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Seabird bycatch by Southern Fishery longline vessels in New Zealand waters

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This series documents the scientific basis for stock assessments and fisheries management advice in New Zealand. It addresses the issues of the day in the current legislative context and in the time frames required. The documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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Talbot Murray, Paul Taylor, Jacqui Greaves, J.A. "Sandy" Bartle, and Janice Molloy

1. Statement of the problem

The problem of seabird bycatch on tuna longlines was first raised internationally after independent researchers studying albatross in southern latitudes noted major declines in several different populations (Tomkins 1985, Weimerskirch & Jouventin 1987, Weimerskirch *et al.* 1987, Jouventin & Weimerskirch 1988, Croxall *et al.* 1990). They found that adult and juvenile survival was depressed while breeding success remained constant, indicating that birds were dying prematurely at sea. Reports of seabirds caught in fishing gear suggested that this may be a cause of increased albatross mortality. Observations on board longline vessels fishing off Tasmania further suggested that albatrosses were being caught at a rate that could account for the declines observed (Brothers 1991).

Specific ocean areas can be important forage grounds for some species leading to localised concentrations of seabirds (Schneider 1982, Schneider *et al.* 1987). Oceanic seabirds, especially albatrosses, are highly mobile and often feed far from their breeding grounds. Weimerskirch & Jouventin (1987) reported recoveries of banded albatross up to 1800 km from breeding sites, noting that during the incubation and fledgling period these birds have a potential foraging range of 3000 km. Within the New Zealand EEZ, some feeding areas may be similarly important for endemic and migrant seabird populations. The extent to which such areas overlap with fishing grounds is likely to be related to incidental seabird catches.

Apparent declines have been recorded for wandering albatross (Walker *et al.* 1991) and for several mixed colonies of grey headed and black browed mollymawks (Moore & Moffatt 1991) on New Zealand subantarctic breeding grounds. The apparent declines are of the order of 25 to 50% although some individual colonies showed larger declines. Since these breeding grounds are within the foraging range of fishing areas for both the southern and Northern Fishery, longline fishing in the EEZ may affect seabird populations in New Zealand. Similar declines linked to fishing have been reported in other countries.

This report describes the tuna longline fishery in the New Zealand EEZ and how seabirds are caught by longline vessels, summarises information available on seabird population trends, and estimates the scale of the incidental capture of seabirds in the larger of two tuna longline fisheries in the EEZ. Measures which could reduce the number of seabirds caught by tuna longlines are also described.

2. Background to the bycatch of seabirds on longlines

2.1 Fishery/gear involved

Since the early 1950s foreign longline vessels have fished in what is now the New Zealand EEZ. The two tuna longline fisheries in the EEZ have been licensed since 1979; they operate in different areas and target different tuna and billfish species. The Northern Fishery comprises vessels from Japan and the Republic of Korea and targets albacore, yellowfin tuna, bigeye tuna, and swordfish with the last two species predominating in recent years. The wholly Japanese Southern Fishery targets southern bluefin tuna, bigeye tuna, and swordfish. Figures 1 and 2 show set positions for the southern and Northern Fishery during the period 1987–89, when seabird bycatch was monitored by observers.

Tuna longlines consist of a continuous length of line (the mainline) suspended beneath the surface from buoylines at regular intervals. Hanging from the mainline are a series of baited hooks and artificial lures. The number of hooks between each buoyline (termed a basket) varies depending upon the depth to which the hooks are intended to fish. When fishing in New Zealand waters, about 6 hooks per basket are attached along the mainline whose total length is usually 100–140 km. Hooks are usually set to fish at depths of 100–170 m. Figure 3 shows a typical Japanese tuna longline.

Longline vessels in the Southern Fishery fish along the south and east coasts of New Zealand between 30° and 50° S. In recent years fishing has begun in March-April in the south with the fleet moving northwards from May through September when they leave the EEZ. The timing of fishing and the fleet distribution pattern varies from year to year; most effort and the highest catches occur between March and August. In all years the fishing pattern is separated into distinct fishing grounds, one south of the Chatham Rise (about 44° S) usually fished from the start of the season to June and one north of the Chatham Rise fished from May to September.

Table 1 summaries the number of vessels, sets, and hooks fished for the southern and Northern Fishery for 1987–89. During this period total fishing effort by the two fisheries within the New Zealand EEZ declined by nearly 45% from over 18 million hooks to fewer than 10 million. The decline in fishing effort in the Southern Fishery, the subject of this report, was nearly 36% during the same period.

2.2 Cause of seabird mortality

Brothers (1991) observed that most seabirds are caught in the brief period after the baited hook is thrown overboard, and before it sinks beyond the birds reach. He noted for albatross that the critical distance behind the ship at which birds took baits was 50 m; further astern baits tended to be too deep for albatross to reach. Once a hook has been swallowed the bird is pulled under water by the sinking longline and drowned. Although it has not been observed, some birds are probably also caught during hauling, as there have been instances where birds have been landed alive.

Table 1: Number of southern and Northern Fishery longline vessels and fishing effort within the New Zealand EEZ, 1987–89.

