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Southern royal albatrosses (*Diomedea epomophora*) injured by bands

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Abstract More than 35,000 southern royal albatrosses (*Diomedea epomophora*) were banded on Campbell Island from 1941 to 1998. Recoveries of 2187 birds while breeding on Campbell Island during 1994-98 included 54 (2.5%) that were injured by their bands; over all years, 195 (3.4%) injured birds and 225 others with bands fitted incorrectly were reported. Injury rates were higher for birds banded as chicks (7%) than adults (0.5%). Untrained volunteer banders from the island's meteorological station banded up to 5200 birds annually, and in some years bands were not closed properly. The partially open bands eventually embedded in the leg or ankle, crippling the birds. Six annual banding cohorts were responsible for 83% of injuries and almost half (n = 90) came from the 1979 cohort. Banding quality improved after 1982 and only two injured birds have been found from more recent cohorts. The band's large circumference relative to its thickness may have contributed to it springing open with time, so a stronger band is recommended. For animal welfare reasons, a band repair operation should be conducted. If nothing is done, the situation will improve over the next 20-30 years as birds die, but regular band maintenance would prevent future problems.

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Keywords southern royal albatross; *Diomedea epomophora*; bands; injury

INTRODUCTION

Banding is a long-established and widely used technique for marking birds. Most bird marking techniques are known to cause injuries (e.g., Marion & Shamis 1977) but, generally, it is assumed that metal leg bands are fairly harmless as reported injuries are rare (Calvo & Furness 1992). Plastic colour leg bands and less conventional markers such as leg flags, wing tags, neck collars and nasal discs and saddles have more often been identified as injuring birds than metal leg bands. For example, the injury rate of 617 banded willow flycatchers (*Empidomax traillii*) was 9.6%, most of which was caused by plastic colour bands developing sharp edges; injuries from metal bands afflicted only 0.65% (Sedgwick & Klus 1997).

Banding of southern royal albatross (*Diomedea epomophora*) at its main breeding site on Campbell Island (52°32'S, 169°10'E), about 660 km south of New Zealand's mainland (Fig. 1) has a long history. More than 35,000 royal albatross were banded there between 1941 and 1998. Banding in the 1940s was part of a small nesting study (Sorensen 1950). In the 1960s, staff of the

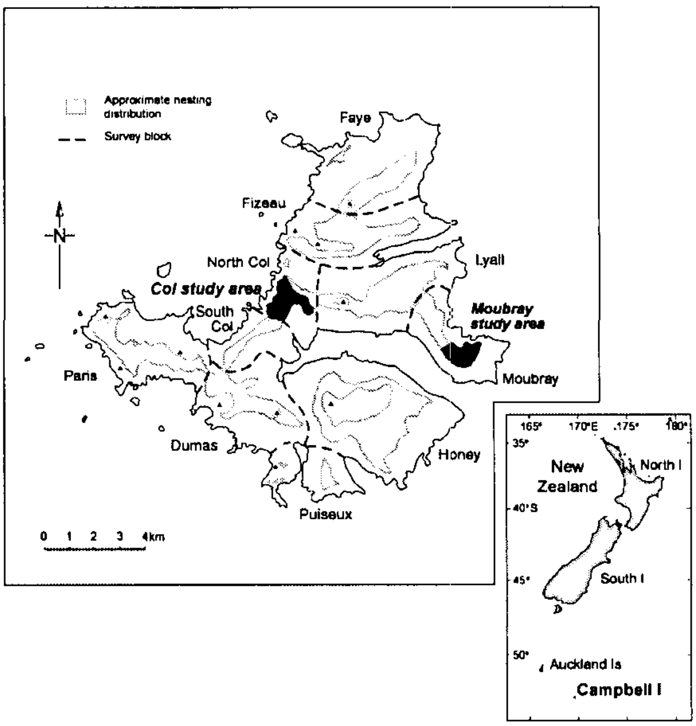

Fig. 1 Campbell Island, showing location of banding study areas and survey areas.

