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Band recoveries of southern royal albatrosses (*Diomedea epomophora*) from Campbell Island, 1943-2003

PETER J. MOORE
Research, Development & Improvement Division, Department of Conservation, P.O. Box 10-420, Wellington, New Zealand. *pmoore@doc.govt.nz*

SUSAN M. BETTANY
2 Nor'east Drive, Browns Bay, Auckland, New Zealand

Abstract 35,289 southern royal albatrosses (*Diomedea epomophora*) were banded on Campbell Island between 1941 and 1998, including 24,258 chicks and 11,031 adults. By 2003, 240 (0.68%) band recoveries and live recaptures away from Campbell Island had been reported. Birds banded as chicks were reported at a median age of 2 years (range 1-28 yrs), and adults at a median of 4 years after banding (range 0-27 yrs). The peak of band recoveries occurred close to the peak of banding in the late 1960s. Recoveries were generally made between latitudes 30-55°S in southern Australasia and South America; 43% were on coasts and 56% at sea. Birds recovered at sea (n = 134) were usually in waters over the continental shelf (up to *c.* 200 m deep water; 55% of records) or slope (200-1000 m; 19%). Distribution varied with age, with 56% of juveniles (<20 months old, n = 78) found on the west side of South America (especially in December - February), 54% of immature birds (<6 years old, n = 48) on the east side of South America (especially in June - July) and 55% of adults (≥ 6 years old, n = 114) in the New Zealand region. Most (94%, n = 102) birds recovered on the coast were dead, compared with 46% (n = 134) of those found at sea. Some birds were apparently caught to read bands, and 36% of the live birds (n = 78) were released without their bands, and of the remainder, 3 birds were seen again on Campbell Island. About half (49%, n = 61) of deaths at sea were caused by accidental capture on fishing lines. A possible decrease in the population during the 1970s - early 1980s coincided with the peak in long-line fishing in the New Zealand region and suggests this albatross could be affected by any new fisheries or intensification of fishing without adequate mitigation. It would be prudent to monitor the trends, dynamics and foraging of a range of New Zealand albatross species within an, as yet undeveloped, strategy for research and monitoring of seabirds in New Zealand.

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Keywords Southern royal albatross; *Diomedea epomophora*; Campbell Island; southern ocean; band recoveries; dispersal; fisheries bycatch; mortality

INTRODUCTION

The southern royal albatross (*Diomedea epomophora*) breeds at Campbell Island (52° 33'S, 169° 08'E) and the Auckland Islands (50° 30'S, 166° 17'E). In the wake of Europeans first encountering these islands in 1806-10, the combined effects of sealing and hunting, introduced mammals, and burning of vegetation took a large toll on the albatross populations and nesting habitats. The species disappeared from Enderby Island (Auckland Islands) around 1868 (Taylor 1971) and numbers were also severely depleted on Campbell Island by the 1920s (Oliver 1930; Guthrie-Smith 1936; Westerskov 1959). With formal protection (Auckland Islands in 1934, Campbell Island in 1954), introduced mammals were gradually removed and the southern royal albatross population began to recover (Dilks & Wilson 1979; Moore *et al.* 1997; Childerhouse *et al.* 2003). At present 8200 - 8600 pairs nest annually on Campbell Island (Moore *et al.* 1997) and 70 pairs on the Auckland Islands (Gales 1998).

Southern royal albatrosses spend much of their lives at sea where they feed and scavenge on squid and fish. When chicks fledge, they leave the islands for four or more years (Marchant & Higgins 1990; Westerskov 1963), do not breed until they are at least six years of age, and breed biennially for at least 35 years (PJM unpubl.), possibly living to 51 - 61 years, as is the case in the closely related northern royal albatross (*Diomedea sanfordi*)[1] (Robertson 1993).

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[1] Taxonomy in this paper follows Robertson & Nunn (1998) who separated the two royal albatross species based on mitochondrial DNA sequencing and morphological differences. This has not been universally accepted, for example, Penhallurick & Wink (2004) regard the taxa as subspecies of *D. epomorphora* based on close genetic distances.

Table 1 Number of southern royal albatrosses banded at, and recovered beyond, Campbell Island, by decade and region

Decade banded	No. banded	1940 -1949 n (%)	1950 - 1959 n (%)	1960 - 1969 n (%)	1970 -1979 n (%)	1980 - 1989 n (%)	1990 - 1999 n (%)	2000 - 2003 n (%)	TOTAL n (%)
Unknown	5								
1940-49	374	1(0.27)	0	0	0	0	0	0	1(0.27)
1950-59	546		0	4(0.73)	1(0.18)	0	0	0	5(0.92)
1960-69	17855			99(0.55)	40(0.22)	13(0.07)	3(0.02)	0	155(0.87)
1970-79	10144				40(0.39)	13(0.13)	5(0.05)	2(0.02)	60(0.59)
1980-89	3764					6(0.16)	4(0.11)	1(0.03)	11(0.29)
1990-99	2601						7(0.27)	1(0.04)	8(0.31)
Total	35289	1(0.27)	0	103(0.55)	81(0.28)	32(0.10)	19(0.05)	4(0.01)	240(0.68)
Cumulative total		1(0.27)	1(0.11)	104(0.55)	185(0.64)	217(0.66)	236(0.67)	240(0.68)	
New Zealand				23	38	21	3	4	89
Australia				6	12	1	6	0	25
Ocean				7	3	1	3	0	14
West S. America		1		25	21	3	0	0	50
East S. America				42	7	6	7	0	62