Year	No. vessels	No. sets	No. hooks	Mean longline length (km)
Southern Fishery (Japan)				
1987	38	4999	14 659 858	130
1988	38	4192	12 152 613	125
1989	32	3249	9 418 562	122
Northern Fishery (Japan)				
1987	16	711	2 105 949	119
1988	20	262	790 387	121
1989	5	66	200 620	130
Northern Fishery (Korea)				
1987	8	417	1 248 292	123
1988	14	602	1 839 611	111
1989	6	108	340 685	136

2.3 Collection of seabird bycatch data

MAF Fisheries observers collected seabird bycatch data during 15 sea voyages on 13 Southern Fishery vessels between 1987 and 1990. All birds caught in 286 observed hauls were noted. Observers stayed on deck throughout the haul. Line setting was not usually observed. At sea, observers attempted to identify some, but not all, seabirds. The times of setting and hauling longlines, and the time at which seabirds were brought on board, was recorded to estimate the time of day when each bird was hooked. No vessels from the Northern Fishery which targets albacore, bigeye tuna and swordfish carried observers.

Observers were asked to return all seabirds landed dead, but this was not always possible due to constraints on freezer space and attitudes of some crew. While many of the seabirds killed were returned for identification by J. A. Bartle (Curator of Birds, National Museum), it is not clear if the birds retained were representative of the species landed. Care was taken in observer debriefing sessions to gauge whether there was any bias towards type or size of seabird when only part of the catch was retained. While no known bias exists in the species returned, the possibility of unintentional selection for size or some other attribute can not be excluded.

Appendix 1 summarises fishing effort and observer coverage of tuna longline vessels in the Southern Fishery from 1987 to 1990.

2.4 Species caught

The following list of species returned for identification may be incomplete since only 31% of the seabirds caught were returned for identification.

Albatrosses

Snowy albatross	*Diomedea exulans chionoptera*
Wandering albatross (Auckland Is)	*D. exulans* ssp. *
Southern black-browed mollymawk	*D. melanophrys melanophrys*
New Zealand black-browed mollymawk	*D. melanophrys impavida* *
Southern Buller's mollymawk	*D. bulleri bulleri* *
New Zealand white-capped mollymawk	*D. cauta steadi* *
Grey-headed mollymawk	*D. chrysostoma*

Petrels

Grey petrel	*Procellaria cinerea*
Westland petrel	*P. westlandica* *

Species marked * are endemic.

Throughout the remainder of this report the two genera caught will be referred to as albatrosses and petrels.

2.5 Geographic areas of concern

Table 2 shows the number of each species landed during 1989 and 1990. If the samples returned by observers are representative of all seabirds caught, then seabird abundance and/or vulnerability to longlines appears to differ in the two fishing areas. The confirmed identifications suggest that albatross bycatch is of greater concern in the Chatham Rise-Challenger Plateau fishing area (areas 3 and 4 of Figure 1) and grey petrels are of greater concern in the Wairarapa-Bay of Plenty fishing area (areas 1 and 2 of Figure 1).

Table 2: Numbers and frequency of each seabird species returned to shore from the main fishing areas for the Southern Fishery 1989–90.

Species	Wairarapa-Bay of Plenty (Areas 1 and 2) (no. sets = 48)		Chatham-Challenger (Areas 3 and 4) (no. sets = 41)	
Diomedea exulans	5	(36%)	9	(64%)
D. cauta	0		5	(100%)
D. bulleri	0		14	(100%)
D. chrysostoma	1	(16%)	5	(84%)
D. melanophrys	4	(100%)	0	
D. impavida	9	(100%)	0	
Total albatrosses	19	(37%)	33	(63%)
Procellaria westlandica	0		1	(100%)
P. cinerea	30	(100%)	0	
Total petrels	30	(97%)	1	(3%)

Nearly all petrels returned to shore during this period were caught in areas 1 and 2, whereas about twice as many albatrosses were returned from areas 3 and 4 compared to areas 1 and 2.

For albatrosses, the primary area of concern extends from south of the Chatham Rise 12–250 n.miles offshore including the southern tip of the South Island and the area 12–120 n.miles along the west coast of the South Island. For petrels, and to a lesser extent albatrosses, the area of concern extends from the northern flank of the Chatham Rise northwards into the Bay of Plenty 12–180 n.miles offshore. Within these areas there may be localised "hot spots" of high seabird abundance such as Puysegur Bank and East Cape which because these areas are believed to be seasonal foraging zones for particular species and may overlap with areas of longline activity.

Although data on seabird catch have been collected only from the Southern Fishery thus far, tuna longliners in the Northern Fishery are also likely to catch seabirds, and therefore, this area is also of concern.

2.6 Seabird capture in relation to time of day

The estimated times when seabirds were caught on longlines together with the time of longline setting are summarised in Table 3. In the Chatham Rise-Challenger fishing area most birds are caught during daylight hours (0800 to 1700 hours approximately). In the Wairarapa-Bay of Plenty fishing area high catches can occur anytime before midnight, although 58% were caught early in the morning (0600 to 1000 hours) or in the afternoon and evening (1400 to 1800 hours).

