At-sea distribution of the black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island), 2009/10: Part 2 – Overlap with fisheries.

Elizabeth A. Bell[1], Joanna L. Sim[2], Edward Abraham[3], Leigh Torres[4] and Scott Schaffer[5]

[1] Wildlife Management International Limited, PO Box 607, Blenheim 7240, New Zealand, Email:biz@wmil.co.nz

[2] DabChickNZ, Levin, New Zealand

[3] Dragonfly Science, Wellington, New Zealand

[4] NIWA, Greta Point, Wellington, New Zealand

[5] San Jose State University, California, USA

Abstract

This report is part of an ongoing long-term study of the black petrel, *Procellaria parkinsoni,* on Great Barrier Island (Aotea Island) that was begun in the 1995/96 breeding season, and aims to describe foraging information and spatial overlap with fisheries. Since the 2005/06 season, 92 Lotek™ geo-locator data-loggers have been deployed on breeding black petrels; of these, 86 were retrieved for analysis. These indicated that the foraging range for the black petrels was highly variable and inconsistent between breeding phase and sex. During the breeding season, birds foraged around the northern New Zealand, particularly along the continental shelf edges or seamounts, travelling near the Chatham Rise, further north into the Pacific (towards Fiji) and to the eastern Australian coast. Fishing effort for trawl, bottom longline and surface longline fisheries in New Zealand fisheries waters was used to define the overlap with the black petrel foraging range. The overlap between black petrel distributions and observed effort was highest for snapper bottom longline, bigeye tuna surface longline, and scampi trawl fisheries. In all three methods, the fishery with the highest overlap between black petrel distributions and observed effort had the highest number of observed captures. Continued bycatch of breeding adults in New Zealand and overseas fisheries has the potential to seriously affect the species.

Keywords: black petrel, *Procellaria parkinsoni*, geo-locator, data-logger, foraging, fisheries, overlap, Great Barrier Island (Aotea Island), New Zealand

1. Introduction

The black petrel, *Procellaria parkinsoni*, is a medium-sized endemic seabird which is only known to breed on Hauturu/Little Barrier Island (36°199'S 175°082'E) and Great Barrier Island (Aotea Island)

(36°187'S 175°4125'E), New Zealand (Heather and Robertson 1996). The main breeding area on Great Barrier Island (Aotea Island) is around the summit of Mount Hobson (Hirakimata) (hereafter Mount Hobson). Monitoring work carried out during the 2009/10 breeding season was a continuation of the study begun in 1995/96 (Bell & Sim 1998a, b, 2000a, b, c, 2002, 2003a, b, 2005; Bell et al. 2007, 2009; Bell et al. 2011a, b), adding to the baseline data on the Great Barrier Island black petrel population. Field work carried out in 2006/07 season was privately funded and has not been reported through the DOC publication process. The annual report for that season can be obtained from the lead author (EAB). This part of the study builds on the earlier tracking and foraging studies (Bell et al. 2009, Bell et al 2011c), and uses this data to quantify spatial overlap with fisheries.

2. Objectives

The objective of the research reported here was to use light geo-locator data-loggers to determine at-sea distribution of black petrels during their breeding season and use this data to describe the spatial and temporal overlap with fishing effort identifying where black petrels are at highest risk of interaction with fishing gear.

Population monitoring aspects are reported in Bell et al. (2011b) and at-sea distribution in relation to environmental variables is reported in Bell et al. (2011c).

3. Methods

3.1 Study sites

The 35 ha study area at and around the summit of Mount Hobson on Great Barrier Island (Aotea Island; Fig. 1) was monitored three times during each of the breeding seasons between 2005 and 2010. During these visits over the 5-year period, 92 breeding black petrels were selected from the study burrows (n = 393) to have Lotek™ geo-locator devices deployed over the breeding and non-breeding phases.

In addition, six black petrels breeding on or around the summit of Hauturu/Little Barrier Island were also included in the at-sea distribution study.

3.2 Deployment of Lotek™ geo-locator devices

A total of 92 Lotek™ LAT2500 geo-locator data-loggers (Lotek Wireless, Ontario, Canada) were deployed on known breeding adult black petrels on Great Barrier Island between December 2005 and February 2010 (Bell et al. 2009; Bell et al. 2011a; Table 1). The birds were chosen from study burrows within the 35-ha study area if they had been successful breeders for at least five seasons and had been in the same pair for over the same five seasons. A further 7 Lotek™ geo-locator loggers were deployed on known breeding adult black petrels on Little Barrier Island/Hauturu between December 2007 and February 2008 (Table 1).