Traditionally, the dispersal of seabirds has been studied from sightings at sea. Unfortunately, sightings of royal albatrosses are of limited value because of confusion between species. Also, because of their former sub-specific status, most past records of southern and northern royal albatrosses were combined (Roberston & Kinsky 1972; Enticott 1986; Marchant & Higgins 1990; Tickell 2000). More useful for determining distribution were the band recoveries from large numbers of southern royal albatrosses banded on Campbell Island since the 1940s, particularly in the 1960s-70s. Up to 1972, there were 119 band recoveries on the coasts and seas around New Zealand, Chile and Argentina (Robertson & Kinsky 1972). The timing and location of South American and oceanic recoveries suggested a circumpolar migration to feeding grounds in South America and back to New Zealand in an easterly direction (Robertson & Kinsky 1972; Enticott 1986).

This paper analyses the distribution of banded southern royal albatrosses found away from Campbell Island between 1943 and 2003, and updates details given by Robertson & Kinsky (1972). It also discusses potential influences and mortality factors associated with the band recoveries.

METHODS

Banding

A total of 35,289 southern royal albatrosses were banded on Campbell Island between 1941 and 1998 (Table 1). Small numbers were banded in the 1940s-50s (2.6% of all birds banded), but banding effort peaked in the 1960s (50.6%) and 1970s (28.7%), followed by a decrease through the 1980s-90s (18.0%; Table 1). In total, 24,258 (69%) birds were banded as chicks (37% and 38% of which were banded during the 1960s and 1970s respectively); and 11,031 (31%) were banded as adults (80% during the 1960s).

During the 1940s, bands were home-made rings of aluminium, copper or alloy and stamped with a unique number and inscription: "Return Southland Museum, N.Z." (Sorensen 1950, 1954). In the 1950s-60s the New Zealand National Bird Banding Office (NZNBBO) supplied mass-produced aluminium and monel (nickel-copper) alloy bands, and from 1967, hard-wearing stainless steel bands were used. They were stamped with a unique number and inscription: "Send Dominion Museum New Zealand".

Band recovery

The recovery of bands (or the band numbers) from birds found dead or alive away from Campbell Island relied on members of the public, fishers, fisheries observers, researchers and overseas banding schemes passing on the information to the museum or directly to the NZNBBO.

Data Management

We tabulated the numbers of adults and chicks that were banded each year from the 'Operator's Schedule' (a paper record) and birds found away from Campbell Island from a computer record held by the NZNBBO. We sought original letters, recovery forms and published records (e.g., Sorensen 1954; Robertson 1972a) to verify the original data compilation. Additional records were

Table 2 Regional location of band recoveries, and the ages of birds at recovery, of southern royal albatrosses beyond Campbell Island, 1943-2003. Ages defined in text.

	Number of recoveries						
	Location			Age			
	Coast	Sea	Unknown	Juvenile	Immature	Adult	Total
New Zealand	65	23	1	19	7	63	89
Australia	7	18	0	1	8	16	25
Ocean	1	13	0	2	3	9	14
West S. America	19	28	3	44	4	2	50
East S. America	10	52	0	12	26	24	62
Alive	6	71	1	22	27	29	78
Dead	96	61	1	54	21	83	158
Unknown	0	2	2	2	0	2	4
1941-71	48	73	1	46	33	43	122
1972-03	54	61	3	32	15	71	118
Total	102	134	4	78	48	114	240