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meteorological station on the island were encouraged by Dominion Museum ornithologists to study the royal albatross and band as many adults and chicks as possible. The staff took up this task enthusiastically, marking and following the breeding success of up to 100 nests, often visiting nests daily and banding adults and chicks in many parts of the island. Bird banding was considered by island staff as important for recreation and exercise (Kerr 1976). Activity peaked in 1964-71 when 20,145 albatrosses were banded (57% of the 58-year total) including, in 1967, 2118 adults, 3015 chicks and 111 birds of unknown age.

The enthusiasm of island staff varied between years. Sometimes chicks were banded over the whole island and at other times mainly at Col and Moubray (Fig. 1). With less promotion of bird banding on the island, the numbers of albatrosses banded decreased overall by the mid-1980s.

I first became aware of albatrosses injured by bands embedded in their legs while surveying albatross nests at Col and Moubray in 1987 (Moore & Moffat 1990). We removed the offending bands and applied new ones to their uninjured legs. Around this time, unsupervised banding by meteorological station staff ceased. During five breeding seasons (1994 to 1998), as part of a more detailed albatross study, my field assistants and I systematically searched for banded birds in five areas of 200-600 nests.

In this paper I document the extent of the band-injury problem in order that it can be rectified or avoided in future banding programmes.

METHODS

Band type and shape

Bands applied to southern royal albatross carried a letter to indicate their size, and an individual number. In the 1940s home-made A-bands were used (Sorensen 1950), in the 1950s numbered bands without a prefix were used and in the 1960s-1990s, R-bands. Over the years the metal used for R-bands changed and the band's size decreased. Aluminium bands (80 mm circumference, 14 mm high x 1.7 mm thick) were used until 1966, monel (nickel-copper) alloy (73 x 15 x 1.0 mm) in 1966 and 1967, and stainless steel (66 x 12 x 1.0 mm) afterward. Exceptions were in 1978, when some smaller (56 x 12 x 1.0 mm) O-bands were used, and 1998, when some larger (74 x 12 x 1.0 mm) RA-bands were applied.

When fully closed and rounded the inside diameter of the aluminium, monel and stainless steel bands were about 23, 22 and 20 mm respectively. The circumference of royal albatross legs at the narrowest point of the tarsus was 56 ± 2 mm (n=14) for males and 52 ± 1.4 (n=14) for females and on birds with thin legs (usually small females) the circular bands could move up and down the tarsus and rest against the ankle joint when the bird was standing. However, for birds with thicker, more robust legs (usually large males), the smaller stainless steel bands required careful shaping into an oval that approximated the cross-sectional shape of the bird's tarsus (Fig. 2c).

Sources of data

Individual band histories of 35,000 birds were created by combining information from band schedules and a computerised recovery file, maintained by the New Zealand National Bird Banding Office (NZNBBO), and various band lists and collations (C.G. Surrey and D. Paull, 1960s; P. Dilks, 1970s; C.J.R. Robertson). A list of bands that caused injury or required adjustment was compiled from the annotations on the band schedules, comments on the recovery reports and sightings forms (paper records held by NZNBBO), entries in Moubray Hut Book (Campbell Island), collations from notebooks of G. Taylor (1984-86), annual band lists (1991-93), and my own field observations (1987, 1994-98).Years referred to in this paper are breeding seasons; e.g., 1987 is the 1987/88 season.

Before 1987, most injured birds were found opportunistically. Between 1987-94 most were found by observers in transit to different parts of the island or when visiting nests at Col and Moubray as part of breeding surveys. In 1994-98 they were found almost solely by checking the legs of incubating birds at those breeding areas and within the Faye, Honey and Paris survey blocks (Fig. 1). Some neighbouring areas were also searched to check the proportion of birds that were banded and injured by their bands.