These data-loggers were light (6 g), small (35 mm in length and 11 mm diameter) and glued to a specially designed holder, which was then attached to the bird's leg by two cable ties. The data-loggers were attached to the bird's leg in about a minute. Removal of the tag was by cutting the cable ties with scissors. The total instrument load (percentage of bird's weight) is 0.86% (for a 700 g breeding bird).

These LOTEK™ data-loggers record sea surface temperature and ambient light data every six minutes, allowing the calculation of position, flight time and time spent on the water. The data was downloaded as the devices were retrieved (between January 2006 and March 2010) and analysed using software developed in the USA (Shaffer et al. 2005).

Tracks from 40 black petrels from Great Barrier Island and 6 from Hauturu/Little Barrier Island have been processed and analysed for this report (Table 2). Additional tracks from Great Barrier Island birds (*n* = 46) and data will be compared in the future.

Animal ethics approval for the use of all Lotek™ geo-locator devices was given by the DOC Animal Ethics Committee (15/12/2005, AEC127; 1/12/2007, AEC162 and 4/12/2008, AEC184).

3.3 Analysis and filtering of tracks from Lotek™ geolocator devices

Data from the Lotek™ geolocator devices were processed by algorithms developed by Shaffer et al. (2005) and filtered by sea surface temperature and speed (using maximum distances and speed reported by Freeman et al. 2010 for black petrel and Phillips et al. 2006 for white-chinned petrel, *Procellaria aequinoctialis*) to remove large location errors in data points (each geolocator point has an estimated location error of ±200 km). This filtering process is detailed in Bell et al.

(2011c). These filtered points were then classed by breeding phase (Table 2) based on date and location. Detailed plots of each flight were mapped onto New Zealand bathymetry maps. Positional data and kernel density plots (with density contours of 95%, 75% and 50% use) from the tracks identified areas of high use by black petrels (for all birds as well as separate sexes and within different stages of the breeding cycle) within the New Zealand EEZ (Bell et al. 2011c).

3.2 Fisheries overlap (New Zealand trawl and longline fisheries) with black petrel distribution

Black petrel distributions were characterised by kernel density distribution derived from surveys made during the pre-egg-laying (1 survey), incubation (3 surveys), and guard and chick rearing stages (1 survey) (Figures 3-5, 8 and 9 in Bell et al. 2011c; Table 3). In calculating the overlap, kernel densities made by combining tracks from male and female birds were used. From the 95%, 75% and 50% contours of the kernel density, the relative black petrel density at a point *x*, *y*, d*(x, y)* was derived, so that the density was uniform within each contour, and the integral of the density over the area enclosed by the 50%, 75% and 95% contours equalled 0.5, 0.75, and 0.95, respectively.

Fishing effort reported in Abraham and Thompson (2011) for trawl, bottom longline, and surface longline fisheries was used to define the overlap. Fisheries were defined by target species for the three methods (surface longline: southern bluefin tuna *Thunnus maccoyii*, bigeye tuna *Thunnus obesus*, albacore tuna *Thunnus alalunga*, swordfish *Xiphias gladius*, and other; bottom longline: snapper *Pagrus auratus*, ling *Genypterus blacodes*, bluenose *Hyperoglyphe antarctica*, hapuku *Polyprion oxygeneios,* and other; and trawl: mackerel *Decapterus macarellus*, deepwater, squid *Mastigoteuthis psychrophila*, scampi *Metanephrops challengeri*, southern blue whiting *Micromesistius australis*, ling, hoki *Macruronus novaezelandiae*, middle-depths, inshore and flatfish). For each fishing event, *i*, with effort e_i, at a position *x*, *y,* an overlap was calculated as $o_i = e_i\, d(x,y)$. For trawl fisheries the effort e_i was the reported number of tows, and for longline fisheries the effort was the number of hooks set. The total overlap for a fishery was the sum over all fishing events of the associated overlap. Due to the use of different effort measures, and the different vulnerability of black petrel to capture by each of the fishing methods, the overlap is not comparable between fishing methods, but does provide a relative measure of overlap between different target species within the same fishing method.