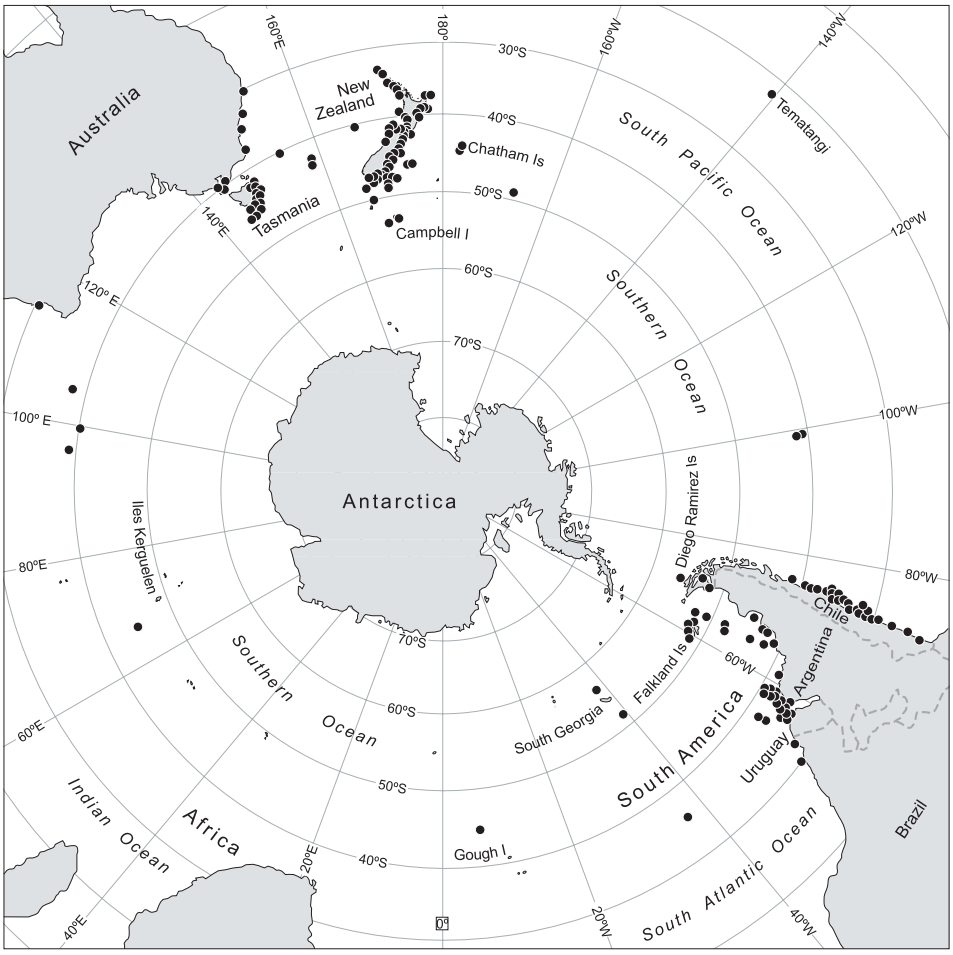

Figure 1 Locations at which 240 banded southern royal albatrosses from Campbell Island were recovered around the southern oceans, 1943-2003 (two records, in the Indian and Atlantic Oceans, are not plotted as positions were not given).

found in annual reports of bird banding (Sibson 1963; Robertson 1972b), folders of unusual bird recoveries, and miscellaneous Campbell Island papers (held by NZNBBO).

Years refer to breeding seasons, which are approximately from November (when eggs are laid) through to the following October - November (when chicks fledge). Hence, a breeding adult, which was banded in November 1963, and its chick, which was banded in August 1964, were both categorised as having been banded in 1963. A juvenile found away from the island between November 1964 and October 1965 was categorised as being recovered in 1964. Juveniles were considered to be birds <20 months old (approximately one year after fledging), immature birds were younger than six years old, and adults were at least six years old.

Statistical Methods

To explore variables that may affect the recovery location of southern royal albatrosses found away from Campbell Island, AnswerTree (SPSS Inc.) was used to create classification trees (De'ath & Fabricus 2000). Trees were constructed using the exhaustive Chi-squared automatic interaction detector (CHAID), stopping rule of 5 (maximum tree depth) and minimum cases of 20 (parent node) and 10 (child node). Geographic region was the target variable and divided into five areas: New Zealand (including eastern Tasman Sea, Chatham and Campbell Islands), Australia (including western Tasman Sea), western South America (Chile), eastern South America (Argentina, Uruguay and southern Brazil), and oceanic areas (Pacific, Atlantic and Indian Oceans). Other variables examined were age (juvenile, immature, adult), status (dead, alive), decade, month (numbered with November as the first month and October as the 12th month to follow the breeding cycle), and location (at sea, coastal).

RESULTS

A total of 240 (0.68%) banded birds were found away from Campbell Island between 1943 and 2003 (Table 1). The majority (65.8%) were dead (Tables 2, 3), including at least five birds that were destroyed because of their injuries or died shortly after their discovery.

Locations of recoveries

Band recoveries were in the southern hemisphere, mainly between latitudes 30-55°S (Fig. 1). The northern-most recovery was a leg bone found at Tematangi, Tuamotu Archipelago (21° 42'S, 140° 38'W), near Tahiti (Robertson 1972a) and the southern-most was a bird shot at Diego Ramirez Islands (56° 30'S, 68° 40'W), southern Chile.

Similar proportions (47.5% and 46.7% respectively) of recoveries were in Australasian (New Zealand and Australia) and South American regions, and the remaining 5.8% were in the Pacific, Atlantic and Indian Oceans (Table 2). Of all recoveries, 55.8% of birds were found at sea and 42.5% on land.