Timing of longline sets when observers were present differed markedly between the two fishing areas. In the Wairarapa-Bay of Plenty area 43.2% of sets were made during the night while 56.8% of sets occurred either entirely, or in part, during daylight hours. In the Chatham Rise-Challenger Plateau area over 2.5 times as many sets occurred during periods of daylight (27.8% were made during the night while 72.2% of sets occurred either entirely, or in part, during daylight hours).

Table 3: Time of day, frequency of longline setting time and of seabird catch by fishing area for the Southern Fishery. Times indicated for sunrise and sunset are taken for the port most central to the observed fishing area and time (31 May at Dunedin for Chatham-Challenger, 20 June at Gisborne for Wairarapa-Bay of Plenty fishing areas)

Fishing area	Time	Percent of sets	Percent of birds caught	
Wairarapa-Bay of Plenty (Areas 1 and 2)	0001–0200	19.2	1.1	
	0201–0400	5.8	1.1	
	0401–0600	3.7	1.1	
	0601–0800	1.2	11.6	
	0801–1000	1.0	14.9	(sunrise 0819)
	1001–1200	3.5	3.3	
	1201–1400	8.6	8.8	
	1401–1600	16.7	11.0	
	1601–1800	16.3	19.9	(sunset 1658)
	1801–2000	6.9	10.5	
	2001–2200	8.3	8.8	
	2201–2400	8.8	7.7	
	(Total no.)	(1180)	(181)	
Chatham-Challenger (Areas 3 and 4)	0001–0200	6.0	2.3	
	0201–0400	7.5	2.3	
	0401–0600	11.9	0.0	
	0601–0800	9.7	11.4	
	0801–1000	17.0	17.0	(sunrise 0807)
	1001–1200	11.0	28.4	
	1201–1400	3.3	15.9	
	1401–1600	2.8	5.7	
	1601–1800	9.0	5.7	(sunset 1702)
	1801–2000	13.3	2.3	
	2001–2200	2.4	2.3	
	2201–2400	6.1	6.8	
	(Total no.)	(1009)	(88)	

Grouping estimated capture times according to hours of daylight or dark based on times of sunrise and sunset indicated that seabirds are twice as likely to be caught during daylight hours than at night in the Chatham Rise-Challenger fishing area. No statistically significant difference between day and night longline sets was found in the Wairarapa-Bay of Plenty fishing area. The frequency of capture corresponds well with the relative frequency of daylight versus night sets in each area. It also corresponds with the feeding patterns of these two seabird groups (depending upon species, petrels can be night or day feeders while albatrosses are generally considered to be day feeders only) and the relative proportions of the species caught in each of the two main fishing areas (*see* Table 2). The feeding periods for albatross would explain the lower capture rates at night in the Chatham-Challenger fishing area where these species appear to dominate the seabird bycatch. It would also explain the apparent lack of diel pattern in seabird capture in the Wairarapa-Bay of Plenty fishing area where both petrels and albatrosses are caught.

The present data do not allow clear separation of the effects of daylight on seabird vulnerability from those of different levels of effort during day and night in the two areas. However, the correspondence between these factors simplifies estimating the magnitude of seabird bycatch as we do not have to remove any confounding effects before extrapolating from catch rates by observed vessels to unobserved vessels in the same area and time.

2.7 Magnitude of seabird bycatch

A total of 269 seabirds were caught during the 296 sets observed between 1987 and 1990. This is equivalent to an average catch rate of 0.91 birds per set.

The data used in this study suffer from poor field identifications by observers and variable geographic and temporal coverage of observed vessels. Whereas these problems place constraints on data interpretation, the sample size when all species are pooled is much larger than earlier studies of a similar fishery in Tasmanian waters (Brothers 1991). The present study also covers a large geographical area (12° of latitude and two distinct fishing areas) and by extension a more diverse avifauna. Although observer coverage is low (never more than 10% of sets for periods and areas), pooling of species and areas has allowed us to provide reasonably robust estimates of the total seabird catch (coefficients of variation ranged from 4 to 7%). These estimates are provided in Appendix 1 for the period when observers were present.

The estimates of total birds killed (Appendix 1) do not include months or areas where observers were not present and assume that the bird catch rate on vessels with observers is equal to that of all vessels fishing in the area at the same time. The estimation procedure for the mean and variance uses a "Bootstrap" resampling procedure (Efron & Tibshirani 1986) given a binomial distribution of capture (birds are caught or not caught during a set) and an observed frequency distribution of bird captures (1 per set, 2 per set, etc.). The estimate is then scaled upwards using the fishing effort of the entire fleet operating in the area at the time to reflect the total seabird catch while observers were present in the fleet.

If we further assume that the number of seabirds caught by longlines is the same in those months when observers were not present (for the same areas) then the estimated number of birds caught by Southern Fishery longliners for the major fishing areas for the entire season would be in the range listed in Table 4. These are likely to be conservative estimates of the total seabird catch by longline since fishing areas for the Southern Fishery for which no observer data are available and all sets made by Northern Fishery vessels have been excluded.

Table 4: Estimated numbers of seabirds caught by Southern Fishery vessels in the main fishing areas of the New Zealand EEZ in 1988 and 1989 (upper and lower 95% confidence interval during periods of observer coverage scaled up to include sets when no observers were present in the area).