In the 2007/08, 2008/09, and 2009/10 fishing years, most fishing effort was reported with latitude and longitude positions, and so could be spatially located. Prior to that, reporting of small-vessel bottom longline and trawl fishing was frequently made by statistical area, without the position being included. After calculating the overlap, a multiplicative correction was made by fishery and year, to account for effort that was recorded without latitude and longitude positions. In calculating the overlap, fishing effort was restricted to the season corresponding to either pre-egg-laying (October 1 to November 15), incubation (November 16 to January 31), or chick rearing (February 1 to May 15). Overlaps with each of the three distribution maps available during the incubation period were averaged together. Overlap calculations were repeated for the total effort and for the observed effort.

4 Results

4.1 Analysis of Lotek™ geolocator deployment

There were 99 deployments of LOTEK™ geolocator data-loggers between December 2005 and February 2010, of which seven devices still have to be retrieved (Table 1). Two birds that had devices deployed were recaptured, but had lost their devices at sea (Table 1). Tracks from 46 deployments were used for analyses reported here. Additional details on these Lotek™ deployments can be found in Bell et al. (2011c).

Distribution patterns varied by breeding phase and ranged across the Tasman Sea to the Australian coast and east to 160°W (Bell et al. 2011c). Generally, distribution centred over the Hauraki Gulf for all density plots; although females appeared to travel further from the colony compared to males during incubation over all years (Bell et al. 2011c). Complete details on distribution and habitat use for all phase of the breeding season and migration to and from Eucador can be found in Bell et al. (2011c).

4.2 Fisheries overlap with black petrel distribution

The overlap between black petrel distributions and fishing effort is presented in Table 3. Of the bottom longline target fisheries, snapper had the highest overlap, followed by the bluenose target fishery. Overlap in other bottom longline fisheries was relatively low. Of the surface longline target fisheries, the only fishery with significant overlap was the bigeye tuna fishery. Of the trawl fisheries, most overlap was associated with inshore fisheries, with some overlap also associated with the scampi fishery. Overlap between black petrel and other trawl fisheries was minimal (less than 0.1 tows km^{-2}) and were not shown.

In each of the three fishing methods, most overlap occurs during either the chick rearing or incubation stages, with the highest overlap between bottom longline fisheries and black petrel distributions occurring during the chick rearing season (Table 3).

The overlap between black petrel distributions and observed effort was highest for snapper bottom longline, bigeye tuna surface longline, and scampi trawl fisheries. Bluenose bottom longline and inshore trawl had a low overlap with observed effort, when compared with the overlap with all effort (less than 1% in both cases). In all three methods, the fishery with the highest overlap between black petrel distributions and observed effort had the highest number of observed captures.

5 Discussion

The black petrel population on Great Barrier Island has been monitored since the 1995/96 breeding season (Bell & Sim 1998a, b, 2000a, b,c, 2002, 2003a, b, 2005; Bell et al. 2007, Bell et al. 2009; Bell et al. 2011a; Bell et al. 2011b; Bell et al. 2011c).

Little was known about the foraging range and at-sea distribution of the black petrel beyond anecdotal records from band recoveries, bird watching expeditions, fishermen, Ministry of Primary Industries observers and other vessels (Bell et al 2011a). Many records provide only general locations, and may be related to black petrels' habits of following boats to scavenge (rather than the routes they would follow in the absence of fishing boats).

A large scale analysis (200 km^2 and 1 day) was undertaken in this study due to the spatial error associated with light-geolocator tracking technology. However, the large sample size of tracks and the long-term tracking record allowed good comparative results. Black petrels demonstrated large variability in habitat use patterns and foraging ranges and results indicated that birds distribute themselves across available habitat based on resource distribution to exploit habitats relative to the environmental variability (Bell et al. 2011c). The integration of these results produces compelling findings on how these seabirds use foraging habitat relative to fisheries distribution.

For each fishing method, the fisheries with the highest overlap with black petrel distributions were snapper bottom longline, bigeye tuna surface longline, and inshore trawl. Within their respective fishing methods, these fisheries had the highest overlap in each of the three breeding seasons, as well as overall. Because of differences in the fishing methods, the overlap may not be directly compared between the three methods, but should be used as a comparison between fisheries using the same method, and between seasons.

Over the three years covered by the analysis (2007/08, 2008/09 and 2009/10) there were 64 black-petrel captures on observed fishing (Table 3; Abraham & Thompson 2012a, b, c). Of these captures, 51 occurred between January and April (inclusive), 6 occurred in May, and the remaining 9 captures occurred between October and December (inclusive). These observed captures were consistent with the highest overlap with observed fisheries being in the incubation and chick-rearing stages.