Analysis of data

Injury categories

These were defined as:

minor – slightly open bands which caused skin swellings (Fig. 2a), pinched leg tendons or had broken the skin, bands that no longer moved on the leg because the skin had started to grow around the point of contact with the open part of the band or bands that had passed through a healed fold of skin. Blisters were observed in a few recently-banded birds but these were not included in the injury categories;

major – a band embedded in a large hard callus or gall of inflamed tissue, typically part-way up the tarsus or in the ankle joint itself, which crippled the bird (Fig. 2b). The foot could not be held flat on the ground, resulting in a pronounced lurching limp when the bird walked. Often, 10-30 mm of each end of the circumference of the band was buried in the tissue. In the worst example, a large gall had

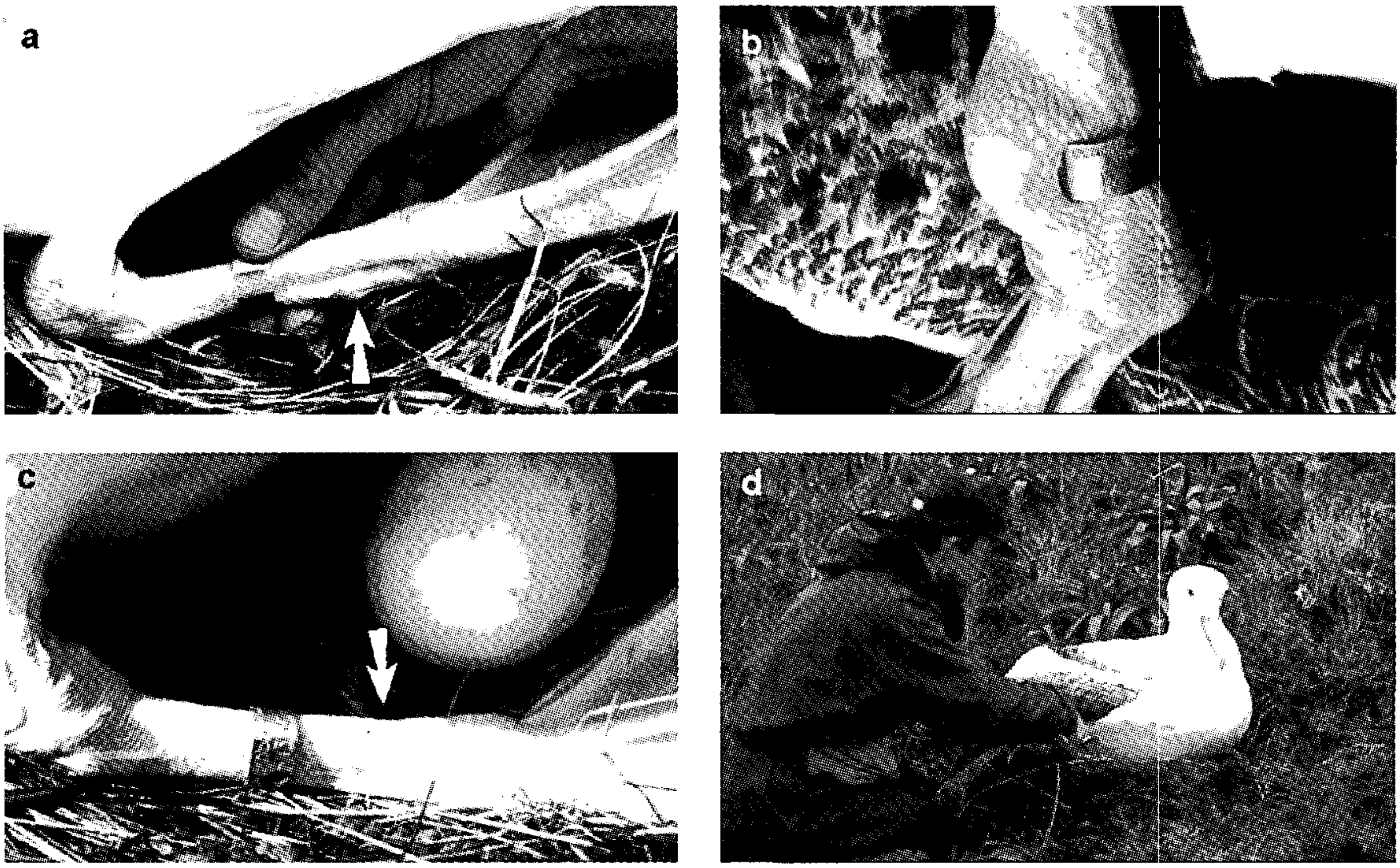

Fig. 2 a) A wide-open band irritated the leg and started forming a callus (indicated by an arrow). b) Typical injury of a southern royal albatross caused by the open band embedding into tissue of the lower tarsus and forming a large callus. Note that the ankle joint is crippled and the foot cannot be flattened properly. c) A correctly fitted band on the leg of a southern royal albatross. Note that for male birds with large legs such as this the band required careful shaping into an oval in order to fit it on. The indent near the ankle (indicated by an arrow) was formed by a misshapen band pressing on the leg. d) Banding a royal albatross at the nest requires skill and care but results in less visible stress to the bird or risk of abandonment of the nest than if the bird was handled.

formed either side of the leg and only a small section of the band was visible on the underside; and

probable – bands replaced or removed in 1984, 1986, 1987 and 1992 that came from high injury years or the recovery notes described them as "badly banded" or "badly fitted". Two individuals that had been put in this category were moved to the "major injury" category because they were later found to have typically scarred legs.

Band problem

Incorrectly fitted bands that had not caused injury included those that were:

wrong size – O-bands were too tight and caused indenting and compression of the leg. Stainless steel R-bands were very tight on the larger individuals and caused minor indenting of legs in the ankle area, but these were not considered incorrectly fitted;