Longline fishing area	Year	No. sets	Estimated no. seabirds caught
Wairarapa to Bay of Plenty	1988	1864	570.8 to 793.4
Other areas	1988	2328	no data
Wairarapa to Bay of Plenty	1989	1045	1548.7 to 2357.2
Chatham Rise to Challenger Plateau	1989	2138	1571.2 to 1849.6
Other areas	1989	66	no data

These (probably conservative) estimates should be regarded as indicative of the scale of seabird bycatch on longlines as it is currently not possible to verify the assumption of equal capture rates in months and areas where observers were not present. However, *if we accept these assumptions* then our best estimate of the number of seabirds caught on longlines by the Southern Fishery was 3100 to 4200 birds in 1989, the only year for which data for the two major fishing areas are available (figures from Table 5, rounded to the nearest 100). Comparison of the 1988 and 1989 Wairarapa-Bay of Plenty estimates suggests that considerable variation in seabird catch between years may occur (i.e., the estimated seabird bycatch in 1989 is nearly three times higher than in 1988). No data are available for the Chatham Rise-Challenger Plateau fishing area in 1988.

Two factors further suggest that seabird captures may have been higher before this study. First, total fishing effort was higher and, second, the use of bird scaring devices has recently been introduced into the longline fleet. "Tori poles" and streamers are reported to be used by some vessels in New Zealand waters to deter birds from taking bait. In the 1991 fishing season over two-thirds of longline vessels checked in port (24 of 33 vessels) were outfitted with these devices. This technique was apparently used during part of the study period and may to reduce seabird catches by up to 75% (Brothers, pers comm 1991). Unfortunately, observers did not record the extent to which this technique was used during the sampling period or its effectiveness in New Zealand waters.

3. Effect of incidental catch on the population

In the Indian and Atlantic Oceans, where seabird populations have been better studied, declines in breeding populations coincided with the expansion of distant water tuna longline fleets into the Southern Hemisphere. Weimerskirch & Jouventin (1987) found the breeding populations of wandering albatross on three islands in the Crozet group decreased at annual rates of 2.6%, 4.9%, and 6% between 1966 and 1985. On the best monitored island in the group, Possession Island, the population was reduced by half during this period. In a separate study, Croxall *et al.* (1990) found wandering albatross populations at Bird Island, South Georgia had declined at a rate of 1% per annum since 1961. In the Kerguelen Islands, Weimerskirch *et al.* (1989) found the monitored wandering albatross population had been reduced by almost half between 1973 and 1984. In all three studies, the adult mortality was abnormally high, while breeding success was either stable or had increased over the period. In the absence of evidence of changes in environmental conditions in areas where birds forage, the authors suggest that human factors such as fisheries interactions may be responsible for the decline.

This view is supported by the results of a banding study by Croxall and Prince (1990) from 1975 to 1988 in which 64% of banded South Georgian wandering albatross (21 birds) were killed by fishing gear. Seventy-six percent of these (16 birds) were caught on longlines. Weimerskirch & Jouventin (1987) reported that wandering albatross are known to have been shot or trapped and used for food during recent times and they are caught incidental to longline, sinker-less baited hook, and trawl fisheries. Croxall *et al.* (1990), however, provided compelling evidence of significant impacts of longline fishing in their demographic study of wandering albatross. They estimated annual mortality rates of 2–3% for adults and possibly 14–26% of juveniles for the South Georgia population, and concluded that "this would be amply sufficient to establish the long-line fishery as the single most serious present cause of death of South Georgia wandering albatross and the most likely factor to account for the recent population decline".

In New Zealand, data on population trends exist for three bycatch species which occur in two localities. These are the wandering albatross population on Adams Island and the black-browed and grey-headed mollymawks which breed on Campbell Island.

Photographic evidence of the black-browed and grey-headed mollymawk population on Campbell Island show that in the 1940s between 47 000 and 67 000 pairs bred on the island. By 1988 this population had declined to 29 000 pairs (Moore & Moffat 1991). This represents a 38–57% decline. Some colonies, such as that at the Courrejolles Isthmus, have declined by up to 88% during this period, particularly in areas where grey-headed mollymawks predominate.

On Adams Island, Walker *et al.* estimated there to be 7000 pairs of wandering albatross in 1972–73, whereas in 1991, 4000 pairs were recorded. Further research is needed to assess population trends on this island because counts from the two surveys may not be directly comparable.

Although no population data exist for the grey petrel, it is worth noting that the impact of bycatch on the population may be disproportionate to the number of birds caught as there appears to be a strong sex bias in grey petrels caught on longlines in New Zealand waters. Of 30 grey petrels caught in the 1989 and 1990 seasons, 28 were females (Bartle 1990). A sex ratio bias in capture has a disproportionate effect on breeding success in long lived bird populations such as procellariforms where the expected sex ratio is about 1:1 and long term pair bonds are required for successful breeding (Weimerskirch & Jouventin 1987). Furthermore, in such burrowing petrels less than 30% of adults which complete their reproductive lives produce offspring (Wooller *et al.* 1989) with productivity rising where birds pair for 3 years or more.