An indication of the relative capture rates of the three different fishing methods may be obtained by comparing the observed overlap with the observed captures. In bottom longline fisheries the total annual observed overlap was 267 hook km^{-2} which was associated with 54 observed captures over three years. This resulted in observed captures per unit overlap of 0.067 captures $km^{2}.hook^{-1}$. In comparison, the annual observed overlap with surface longline fisheries was 31 km^{2} $hook^{-1}$, which was associated with 9 observed captures. This resulted in an observed capture per unit overlap of 0.096 captures km^{2} $hook^{-1}$. When corrected for overlap, the observed capture rate of black petrel was within a factor of 1.5 of the observed capture rate in surface longline fisheries. Across inshore and scampi trawl fisheries, there was one observed capture, the observed overlap was 0.17 tow km^{-2} and the observed capture rate per unit overlap was 1.96 captures km^{2} tow^{-1}. Because of the small number of observed capture events, extrapolation from these observed rates to estimate captures across all fishing effort would have high uncertainty.

Over the three year period, there were only two fisheries (swordfish surface longline and scampi trawl fisheries) that had observer coverage of the overlap of 10% or more. There was very low observer coverage (less than 1% of the overlap) in inshore trawl fisheries and in bluenose bottom longline fisheries. Inshore trawl fisheries have the highest overlap of any of the trawl fisheries, and in the small fraction of observed bluenose fishing there were 15 captures. There were no observed captures in inshore trawl fisheries during the three fishing years considered here.

However in April 2007 a black petrel was caught in a trawl net by an 18 m vessel targeting John Dory, close to the Hen and Chicken islands in the Hauraki Gulf. Despite the low observer coverage, this capture demonstrates that black petrel captures occur in inshore trawl fisheries. Improving observer coverage in inshore trawl fisheries and in bottom longline fisheries, within the region of overlap, would help to better define the extent of the impact of fishing on black petrel populations.

A total of 79 black petrels (including two banded by the authors) were recorded as caught and killed on commercial fishing vessels in the New Zealand fisheries between 1 October 2003 and 30 September 2011 (Conservation Services Programme 2008; Rowe 2009, 2010; Thompson 2010a,b, c; Abraham & Thompson 2012a, b, c). Other black petrel captures were also reported prior to that (Robertson et al. 2004; Conservation Services Programme 2008). Black petrels have been caught on both trawl and long-line vessels between October and May, either east of North Cape, near the Kermadec Islands or north of Great Barrier Island (Robertson et al. 2003, 2004; Conservation Services Programme 2008; Rowe 2009, 2010, Abraham & Thompson 2012a, b, c). The timing of their capture suggests that most may have been breeding adults. This means that their deaths would have reduced overall productivity and recruitment (as one bird cannot incubate an egg or raise a chick) and pair stability. The level of bycatch for black petrels outside New Zealand waters is unknown, and may impact on the population dynamics of the species.

If breeding adults continue to be caught by commercial fishing operations in New Zealand and overseas, this species could be adversely affected even by a small change in adult survival, especially as black petrels have delayed maturity, low reproduction rates and high adult survival (Murray et al 1993). Continued bycatch of breeding adults in New Zealand and overseas fisheries has the potential to seriously affect the species.

It is important to continue to monitor the Great Barrier Island black petrel population. Long-term population data combined with improved technology and further use of light-geolocator and high-resolution GPS data-loggers can be used to develop an accurate population model to determine adult survivorship, recruitment, mortality and productivity as well as assess factors affecting the black petrel population on land and at-sea. This would allow the assessment of changes in habitat, foraging zones and prey species, likely overlap or risk areas with fisheries and the overall effects of fisheries bycatch by the commercial fishing industry.

6 Recommendations

In relation to future assessment of foraging behaviour, the authors recommend that:

- A sample of 50 black petrels should carry high-resolution GPS data-loggers over three consecutive breeding seasons to accurately investigate foraging behaviour including distances, locations and flight patterns throughout the breeding period. This information should be assessed in relation to fisheries overlap.
- A sample of 50 black petrels should carry time-depth recorders over three consecutive breeding seasons to accurately investigate foraging behaviour including depth, number of dives and location (if deployed in conjunction with GPS loggers) throughout the breeding season.
- A sample of 50 black petrels should carry light-geolocator data-loggers over two consecutive breeding seasons and the intervening non-breeding period (including migration to and from South America) to accurately investigate foraging distances and locations, water temperature and flight patterns throughout the breeding and non-breeding seasons. This information should be assessed in relation to fisheries overlap.