wrong shape – the ends of the bands were skewed rather than flush or closed unevenly so that one arm of the band pressed onto the leg (Fig. 2c); and

not closed – the ends of the bands were partially or almost fully open.

Band injury rates and recapture probability

A model was created for 1994-98 data to test for the connection between band injury (and adjustment) rates and recapture probability (see Appendix 1).

Band adjustments

Injured birds had their bands removed, replaced or shifted to the other leg, or no action was taken. In some years banders improvised their equipment (Dilks & Dunn 1978) and in others banding pliers were supplied. These had cut-outs in the shape of a band circle but would not have been useful for removing bands. In the 1980s and 1990s, banders were carrying slip-joint gripping pliers for shaping and closing the band oval. 'Circlip' pliers with narrow prongs that opened outwards were used to repair any bands that were accidentally overlapped or had sprung open, to remove old or incorrectly fitted bands, or to extract embedded bands from the birds' legs. Except for serious

Table 1 Number of bands applied to southern royal albatrosses (*Diomedea epomophora*) on Campbell Island 1941-98, the proportion recovered in all years and 1994-98, and the number and proportion of those recovered that were injured birds, grouped according to the period that they were banded.

Decade	Birds banded					Birds recovered		Birds found injured			
	New bandings			Rebands	Total	All years	1994-98	All years		1994-98	
	Adult	Unk.	Chick			% of cohort seen	% of cohort seen	N	% seen	N	% seen
unk.	15	6	3	0	24	91.7	12.5	2	0	0	0
1940s	68	0	306	0	374	3.7	0	0	0	0	0
1950s	216	0	329	0	545	16.9	0.2	0	0	0	0
1960s	8648	165	9026	240	18079	16.5	1.2	46	1.73	7	3.15
1970s	816	87	9240	182	10325	11.6	6.4	131	11.2	41	6.36
1980s	129	136	3499	111	3875	26.1	20.5	15	1.53	5	0.64
1990s	731	14	1855	158	2758	21.4	20.9	1	0.18	1	0.18
Total	10623	408	24258	691	35980	16.4	6.2	195	3.44	54	2.47

Table 2 Number and proportion of banded southern royal albatrosses (*Diomedea epomophora*) on Campbell Island recovered in 1943-98, and the number and proportion of those seen that were injured by their bands or had incorrectly fitted bands requiring adjustment (Adj.)