4. Information requirements

Existing data on seabird bycatch by tuna longlines suffer from three likely sources of bias. First, the seasonal coverage is limited to a few months in the middle of the fishing year and observer coverage is particularly low in the portions of the Chatham-Challenger fishing area most frequently fished (Southland and South Otago coast). Second, it is impossible to be certain that the estimated catches and species composition adequately reflect seabird bycatch in the Northern Fishery as vessels in this fishery have not carried observers and fish different areas and seasons. Third, it is possible that some seabird species may concentrate in localised foraging areas which could overlap to an unknown extent with the longline fleets. The placement of observers (with the current low coverage) could yield estimates that either over- or under-estimate the true magnitude of seabird bycatch.

It is therefore desirable to extend observer coverage in the Southern Fishery and to initiate its coverage in the Northern Fishery. Data collection for estimating impacts of incidental longline capture on seabirds would benefit from increased involvement with trained ornithologists. In particular, the ability of MAF Fisheries observers to identify birds at sea could be significantly improved by involving ornithologists in observer training programmes.

The lack of detailed demographic information on many of the endemic seabird species and subspecies makes assessment of the impacts of longline bycatch on these populations in New Zealand impossible. To remove the qualitative nature of current assessment of risk, it is essential that studies of population dynamics and long-term monitoring of seabird populations be implemented.

5. Possible mechanisms to reduce seabird bycatch

5.1 Use of bird scaring devices

In Australian waters the use of tori poles and streamers during longline sets is reported to reduce the bycatch of albatross species by up to 75% (Brothers, pers. comm. 1991). Some longline vessels fishing in the New Zealand EEZ are known to have such devices on board (two-thirds of all vessels checked in 1991). It is not known to what extent tori poles are used during commercial longline fishing. Brothers (pers. comm.) reports that in Australia these devices have been voluntarily adopted by the Japanese southern bluefin tuna fleet since they reduce bait loss and hence improve the efficiency of fishing. Use of these devices has also been strongly endorsed through the Convention for the Conservation of Antarctic Marine Living Resources and the International Council for Bird Preservation.

5.2 Night setting

Albatross are reported to feed primarily during the day and during this study the number of seabirds caught in southern waters, where albatross are more abundant, occurred twice as often during the daytime as at night. It is therefore likely that restricting longline sets to periods of darkness and reducing deck lighting during longline sets would reduce the albatross bycatch. Anecdotal reports from the Hawaiian longline fishery for swordfish and from the developing domestic longline fishery in New Zealand indicate that seabird bycatch is dramatically reduced when longlines are set at night.

5.3 Area closures

Data analysed to date suggest that there could be localities where seabirds are particularly likely to be caught on longlines. The extent and location(s) of such areas is presently unknown as is the degree of overlap with longline fishing areas. Additional information is required to determine whether small scale time/area closures would be effective in reducing the seabird bycatch.

6. Summary

Several seabird populations, primarily albatross species in the Indian and South Atlantic Oceans, declined significantly during the period that tuna longline fishing effort by distant water fishing nations expanded. Japanese tuna longline vessels targeting southern bluefin tuna off southeastern Australia and off the south and east coasts of New Zealand have a potentially significant incidental catch of seabirds.

In the New Zealand EEZ at least nine different seabird taxa are caught by tuna longlines. Most of these are endemic species or subspecies and therefore of particular conservation concern. Though the estimated catch rate of seabirds is small (0.91 per longline set), the best estimate of the total seabird bycatch suggests that 3100–4200 birds may be killed in some years by the larger of the two fleets alone. The magnitude of seabird bycatch is still somewhat uncertain due to low observer coverage (3–10% of all sets), poor temporal and spatial coverage, and that one of the foreign longline fleets has not been studied.

Although seabird bycatch can be high, the impacts of longlines on seabird populations cannot be assessed because of the general lack of adequate information on population dynamics of most New Zealand species. However, even with the present uncertainties, least three species appear to be affected by longline fishing and hence are of immediate concern. These are grey petrel in fishing areas north of the Chatham Rise, and Buller's mollymawk and wandering albatross south of the Chatham Rise.

Analysis of the time at which seabirds are caught in the two main fishing areas for the Southern Fishery suggests that restricting the time during which longline sets are made to periods of darkness could reduce the bycatch of all albatross species. As some petrels, unlike albatrosses, feed at night this restriction may not greatly reduce petrel bycatch. However, since all seabirds must be able to see a baited hook in the water, reducing the amount of deck lighting, particularly at the stern, during longline setting may help lower petrel bycatch. Tori poles and streamer lines reduced seabird bycatch in Australian waters and should also further reduce the bycatch of all seabird species.

Present uncertainty regarding the scale and impact of longline fishing on seabirds can be improved only through further study. The continued collection of seabird bycatch data and expansion of observer coverage to improve estimates of seasonal and area specific mortality rates is considered essential for accurate estimates of fishery impacts on population size. Studies of seabird populations on breeding sites are also essential to forecasts of population change and impacts of fishery induced mortality.

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Appendix 1. Variation in the number of seabirds caught by tuna longline between areas and years. Wairarapa-Bay of Plenty fishing area refers to Areas 1 and 2 of Figure 1; the Chatham Rise-Challenger Plateau fishing area refers to Areas 3 and 4 of the same figure.