Bell et al (2011b) make further recommendations in relation to population monitoring and wider conservation actions for this species.

7 Acknowledgements

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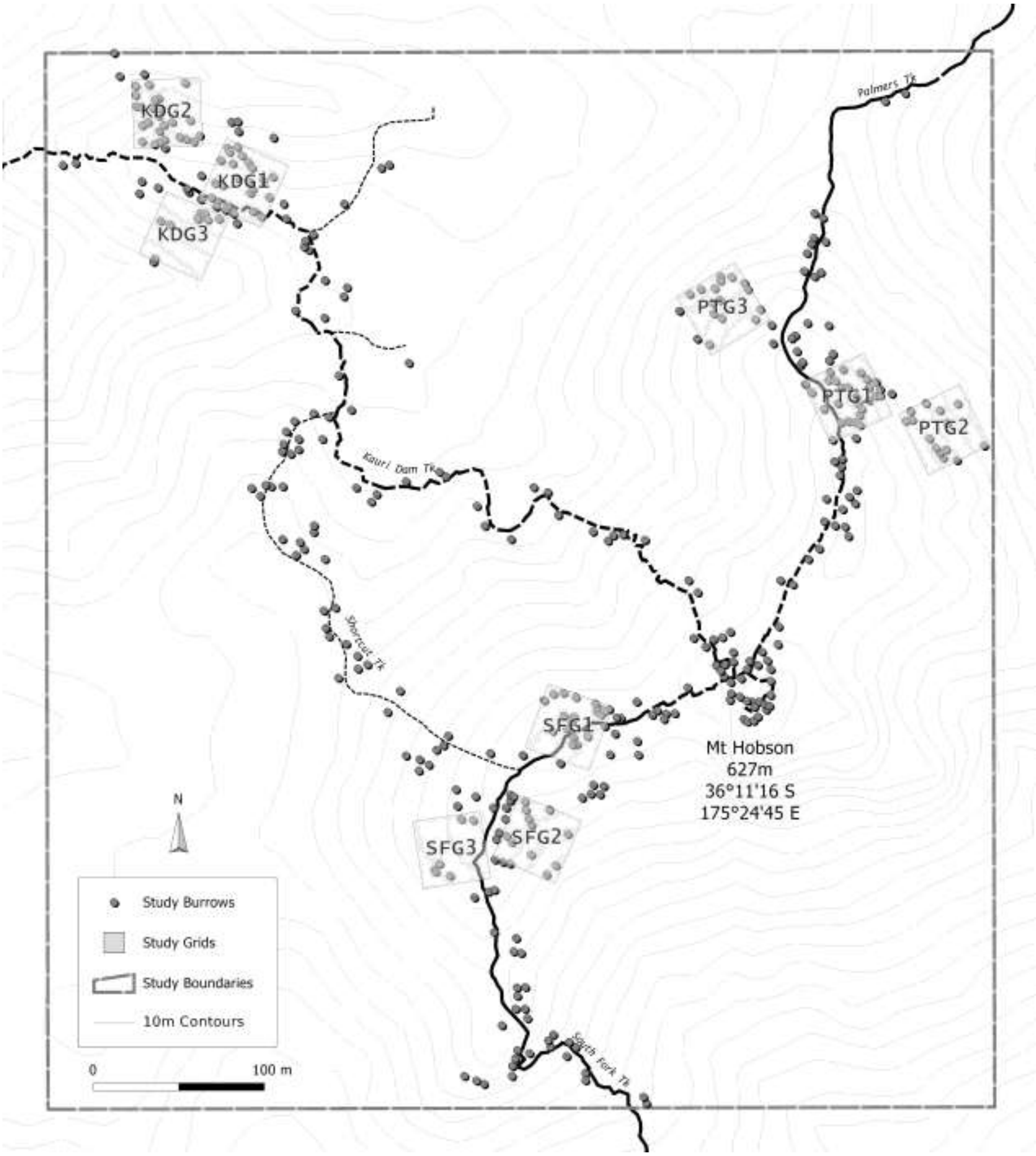
Figures

Figure 1 Location of the black petrel (*Procellaria parkinsoni*) study burrows and census grids within the study area on Great Barrier Island (Aotea Island). Altitude (621 m a.s.l.) is shown. Approximate North is shown (N). KDG = Kauri Dam Grid; SFG = South Forks Grid; PTG = Palmers Track Grid.



