify which areas and times were most important for managing interactions between trawl and 2 longline fishing methods and the shearwaters from these colonies during the 2 mo study period. The 2 study populations showed a diversity of foraging movements. The shearwaters were using both shelf and pelagic waters, with an average maximum distance of 370 km from their nests and an average travel distance of 1200 km per trip. Such foraging distances are not unusual for shearwaters during breeding, when they often adopt dual feeding strategies to exploit distant resources to maintain adult body condition and feed on nearby resources to provision their chicks (Weimerskirch 1998, Granadeiro et al. 1998, Magalhães et al. 2008). There was some indication that a mix of strategies was being employed by flesh-footed shearwaters in this study, as individuals were foraging at both short and long distances.

The areas used most intensively by birds from Ohinau Island were the shelf waters around the breeding site and between that area and the easternmost point of the New Zealand mainland (East Cape). A third hotspot of activity occurred near Mahia Peninsula on the lower east coast of the North Island of New Zealand. Throughout their range, flesh-footed shearwaters appear to be in waters at or to the north of the sub-tropical convergence zone (Heath 1985, Rayner et al. 2011, this study). The shearwaters also used waters far to the east of the NZEEZ. When doing so, they were far from sub-marine features such as seamounts. There is no convergence zone in the area in which they predominantly fed, but strong current systems have been identified running up and down the eastern side of the lower North Island (Stanton 1973, Heath 1985). Such mixing zones can be productive areas for both foraging seabirds and fisheries (Russell et al. 1992, Hyrenbach et al. 2006). Detailed data on the fisheries in these high seas areas were not available, but global catch summaries published by the FAO (FAO 2016) show the area in the NZEEZ used by birds from this study, and the high seas area immediately adjacent, to the east, yielded light to moderate catches of tunas and bill fish (between 10 and 4000 tonnes cumulatively over the 5 yr period 2010–2015 per 5° latitude by 5° longitude square; FAO 2016).

There is some indication of segregation of foraging areas between the colonies studied, with those from Titi Island and Ohinau Island (this study), Kauwahaia Island (Rayner et al. 2011) and Lord Howe Island (Thalmann et al. 2009, Reid 2011) all using discreet foraging areas. Segregation of marine areas between colonies is reported among several families of seabirds (e.g. Wanless & Harris 1993, Stahl & Sagar 2000a,b, Ainley et al. 2004, Wakefield et al. 2011, 2013). This finding has implications for managing interactions between fisheries and the shearwater populations, as the impacts of fisheries mortality in one area will not be spread evenly across the whole New Zealand breeding population of the species but may be more intensive for some populations than others.

Overlap with fisheries

The analysis of overlap between 3 major fisheries and the flesh-footed shearwater showed that each fishery had specific areas of most intense interaction, based on the Ohinau and Titi islands tracking datasets. All methods of fishing examined had the potential to overlap with shearwater foraging zones during the 2 periods examined. Because of the relatively light weighting of the Titi Island birds in the analysis, due to the smaller population size at this site, the overlap of intensive fisheries from the Cook Strait area with the shearwaters is slight, except for trawl fisheries, which were particularly active in this area.

Overlap increased between January and February for surface longline and trawl fishing by 25 and 92%, respectively. For bottom longline, overlap decreased by 8% over the same period. During February, birds from Ohinau Island were more concentrated in their foraging activity very near to the breeding site and curtailed their use of areas at the southern edge of their range during incubation. Similarly, the flesh-footed shearwaters from Lord Howe Island were found to overlap most with fishing vessels in the early chick-rearing period but also showed strong overlap in the pre-breeding and early incubation period (Thalmann et al. 2009, Reid et al. 2012). In the south coast region of Australia, the number of entanglements of flesh-footed shearwaters was correlated with their abundance in King George Sound and peaked in the early February period (Dunlop 2007) and in April in later years (Dunlop 2011). The estimated mortality in this fishery decreased between 2006–2007 and 2010–2011 from 300 to 103 individuals (Dunlop 2011). The results from the New Zealand study are similar to those from Australian reports in that the chick-rearing period and areas close to breeding sites are both subject to more intense overlap and interaction with fisheries.

For the New Zealand study, spatially, these areas of strong overlap in early chick rearing were in the same general area for all fishing methods — to the east of Ohinau Island and around the edge of the continental shelf. For surface longline fishing, however, the zone of most intense overlap was slightly further offshore than for other fishing methods. The increased intensity of overlap in February for the Ohinau Island population is likely to be mirrored at other breeding sites. Large colonies of the species occur on islands in the Bay of Plenty and Northland areas, highlighting the need for a greater focus for bycatch monitoring and mitigation in areas within 350 km of the 8 major breeding colonies for the species (see Waugh et al. 2013).