	Parameter		Wairarapa-Bay of Plenty 1988	Wairarapa-Bay of Plenty 1989	Chatham-Challenger 1989
1.	Months fished		May-Sept	Feb-Sept	Feb-July
2.	Total sets fished	1864	1045	2138	
3.	Observer period	June	June	May-June	
4.	No. sets fished in observer period	769	456	1487	
5.	No. sets observed	41	48	40	
6.	No. birds observed	15	90	32	
7.	Estimated no. birds caught in observed period	281.4	852.2	1189.6	
8.	Standard deviation	23.4	90.0	49.4	
9.	Lower 95% confidence interval		235.5	675.8	1092.8
10.	Upper 95% confidence interval		327.3	1028.6	1286.4
11.	% observed sets not catching birds		78.0	58.8	57.5

Appendix 2. Status of seabird species caught on longlines.

Wandering Albatross (*Diomedea exulans* ssp.)

Status: Endemic subspecies

In the New Zealand area this subspecies breeds at the Auckland, Antipodes, Macquarie and (rarely) Campbell Islands. The much larger South Georgia and Indian Ocean subspecies (Diomedea exulans chionoptera) also reaches New Zealand waters and both subspecies are caught on southern bluefin tuna longlines off New Zealand. Concern about this species is due to declines in the main breeding populations since the early 1970s, especially since they are long lived and have low reproductive rates. In the small sample (12 birds) returned from longliners to date it appears that males and females are equally vulnerable to longlines in New Zealand waters. This contrasts with populations of the subspecies in the South Atlantic (Croxall & Prince 1990) and Indian Ocean (Weimerskirch & Jouventin 1987) where females are more vulnerable than males.

Southern black-browed mollymawk (*Diomedea melanophrys melanophrys*)

Status: Common in Southern Ocean

In the New Zealand area this species breeds only on Antipodes and Macquarie Islands with many of the birds foraging in New Zealand waters probably originating from the large populations in the South Atlantic and Indian Oceans. In 1990, four southern black-browed mollymawks were returned from tuna longline vessels. All but one were immature (3–5 years old). Both sexes were equally represented in these captures.

New Zealand black-browed mollymawk (*Diomedea melanophrys impavida*)

Status: Endemic subspecies

The total world population breeds on Campbell Island. This subspecies migrates to subtropical and tropical waters of the western South Pacific in winter (Marchant & Higgins 1990), passing rapidly through southern and central New Zealand shelf waters in April-June (Bartle 1974, Powlesland 1985), with non-breeding individuals more abundant before April (Bartle 1974), and throughout the winter (July-Sept.) (Powlesland 1985).

In 1989–90, nine New Zealand black-browed mollymawks were returned from longline vessels. Eight newly fledged juveniles (4 ♂, 4 ♀) were caught over slope waters north and northeast of East Cape 21–27 June 1989. These birds would probably have left Campbell Island in late April or early May (Bailey & Sorensen 1962).

In addition to the longline catches verified within New Zealand waters, recoveries of banded birds of this subspecies have been made off New South Wales and in tropical seas in a broad arc from Vanuatu east to French Polynesia. All were recovered between March and August and most were caught on tuna longlines.

Southern Buller's mollymawk *(Diomedea bulleri bulleri)*

Status: Endemic subspecies

The world population of this subspecies breeds on Solander Island and on the Snares Islands within foraging range of tuna longline fishing areas. In 1990, 14 adult Buller's mollymawks (8 ♂, 6 ♀) in breeding condition were caught by longline vessels on the western slope of Puysegur Bank. These were caught between 3 April and 14 June, the period when adults would have been feeding chicks on the breeding colonies. Buller's mollymawks were the most abundant albatross caught in Area 4 and, unlike the black-browed and grey-headed Mollymawks, are especially vulnerable as they breed in autumn and winter when longliners are active near breeding sites.

New Zealand white-capped mollymawk *(Diomedea cauta steadi)*

Status: Endemic subspecies

The world population breeds only on Disappointment and Adams Islands (Auckland Islands), and on the adjacent Southwest Cape of the main island. This subspecies is caught in the southern bluefin tuna longline fishery and in the squid trawl fishery. In part of its breeding range it is also vulnerable to feral pigs.

Grey-headed mollymawk *(Diomedea chrysostoma)*

Status: Common in the Southern Ocean

In this species populations from different breeding places cannot be distinguished. It is primarily an oceanic species (Weimerskirch *et al.* 1988) and as such, may be less vulnerable to longline fishing. Five immature birds (2 ♂, 3 ♀) were caught on longlines over the Fiordland Basin (4) and western slope of the Puysegur Bank (1), 2–10 June 1990. Plumage and gonadal development indicated that the birds were 2–4 years old. A juvenile female about 1 year old was also returned from northeast of East Cape, 2 July 1990.