Tables

Table 1 Summary of Lotek™ geo-locator deployments on black petrels (*Procellaria parkinsoni*) on Great Barrier Island (Aotea Island) and Little Barrier Island/Hauturu, 2005/06 to 2009/10.

LOCATION	SEASON		Number of loggers deployed				Number of loggers retrieved	Number of burrows	Breeding success		No. of days loggers worn	
	DEPLOYED	RETRIEVED	Males	Females	Unknown	TOTAL			Logger burrows	All study burrows	Mean (± SEM)	Range
Great Barrier Island (Aotea Island)	2005/06 (December 05)	2005/06 (February 06)	7	3	1	11	11	9	67%	67% (05/06)	45 ± 2	42-57
	2007/08 (December 07)	2007/08 (January 08)	7	1	0	8	8	8	75%	77% (07/08)	33 ± 1	30-35
	2007/08 (December 07)	2008/09 (December 08)	12	4	0	16	16[1]	13	77% (07/08) 85% (08/09)	77% (07/08) 76% (08/09)	360 ± 1	354-369
	2007/08 (December 07)	2008/09 (February 09)	1	0	1	2	2[2]	2	100% (07/08) 100% (08/09)	77% (07/08) 76% (08/09)	418 ± 3	415-421
	2007/08 (December 07)	-	1	0	1	2	0	2	-	-	-	-
	2008/09 (December 08)	2008/09 (February 09)	5	1	2	8	8	8	88%	76% (08/09)	50 ± 2	44-62
	2009/10 (December 09)	2009/10 (February 10)	15	12	14	41	41	34	88%	74% (09/10)	50 ± 1	43-65
	2009/10 (December 09)	-	1	2	1	4	0	3	-	-	-	-
TOTAL (Great Barrier Island)			**49**	**23**	**20**	**92**	**86 (93%)**	**79**			**113 ± 13**	**30-421**
Little Barrier Island (Hauturu)	2007/08 (December 07)	2008/09 (December 09)	2	4	1	7	6	7	-	**-**	**-**	**-**
TOTAL (Little Barrier Island)			**2**	**4**	**1**	**7**	**6 (86%)**	**7**				
TOTAL			**51**	**27**	**21**	**99**	**92 (93%)**	**86**				

[1] All 16 birds recaptured, but one bird only had the attachment present (logger device had fallen off at sea).

[2] Both birds recaptured, but one bird only had the attachment present (logger device had fallen off at sea).

Table 2 Dates of black petrel (*Procellaria parkinsoni*) breeding phases as per Imber (1987) and Lotek™ geo-locator logger analysis.

Phase		**Start date**	**End date**
Breeding	Pre-egg laying	1 October	15 November
	Incubation	16 November	31 January
	Guard & chick rearing	1 February	15 May
Non-breeding		16 May	30 September

Table 3 Breakdown of overlap between black petrel distribution and fishing effort, by fishery and breeding season. Longline overlap is expressed as hooks km^{-2} and trawl overlap is expressed as tows km^{-2}. The numeric values of the overlap may not be compared between fishing methods. The overlap for middle-depths, mackerel, flatfish, hoki, ling, squid, hake, and southern blue whiting trawl fisheries was 0.1 tows km^{-2} or less for each of the breeding seasons, and is not shown.

METHOD	FISHERY	OVERLAP BY BREEDING STAGE			TOTAL			OBSERVED CAPTURES (2007/08 TO 2009/10)
		PRE EGG LAYING	INCUBATION	GUARD AND CHICK REARING	ALL OVERLAP	OBSERVED OVERLAP	PERCENT OBSERVED	
BOTTOM LONGLINE	Snapper	508	1,810	2,729	5,047	224	4.44%	23
	Bluenose	56	656	550	1,261	10	0.79%	15
	Minor species	27	102	184	313	14	4.47%	0
	Ling	20	192	86	298	0	0.00%	0
	Hapuka and bass	40	96	159	295	19	6.45%	16
SURFACE LONGLINE	Bigeye	55	215	215	485	29.02	5.99%	7
	Swordfish	0	6	15	20	2.11	10.31%	2
	Minor species	0	1	4	5	0.00	0.00%	0
	Southern bluefin	0	0	3	3	0.23	7.29%	0
	Albacore	0	1	1	1	0.09	7.55%	0
TRAWL	Inshore	0.47	3.29	2.64	6.40	0.06	0.94%	0
	Scampi	0.01	0.37	0.24	0.61	0.11	17.92%	1