Classification tree analysis showed strong relationships between the recovery 'region' and five other variables ('age', $\chi^2 = 122.0$, $df = 8$, $P < 0.001$; 'status', $\chi^2 = 68.3$, $df = 4$, $P < 0.001$; 'location', $\chi^2 = 62.7$, $df = 4$, $P < 0.001$, 'month', $\chi^2 = 68.9$, $df = 12$, $P < 0.001$; and 'decade', $\chi^2 = 67.9$, $df = 12$, $P < 0.001$). 'Age' showed the strongest influence on region and created the first split of the classification tree. In other words, the different age classes were unevenly distributed: 56% of juveniles were in western South America, 54% of immatures in eastern South America, and 55% of adults in New Zealand (Table 2). The other classification variables were of subordinate influence within each age class. For example, juveniles branched further by 'month' into summer (November - January) records (n= 47), when they were either in New Zealand (34%) or western South America (66%) and the remainder of the year (n = 31), when they were mainly in western (42%) or eastern (39%) South America.

Coastal recoveries

Coastal recoveries of banded birds were mainly reported from the populated shores of southeast Australia and Tasmania, the east coast of South Island and west coast of North Island, New Zealand, central Chile, Argentina, and southern Brazil (Figs. 1,2). Band recoveries on islands included Tasmania and King Island in Bass Strait (Australia), Stewart and Chatham Islands (3 and 2 records respectively), Tematangi (Pacific Ocean), Chiloe (western South America) and the Falkland Islands (3 records; eastern South America).

Almost all (94.1%, n = 102) coastal records were of dead birds (Tables 2, 3). In some cases birds were found shortly after storms, but others were decayed corpses or skeletal material only (and hence died an unknown time earlier). One was found dead on a road in Argentina and three birds were found shot in different years at Kaikoura, New Zealand. Six birds that were found on the coast and released alive included a bird which was taken into captivity for rehabilitation and released successfully seven months later.

Recoveries at sea

Band recoveries at sea (n = 134) were usually in waters over the continental shelf (up to *c.* 200 m deep water; 55.2% of records) or slope (200-1000 m; 18.7%) (Figs. 2,3). Because the continental shelf is generally narrow off New Zealand (Fig. 2), Australia and Chile, these birds were within 50 km of land, whereas east of South America, where the shelf is

Table 3 Details of band recoveries of southern royal albatross away from Campbell Island, 1943-2003. ([1] Includes fishing, research and naval vessels and vessels of unknown type)

Location	Details	Number of recoveries			
		Alive	Dead	Unknown	Total
Coast	Shot	0	3	0	3
	Ill/exhausted	2	2	0	4
	Found, no other details	4	91	0	95
At sea	Total	6	96	0	102
	Shot	0	3	0	3
	Fishing line	2	30	0	32
	Fishing net	3	9	0	12
	Other vessels[1]	62	18	2	82
	Injured/exhausted	4	1	0	5
	Total	71	61	2	134
Unknown		1	1	2	4
Total		78	158	4	240

wide, birds were up to 200 km offshore (Fig. 3). The remaining birds were near the slope (1000-2000 m depth; 12.7%) or over deep oceanic water (2000-5000 m; 13.4%). These groupings are approximate as some positions were based on distances and directions from ports and others were generalised latitude-longtitude positions; e.g. six recoveries east of Argentina (Fig. 3; the original records were not found for confirmation).

Nine percent of recoveries at sea were in nets and 23.9% on long-lines. A higher proportion of birds died when hooked on a line (94.9%) than when caught in nets (72.7%). Fishing lines were responsible for 49.2% of all recorded deaths at sea; 63.3 % of long-line deaths (n = 30) were in Australasian waters, 26.7% in open ocean and 10% in western South America. The 18 dead birds from "other vessels" (Table 3) hit trawl cables, antennae, masts or wheel houses, or died from weather-related causes. Three birds that were shot off the coast of Chile included one taken for a university collection.

Over half (54.5%) of band recoveries at sea were of live birds (Tables 2, 3), 79% of which were in South American waters. The majority of these (43 birds) were in eastern South America; 38 were recorded in the 1960s and 17 were in the Mar del Plata area (Fig. 3) during winter 1968, resulting in the late-1960s peak in offshore recoveries from South America (Fig. 4). Correspondence with individual fishers from the area indicated that some birds were deliberately caught to read their bands (C.J.R. Robertson pers. comm.), partially explaining the high number of birds released alive (62 birds) from the "other vessel" category in Table 3, which included fishing, naval and research vessels. Other

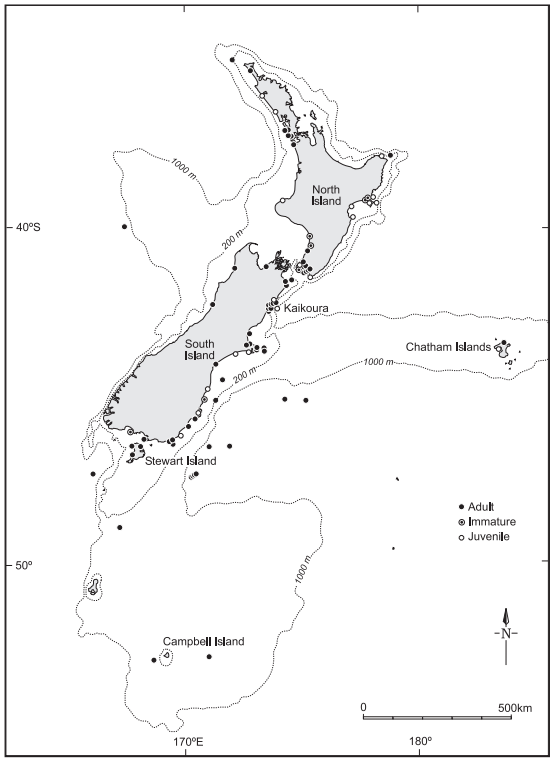

Figure 2 Locations at which, and age at recovery of, banded southern royal albatrosses from Campbell Island recovered in the New Zealand region, 1943-2003 (two locations near Campbell Island are approximate only).