Between-fishery differences could not be assessed in these analyses, as different overlap metrics exist for each fishery method. In effect, this analysis enables fishery and wildlife managers to examine the timing and location of overlap within a fishery, but as different fisheries attract birds (and potentially catch them) differentially, the metrics developed do not allow an indication of between-fishery performance. However, in a cross-fishery analysis of bycatch risk, Richard & Abraham (2013, 2015) concluded that on an annual basis, flesh-footed shearwaters were likely to be caught in greatest numbers in trawl, bottom and surface longline fisheries, in descending order of likelihood. Dunlop (2007, 2011) reported shearwater entanglements and mortality of 6 to 20% of individuals caught in purse-seine fisheries in the south coast region of Australia. The impacts of purse-seine fisheries on New Zealand shearwaters have not been assessed.

A range of factors, including mortality in non-commercial fishing (Abraham et al. 2010), introduced predators (Taylor 2000, Waugh et al. 2013) and pollution (Buxton et al. 2013), may be influencing the flesh-footed shearwater populations in the New Zealand region. A similar range of threats exist for Australian populations (Lavers 2015). The areas to the north and east of the North Island of New Zealand (e.g. Hauraki Gulf and Bay of Plenty) are subject to intense fishing effort by recreational fishers, charter fishers and subsistence fishers, in addition to the commercial fisheries examined in this study. Examination of the 15 flesh-footed shearwaters found dead after collection of over 1000 birds from Bay of Plenty beaches in November 2011 showed that all had suffered injuries likely to have been caused by human interaction. Injuries resulting from fish hooks (recreational type) or puncture or crush wounds were identified by veterinary pathologists and seabird researchers (Tennyson et al. 2012, S. Hunter & B. Gartrell unpubl. data). Similar events have been reported for Australian recreational fisheries with flesh-footed shearwaters killed accidentally or intentionally (Lavers 2015).

Fishery management response

Following the tracking study reported here, the amount of observer effort was increased in the New Zealand fisheries which had strongest potential to interact with the shearwaters. The background level of observer effort in the bottom longline fishery along the eastern coast of the North Island was 150 d yr^{-1} in 2012–2013, which was increased to 600 d in 2013–2014 (DOC 2012, 2013). The areas exploited by the shearwaters in this study and another at-risk Procellariform seabird, the black petrel *Procellaria parkinsoni* (Abraham et al. 2015), were used to refine the focus for the observing in 2014–2015, and the rate of observer cover increased from 10 to 50 % of fishing effort in 2 fisheries that had strong overlap with the flesh-footed shearwater: bottom longline fishing targeting bluenose (205 d) and inshore trawl fishing for various target fish species (600 d) (DOC 2014). New work on the foraging distribution of flesh-footed shearwaters is being commissioned by the Department of Conservation (DOC 2015) to cover additional shearwater colonies and times of year than those reported here.

The information from this tracking study highlighted the exposure of shearwaters to commercial fishing effort, which was particularly intense during the early chick-rearing period compared to the incubation period, for several fishing methods examined. The results highlight the potential areas for mortalities to occur which could threaten the viability of major shearwater populations in the New Zealand area. These results were taken into account in designing observer monitoring programmes to assess whether these interactions are translated into mortalities. Such mortality may be the cause of the estimated decline in breeding numbers at Lady Alice Island (Barbraud et al. 2014, Jamieson & Waugh 2015), a site which will be subject to future shearwater studies (DOC 2015). Mortality of flesh-footed shearwaters from this site is known to occur in Australian fisheries, based on biochemical analyses of specimens recovered from this fishery (Lavers et al. 2013). Fishery observation within 350 km of the centres of populations of the flesh-footed shearwater in the Bay of Plenty and Northland areas is needed to assess whether the catch of shearwaters and other seabirds is unsustainable. Concentrating on the shelf areas and shelf-slope and reinforcing monitoring during February and March, when birds are feeding small chicks nearby their breeding colonies, would allow better quantification of the captures from these populations.

The results generated here are useful for targeting monitoring and eventual bycatch mitigation efforts, and these have been taken up by the agencies monitoring New Zealand fisheries. The research shows, however, that specific areas and times of year can be targeted to better monitor species and fishery interactions. Using foraging and fishery information together to develop more targeted management approaches will enable the costs of these activities to be moderated.

Acknowledgements. We thank the Department of Conservation, who funded this project under CSP programme POP2011-02, along with the Museum of New Zealand, Te Papa Tongarewa. We are grateful to the private owners of the field site, Ohinau Island, Ngati Hei, and particularly Joe Davis for permission to conduct the study. We thank the kaitiaki of Titi Island, Ngati Kuia, for their consent to conduct field studies at that site. Thanks to the many Te Papa and Department of Conservation staff and volunteers who assisted with the programme, particularly Alison Burnett, Simon Hayward, Colin Miskelly, Sarah Jamieson, Robyn Blyth and Jean-Claude Stahl. We thank 4 anonymous reviewers and Igor Debski, whose comments allowed us to improve the manuscript.

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Editorial responsibility: Rory Wilson, Swansea, UK

Submitted: August 24, 2015; Accepted: April 22, 2016
Proofs received from author(s): May 31, 2016