Grey petrel *(Procellaria cinerea)*

Status: Endemic species

In 1989–90, 30 grey petrels were caught by longline vessels in the Wairarapa-Bay of Plenty fishing area between 19 June and 7 August. All were adults, and 28 were females which had bred, but had regressed ovaries suggesting that they were either failed breeders or were feeding chicks (Bartle 1990). Since their main breeding grounds in the New Zealand area are the Antipodes Islands (1000–1500 km south of the capture localities), if the latter explanation for regressed ovaries is true, it suggests that even relatively distant fishing could affect this species. Foraging ranges of this magnitude are not unusual for oceanic seabirds (Bartle 1990), and a more northerly range for females has been found in studies of other species (Jouventin *et al.* 1982).

Grey petrels were caught in three localities, over slope waters to the north and northeast of East Cape (37–88 km offshore), over deep water 160–250 km offshore south of the Brodie Seamount, and in the Hikurangi Trench east of Bare Island (39° 48'S). They generally occur more abundantly seaward of the continental slope and shelf (Bartle 1990).

A sex ratio bias in capture has a disproportionate effect on breeding success in long-lived seabirds (Weimerskirch & Jouventin 1987) as the sex ratio in procellariiform birds is usually close to 1:1, and long term pair bonds are required for successful breeding. Furthermore, in such burrowing petrels fewer than 30% of adults which complete their reproductive lives produce offspring (Wooller *et al.* 1989) with productivity rising rapidly where pairs breed together for 3 or more years. The cumulative effect of this catch of female grey petrels on long-term productivity is therefore likely to be much greater than if equal proportions of males and females had been lost.

Westland petrel (*Procellaria westlandica*)

Status: Endemic species

Only one Westland petrel was returned from a longline vessel. It was caught on the western slope of the Puysegur Bank at 46° 14'S on 17 May, with a well-developed egg (38.1 x 34.2 mm) inside.

This species breeds only at Punakaiki, on the west coast of the South Island. About 2000 pairs breed each year, out of a total population of about 20 000 birds (Marchant & Higgins 1990). Minimum age of first return to the breeding colony occurs at 5 to 8 years, with the age of first breeding at 12 years.

There is good evidence for increased mortality of juvenile and adult females (Bartle, unpublished results). This is due to the different distributions of males and females, which is similar to grey petrels, and the observed unbalanced sex ratio in the breeding population with at least four times more males than females of breeding age.

Figure 1. Tuna longline set positions by the Southern Fishery in New Zealand waters during the period 1987–89 (areas 1–5 represent fishing areas discussed in the text based on natural divisions in set positions).