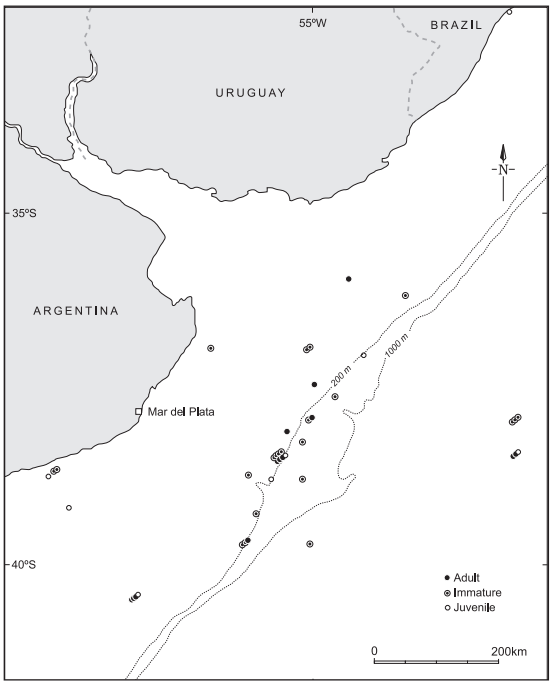

Figure 3 Locations at which, and age at recovery, of banded southern royal albatrosses from Campbell Island recovered in the Mar del Plata area of Argentina, 1943-2003 (some locations are approximate).

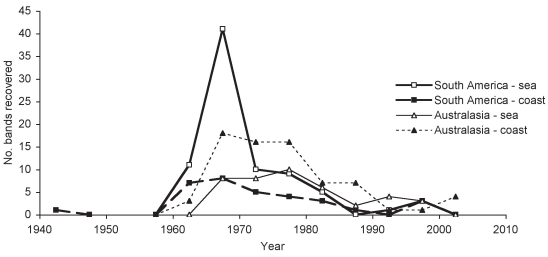

Figure 4 Numbers of banded southern royal albatross recovered in South American and Australasian seas and coasts, in five-yearly intervals, 1940-44 to 2000-04.

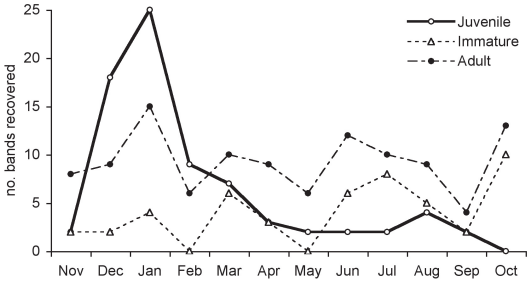

Figure 5 Annual distribution of recoveries of banded southern royal albatross away from Campbell Island, 1943-2003, for juveniles, immatures and adults.

live birds collided with, or landed on, the vessels. Generally it was not recorded what their condition was, but one bird hit a boat and fractured its wing and was released 10 days later. Approximately one-third (35.9%) of the live birds (Table 3) were released without their bands, and only 3 birds (6%) released with bands were later found on Campbell Island.

Age of recoveries

Birds were recovered as juveniles (32.5%), immatures (20%) or adults (47.5%) (Table 2). A higher proportion of birds banded as chicks were found as juveniles and immature birds in the 1940s-70s (113; 0.60% of 18,904 chicks banded during the same period) compared with in the 1980s-90s (13; 0.24% of 5354 chicks).

Recoveries of birds banded as chicks were made mostly in the first one (47.3%) or two (13.3%) years after banding (median 2 yrs, $\bar{x}$ = 4.3 ± *sd* 5.6, range 1-28, n = 165). The shortest interval was a chick banded on 27 October 1972 and found on the coast of Chile in November 1972. About half (52.0%) of the birds banded as adults were found in the first four years after banding (median 4 yrs, $\bar{x}$ = 7.3 ± 6.6, range 0-27, n = 75).

Ratios of recoveries in Australasia compared to South America were 1:2.8 for juveniles, 1:2 for immatures and 1:0.33 for adults. Of the immature birds recovered, more (57.6%) two and three-year-olds were found in eastern South America than other regions, whereas equal proportions (40%) of four and five-year-olds were found in eastern South America and Australia. Of the six to eight-year-old adults, the small number of recoveries (n = 12) were in similar proportions in New Zealand, Australia and east South America, whereas 74% of birds aged nine years and over were found around New Zealand.