Decade	Banded as adults						Banded as chicks						Unknown age		
	No. seen	% of cohort	No. injured	% of seen	No. Adj.	% of seen	No. seen	% of cohort	No. injured	% of seen	No. Adj.	% of seen	No. seen	No. injured	No. Adj.
unk.	15	100	0	0	0	0	1	33.3	0	0	0	0	6	2	13
1940s	12	17.6	0	0	0	0	2	0.7	0	0	0	0	0	0	0
1950s	68	31.5	0	0	0	0	24	7.3	0	0	0	0	0	0	0
1960s	2327	26.9	10	0.4	10	0.4	579	6.4	31	5.4	45	7.8	43	5	0
1970s	243	29.8	5	2.1	16	6.6	928	10.0	126	13.6	99	10.7	14	0	1
1980s	34	26.4	0	0	4	11.8	889	25.4	15	1.7	29	3.3	58	0	3
1990s	533	72.9	1	0.9	1	0.2	23	1.2	0	0	0	0	1	0	4
Total	3232	30.4	16	0.5	31	1.0	2446	10.1	172	7.0	173	7.1	122	7	21
Injury Years															
1967	258	12.2	5	1.9	7	2.7	158	5.2	24	13.9	35	22.2	35	2	1
1970	82	22.8	1	1.2	5	6.1	115	6.4	18	15.7	12	10.4	1	0	0
1973	0	0	0	0	0	0	14	16.5	1	7.1	7	50.0	0	0	0
1978	0	0	0	0	0	0	54	21.8	11	20.4	23	42.6	3	0	1
1979	21	25.0	1	4.8	5	23.8	166	12.9	89	53.6	25	15.1	0	0	0
1981	0	0	0	0	0	0	180	28.3	12	6.7	18	10.0	0	0	0

injuries and very nervous birds, applying a new band (Fig. 2d) and extracting the old band could be done without handling a breeding bird or removing it from its nest.

RESULTS

Number banded and recovered

Table 1 summarises the history of banding of royal albatrosses on Campbell Island; 69% were banded as chicks, 30% as adults and 1% of unknown age, and 2% were replaced in later years.

Sixteen percent of banded birds were seen in subsequent years, including 6% during 1994-98 and individuals from cohorts dating as early as 1957 (Table 1). Recovery of adults (30% of those banded) was higher than chicks (10%), although there was an increasing trend from 1-25% for chick recovery through the decades (Table 2) because of more intensive recovery effort in 1994-98 and an increasing concentration on banding at Col and Moubray. Few chicks were recorded from the 1990s cohorts because the recruitment age of 6-12 years had not been reached. Mean recovery rate of 30 annual cohorts of chicks (1957-87) was 14.9 ± 9.8% (range 4-39%).

Band injuries

Most injuries were major, as the leg was crippled by the embedded band (Table 3). This included four O-bands. All types of bands (aluminium, monel and stainless steel) caused injuries. The probably injured birds included 28 that had the problem band replaced and one O-band that was removed without replacement. Most incorrectly fitted bands were not closed properly (Table 3).

At least 195 birds were injured by their bands during all years combined (Tables 1-3). Nine injured birds were found during the late 1960s-1970s, 72 in the 1980s and 114 in the 1990s (54 in 1994-98). Records were found of 225 other incorrectly fitted bands, 55 that were found in the 1980s and 170 in the 1990s. The 54 injured albatrosses found in 1994-98 represented 2.5% of the total number of bands recovered in the same period (Table 1).

Injured birds were in all areas of Campbell Island, but the highest numbers found (68, 35% of all injuries) were banded at Moubray where also the greatest number of birds had originally been banded (9538, 27% of all bands). This area also had the most other incorrectly fitted bands (67), followed by the main study area, Col (62).

Most injured birds were originally banded as chicks (172, 88% of injuries), compared with only 16 adults (8%)(Table 2). Because fewer chicks were recovered overall they had a high injury rate (7%) compared with adults (0.5%)(Table 2). The remaining seven birds of unknown age when banded also had a high (6%) injury rate, suggesting that they were in fact banded as chicks. Other incorrectly fitted bands followed a similar pattern with adjustment required for 7% of birds banded as chicks and 1% of adults (Table 2).