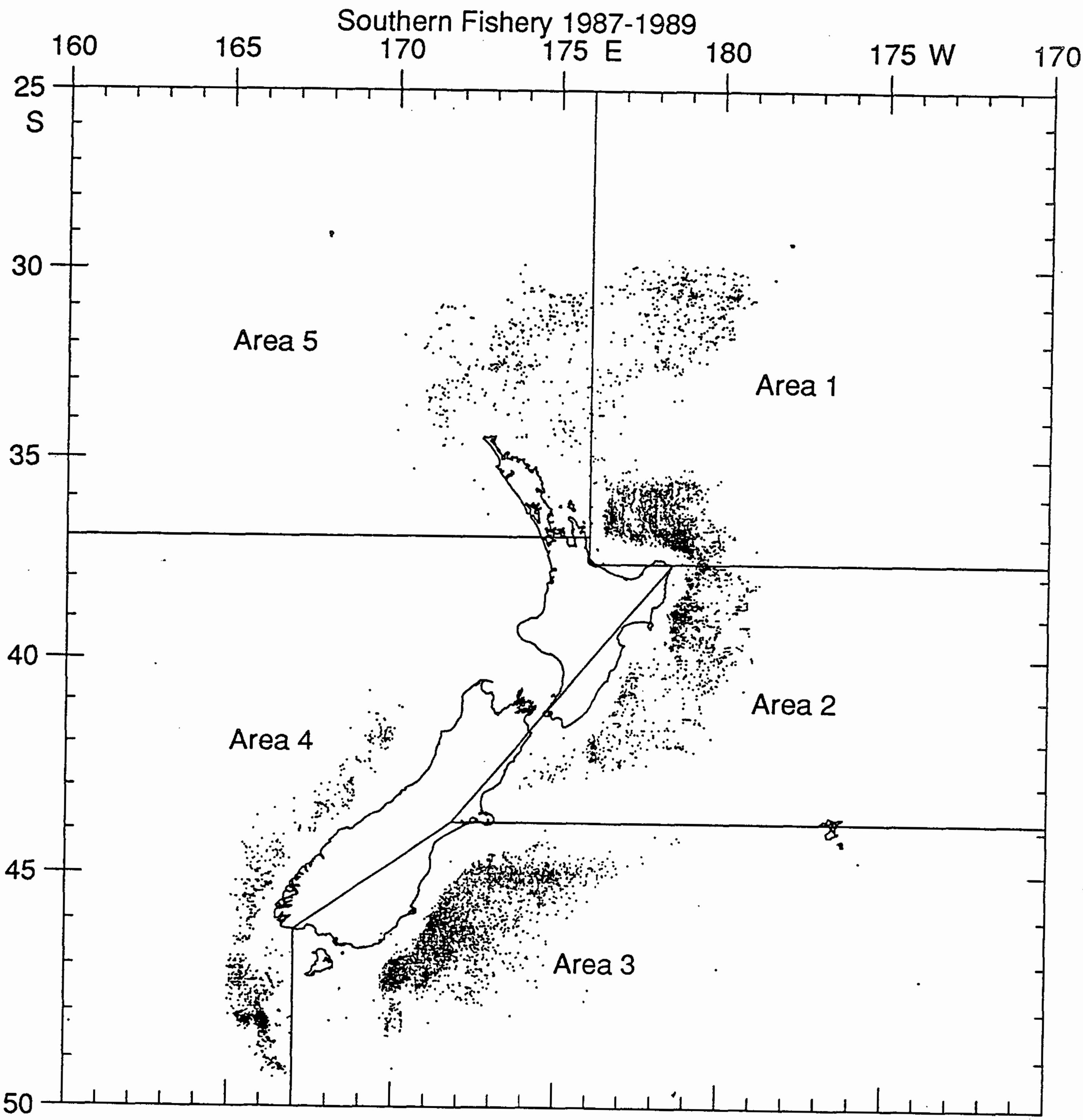

Figure 2. Tuna longline set positions by the Northern Fishery in New Zealand waters during the period 1987–89 (areas 1–5 represent fishing areas discussed in the text based on natural divisions in set positions).

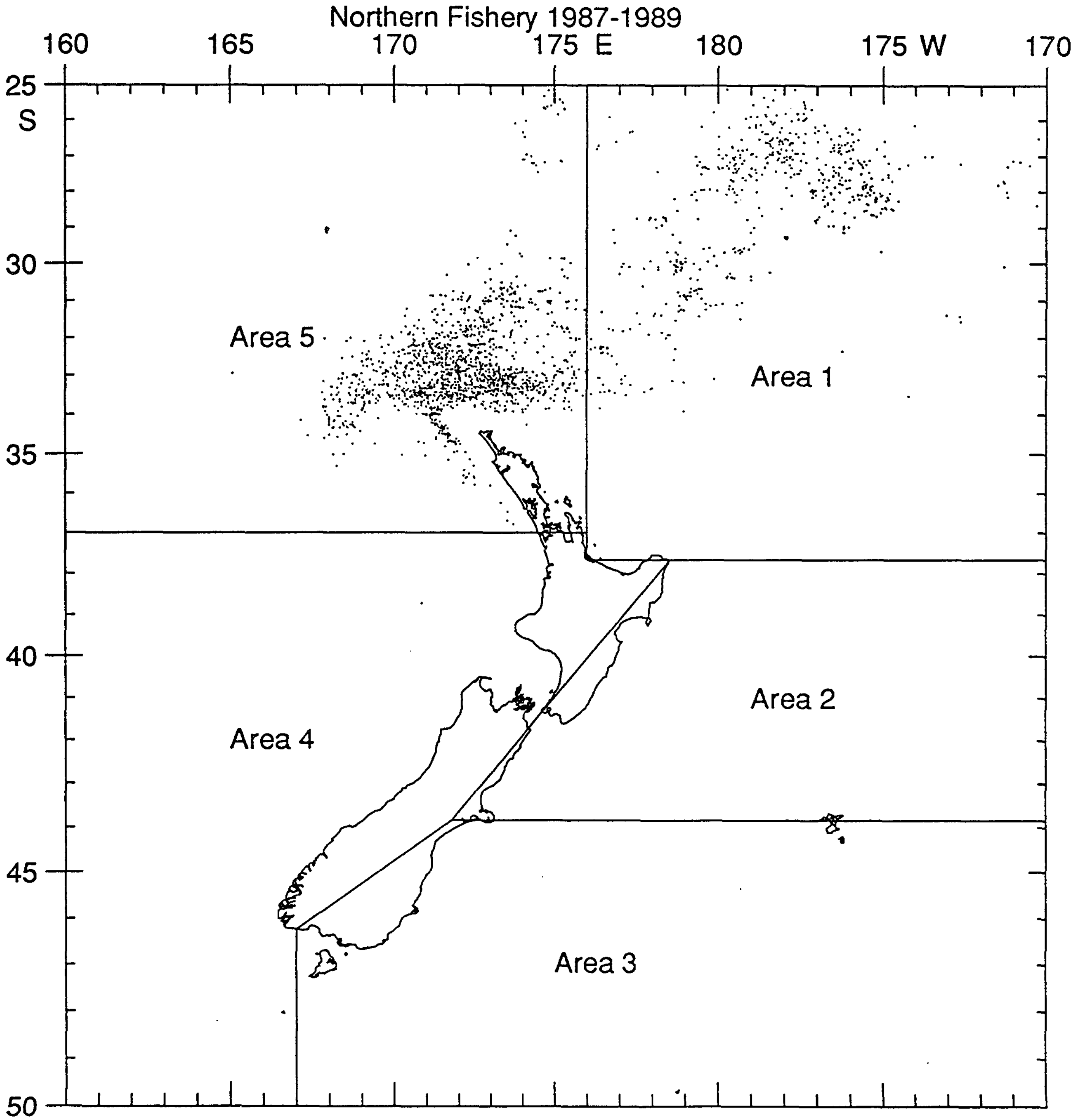

Figure 3. Diagram of a typical Japanese longline used in the New Zealand EEZ.