In Australasia most recoveries on coasts (61.1%; n = 72) and at sea (82.9%; n = 41) were of adults, whereas in western South America 94.7% (n = 19) of coastal recoveries and 82.1% (n = 28) at sea were juveniles. Eastern South America the small number of coastal records were mainly adults (50%; n = 10) and at sea records were mainly immature birds and adults (46.2% and 36.5% respectively; n = 52).

Temporal pattern of recoveries

Most band recoveries were in the 1960s (43.6%) and 1970s (34.3%; Table 1). There were similar band recovery rates for birds banded as chicks (165; 0.68%) and adults (75; 0.68%). The highest rates were usually during the same decade that the birds were banded (Table 1) and this resulted in a similar temporal pattern of banding and recoveries. The exception was the 1950s cohort, which was

banded in the latter part of the decade, and consequently most recoveries were made in the 1960s. The high recovery rate during the 1960s (0.55%) compared with subsequent decades, and the longer period to accumulate records, resulted in the highest recovery rates for the 1950s and 1960s cohorts (0.92%, 0.87% respectively; Table 1).

Band recoveries were made in 39 different years, 29 of which were after 1970. Recoveries per region differed proportionally in different decades. For example, during the 1960s the largest proportion of records came from eastern South America, in the 1970s-80s from New Zealand, and in the 1990s from Australia and eastern South America (Table 1).

The highest numbers of recoveries occurred during the 1960s-70s in both Australasia and South America, but particularly at sea in the latter region in the late 1960s (Fig. 4). Of birds killed on long-lines, most were recorded in the 1960s, 1970s and 1990s (33.3%, 23.3% and 30% respectively; n = 30) and the least recoveries were in the 1980s (13.3%). No birds were recovered in western South America after 1980. The highest number of recoveries in a single year was made in 1968 (43). Relatively high numbers were reported from western South America in 1962 (5), 1968 (10) and 1972 (8); eastern South America in 1963 (7) and 1968 (22); and New Zealand in 1967 (6), 1968 (6), 1969 (7) and 1976 (10).

Birds were found at all times of the year, with the highest proportion of recoveries occurring in December (12.1%) and January (18.3%) and the lowest in May (3.3%) and September (3.3%) (Fig. 5).

There was a temporal and geographic pattern in the recoveries of juveniles (Fig. 5). For example, 78.9% of recoveries in New Zealand were reported in December-January (shortly after fledging), 79.5% of recoveries in western South America were reported in December-February, and 58.3% of recoveries in eastern South America were reported in July-September. For all locations, 55.1% of juveniles were found in December-January, with progressively fewer in later months. The monthly pattern of recoveries for immature birds fluctuated, with peaks in March, June - July and October following the pattern of recoveries in eastern South America. Adult recoveries also fluctuated through the year, with peaks in January and March-April (mainly New Zealand recoveries), and a June - August peak of mostly eastern South American recoveries.

DISCUSSION

Distribution

Early in the 20th century two centres of royal albatross distribution in the southern ocean were known: the New Zealand region near the breeding islands; and the coasts of Chile, Argentina and Uruguay (Oliver 1930; Murphy 1936). A report of large white birds breeding at Tierra del Fuego was thought to explain why so many royal albatrosses were found in South American waters (Murphy 1936) but this was never confirmed or given credence (Robertson & Kinsky 1972).

Band returns of southern royal albatrosses now provide a fuller illustration of the species' range, most records being between 30 - 55°S. The first band recovery in 1943 revealed that a juvenile had migrated to the coast of Chile (Sorensen 1954). Robertson & Kinsky (1972), and our larger data set, illustrate a progression of known-age birds from west to east around the southern ocean, with juveniles being found mainly on the shores or seas of New Zealand and Chile, and immature birds off Argentina. The temporal pattern of juvenile recoveries further illustrates this progression, with most juveniles in New Zealand found in December - January, having recently fledged from Campbell Island, followed by Chilean records in December - February, and eastern South American records in July-September. As most of 2-3 year-old birds were found in eastern South America, presumably these waters are important for their formative years, as well as for failed breeders and successful breeders taking a year off between breeding attempts. The migration to South American waters has been linked to a preference for scavenging post-spawning cephalopods, particularly the squid *Moroteuthis ingens*, which is found mainly over the continental shelf edge and inner slope seas of southern New Zealand and southern South America (Imber 1999). Older, 4-5 year-old immature birds were found near Australia, presumably returning to Campbell Island for the first time (Robertson & Kinsky 1972). In contrast, most adults of nine years or older were found around New Zealand, and presumably these were on foraging trips away from the Campbell Island breeding site.

Despite over 5000 southern royal albatross chicks having been banded on Campbell Island from 1980-96, there have been no further records from Chile and the number of recoveries of juveniles and immatures has more than halved compared with the period before 1980. Adult recovery rates also declined. The comparatively shorter time since 1980 for recoveries to accumulate could partly explain the decrease in adult recovery rate, but not for the younger age classes. Whether these results reflect changes in oceanography, behaviour, mortality or reporting rates is not known.

The use of satellite transmitters could clarify whether dispersal patterns of southern royal albatrosses have changed; however, as yet, only breeders within New Zealand waters have been tracked (Waugh *et al.* 2002; Birdlife International 2004). Fourteen breeding southern royal albatrosses,

carrying transmitters for one trip each in 1997 and 1999, foraged mostly in waters over the continental shelf and shelf break between Campbell Island and southern New Zealand (Waugh *et al.* 2002; Waugh & Weimerskirch 2003). The preference for shallow water (<1500m deep; Waugh & Weimerskirch 2003) supports the findings from band recoveries (74% of records in water <1000m deep; this study). Assuming dispersal behaviour is similar, some inferences about the southern royal albatross can be made from satellite-tracking of the closely related northern royal albatross; breeders and non-breeders foraged primarily over the shelf (<200 m deep), extending to the upper slope (<1000 m deep) (Nicholls *et al.* 1994, 2002), and non-breeders circumnavigated the globe at southern latitudes using the predominant westerly wind flow (Robertson & Nicholls 2000).

Biases in band recoveries

Distributions determined from band recovery locations can be biased. For example, a variable banding effort, as was the case for southern royal albatrosses where highly variable numbers were banded in each of six decades, may fail to provide enough recoveries to reflect changes in distribution over time. Where quality of banding varied between years (Moore 2003), bands may open and be lost. Recoveries, being reliant on voluntary return of information to the NZNBBO, may also have been inconsistent. For example, banded birds are caught because of curiosity about their bands (Moore & Battam 2000), as may have been the case for 17 live birds that were caught by three fishermen in Argentina in 1968. Beach-cast birds may not be reported because people do not check the birds' legs or realise the significance of a band. Fishers may ignore bands or, conversely, collect them as curiosities without reporting them (Moore & Battam 2000; Dyson 2002). Others may not wish to volunteer information to government agencies or researchers (Guillén *et al.* 2000) unless fisheries observers are on vessels (Prince *et al.* 1998). Reporting of band recoveries may also differ between countries because of different attitudes to the killing of birds, and this may change with growing conservation awareness (Stagi *et al.* 1998). In New Zealand, the NZNBBO's parent organisation or name changed several times, yet the band inscription "Send, Dominion Museum New Zealand" remained the same, confusing postal authorities trying to deliver to a long-defunct address with the result that many bands reports were not forwarded (M. Williams, pers. comm.). Apart from the disincentive of overseas postage, this may have exacerbated the decreasing trend in recoveries since 1980, particularly from South America (Table 1). Despite these biases, we consider the long period of banding and recovery provides a reasonable description of southern royal albatross distribution.

Banding is relatively passive and inexpensive compared with satellite telemetry. Ideally though, band recovery and radio tracking studies should both be done in concert and compared. For example, Prince *et al.* (1998) found a remarkable similarity between the locations of live satellite-tracked wandering albatrosses (*Diomedea exulans*) from South Georgia and birds recovered dead from long-line fishing vessels. Also, banding is a long-term monitoring tool by which changes in mortality, such as increased beach wrecks or fisheries capture, can be detected. For example, Prince *et al*. (1998) used band returns of wandering albatrosses in 1985-96 to show that birds were dying on long-lines at a higher rate than found previously.

Band recovery rate

The band recovery rate of 0.68% for the southern royal albatross from Campbell Island falls within the range found for other albatross species, but higher than that found for other species from Campbell Island. For example, 0.16% of banded grey-headed albatrosses (*Thalassarche chrysostoma*), 0.50% of wandering albatrosses, and 1.07% of black-browed albatrosses (*T. melanophrys*) were recovered away from South Georgia from 1959-96 (Prince *et al*. 1998), whereas 0.33% of banded Campbell albatrosses (*T. impavida*) and 0.01% of grey-headed albatrosses were found away from Campbell Island from 1957-96 (Waugh *et al.* 1999a).

Coastal records

The age distribution of coastal records reflected the age distribution pattern shown by band recoveries at sea. For example, more adults were found on New Zealand beaches, but mostly juveniles were found on Chilean beaches. Not surprisingly, most coastal records were near population centres, where people were more likely to encounter birds that had washed ashore. The majority of birds were dead from unknown causes, which may have included storms, starvation, sickness and fisheries-induced injuries.

In New Zealand, some band recoveries may have occurred during beach patrols for dead seabirds by the Ornithological Society of New Zealand (Powlesland & Imber 1988). Between 1939 and 1999 140 royal albatrosses (both species combined) were found during searches of New Zealand beaches (Bull & Boeson 1961; Powlesland 1985, 1986, 1987, 1989a, 1989b; Powlesland & Pickard 1992, Powlesland *et al.* 1992, 1993; Powlesland & Powlesland 1993, 1994a, 1994b; Taylor 1996, 1997, 1999, 2004) and a separate survey of lower North Island beaches after a serious storm found 91 northern and 19 southern royal albatrosses (Kinsky 1968). Royal albatrosses were

found more frequently (0.15 birds/100km) in 1960-83 (Powlesland 1985) than in 1984-99 (0.06 birds/100km; calculated from data in Powlesland 1986, 1987, 1989a, 1989b; Powlesland & Pickard 1992, Powlesland *et al.* 1992, 1993; Powlesland & Powlesland 1993, 1994a, 1994b; Taylor 1996, 1997, 1999, 2004). This would suggest that the recent decrease in band recoveries of southern royal albatrosses was not solely a result of the decreased banding effort. Whether this reflects a change in mortality factors is not known, although in a study of wandering albatross off the east coast of South America, the higher incidence of beach-cast birds in the 1990s was attributed to capture by fishers and birds being cut free from lines or thrown overboard (Prince *et al.* 1998). However, the rates at which seabirds are washed ashore may have more to do with climate change and its effects on ocean systems and coastal wind patterns (Scofield & Christie 2002).

Fisheries capture

The scavenging lifestyle of albatrosses causes them to be attracted to baits and offal around fishing vessels, with the associated risk of being caught and drowned. This bycatch has been linked to population declines in some species (Prince *et al.* 1998; Weimerskirch *et al.* 1997). Many of the band recoveries of southern royal albatrosses at sea were a result of interactions with fishing vessels and at least 49% of deaths at sea in our study were caused by long-lines. Almost two-thirds of these deaths were recorded from Australasian waters and a quarter from open ocean areas. Species that undergo circum-polar migrations, such as royal albatrosses, coincide and interact with fisheries throughout several regions (Gales 1998; Prince *et al.* 1998; Taylor 2000; Robertson *et al.* 2003b) and hence, the global fishing effort could potentially have a serious impact on their populations.

Seabird mortality in New Zealand may have peaked in the 1970s - 80s when total long-line fishing effort (especially Japanese) was at its highest and mitigation methods were not being used (Murray *et al.* 1993; Tuck *et al.* 2003). At the same time populations of some species commonly caught e.g., Campbell mollymawk (*Thalassarche impavida*), declined by as much as 47% (Waugh *et al.* 1999b; Moore 2004). Nest counts of southern royal albatrosses also suggest a stable or declining population during the mid-1970s to early 1980s and again in the 2000s (Moore *et al.* 1997; Moore unpubl.), although the peaks in long-line deaths for banded birds were in the decades immediately preceding these periods. After the mid-1980s, Japanese fishing effort in the Australasian region decreased and use of mitigation methods increased (Murray *et al.* 1993; Klaer & Polacheck 1997). Although Taiwanese and local fishing effort increased at this time (Tuck *et al.* 2003), observed catches of southern royal albatrosses in long-line fisheries in New Zealand waters was low after the mid-1980s (Murray *et al.* 1993; Manly *et al.* 2002; Robertson *et al.* 2003a, 2004). This may have favoured population growth of albatross species on Campbell Island (Moore *et al.* 1997; Waugh *et al.* 1999b; Moore 2004) in the 1980s - 90s.

The absence of oceanic cephalopods in the diet of southern royal albatrosses suggested that they rarely forage over deep water or overlap with pelagic long-line fisheries (Imber 1999). However, at least 24% of birds recovered at sea in our study were caught on long-lines and 26% were oceanic records over water deeper than 1000 m, which suggests that long-line fishing in the open ocean could potentially play an important role in mortality. Furthermore pelagic Japanese tuna long-liners catch royal albatrosses on the high seas (Uozumi 1998; Kiyota & Minami 2001) despite an increasing use of mitigation methods (Tuck *et al.* 2003). No southern royal albatrosses were killed in a small number of observed fisheries in Brazil (Neves & Olmos 1998) and Uruguay (Stagi *et al.* 1998), even though the species frequents Uruguayan waters (this study). However, with high albatross catch rates and recently developed long-line fisheries on the continental shelf areas of south-eastern South America (Prince *et al.* 1998; Tuck *et al.* 2003), there could be an increasing impact on southern royal albatrosses in this region.

Conclusion

Over a 60 year period, band recoveries of southern royal albatrosses have provided a valuable illustration of movements away from Campbell Island, with birds found mainly in the southern Australasian and South American regions. It also provided a record of mortality factors, such as fisheries long-lines. A scavenging lifestyle and circum-polar migration creates the potential for interactions with many fisheries around the southern oceans. A possible decrease in the southern royal albatross population during the late 1970s-early 1980s (Moore *et al.* 1997) during a peak in tuna long-line fishing effort suggests that new fisheries, or intensification of effort without adequate mitigation, could have a future negative impact on this species. Global climate change will also undoubtedly impact the marine environment and albatross populations (Inchausti *et al.* 2003; Weimerskirch 2004). It would be prudent, therefore, to monitor the trends, dynamics and foraging of a range of New Zealand albatross species, including the southern royal albatross, and correlate changes with anthropogenic and environmental factors. To this end, a co-ordinated strategy for research and monitoring of seabirds in New Zealand is required.

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