Six years were identified as having high rates of injury (>7%) and other incorrectly fitted bands (>10%), particularly of chicks (Table 2). Together they comprised 83% of all injuries and 63% of other poorly applied bands. The year with the poorest banding record was 1979 with 90 injured birds identified, 89 of which were banded as chicks (54% of the cohort seen). A further 25 chicks from 1979 had incorrectly fitted bands, so at least 69% of the cohort was poorly banded.

The injury rate after 1982 was low compared with previous years, although few chicks from the 1990s had returned to the island (Table 2).

Band adjustment

A variety of adjustments to bands were made. For injured birds, 29 bands were removed and not replaced, 136 replaced, 22 shifted to the other leg and eight had no recorded action. For birds with incorrectly fitted bands, 32 bands were replaced, one was shifted to the other leg, 88 re-shaped or tightened and four had no recorded adjustment.

Table 3 Numbers of southern royal albatrosses (*Diomedea epomophora*) with injuries or other incorrectly fitted bands found in 1969-93 and 1994-98

	Injured by band			Incorrectly fitted band		
When found	minor injury	major injury	probably injured	wrong size	wrong shape	not closed
1969-93	1	111[1]	29	9	5	72[13]
1994-98	9	45	0	5	18	116
Total	10	156	29	14	23	188
		195			225	

NB – superscript refers to number of bands for which the band number was not recorded, one injured bird in 1993 and 13 birds that had their bands tightened on the same day in 1986

Recovery from injury

Forty-three (31%) birds that had been injured and 35 (48%) that had been found with incorrectly fitted bands before 1994 were seen again in 1994-98. It was noted that eight of the former group had galls of hard scar tissue on the currently unbanded leg, but generally both legs were not checked for scarring. Some of the eight birds held the foot in a manner that suggested that the ankle joint was still crippled, but the swelling was reduced compared with typical current injuries. Five unbanded birds were found in 1994-98 that had similar scarring and these were probably some of the 29 previously injured birds that had their bands removed but not replaced.

Survival of injured birds

Some years with high injury rates also had low band recovery rates. For example, 7.5% of chicks banded in 1979 were seen in 1994-98 (and 12.9% over all years), a lower proportion than other contemporaneous years (Table 2). However, 77% of the 1979 cohort was banded away from Col and Moubray in areas that have rarely been searched for bands.

A model was created for 1994-98 data to test for the connection between band injury (and adjustment) rates and recapture probability (Appendix 1). Its key summary statistic, the median value of the correlation parameter r is -0.503 (95% confidence interval -0.806 to +0.039) indicating a dependence between injury and band recovery. Thus, cohorts that had low recovery rates, after adjusting for location of banding and elapsed time since banding, tended to be cohorts with high band injury rates. However, the 95% interval estimate just includes zero, and so the evidence for correlation is not strong.

Current number of injured birds

In 1997 about 21% of breeding birds on the island had been banded previously, with higher proportions in traditional areas of banding activity (Table 4). The injury rates at Col and Moubray were low that year as most poorly-applied bands had been found and replaced or repaired in previous years. For example, nine injured birds were found at Col in 1994-96, but none in 1997. Therefore, the majority of injured birds were found in areas where there had been few or no previous searches for bands. For example, the combined injury rate at seven areas (excluding Col and Moubray) in 1997 was 5.8% (Table 4). The highest injury rate in an area was at Honey in 1996, when five (16%) out of 31 banded birds were injured.

By using the proportion of birds banded (Table 4) and population estimates for each area (Moore *et al.* 1997), it was estimated that in each year from 1994-98 there were 2300 banded birds amongst those present at the 8000 nests. Assuming an overall injury rate of 2.5% (Table 1), there would have been about 50 injured birds on the whole island in 1997 (20 were found at the areas searched, Table 4). Extrapolating the 5.8% injury rate to areas other than Col and Moubray, there may have been at least 100 injured breeding birds on the island in 1997. A similar number might be expected the following year because of the biennial breeding pattern.

Table 4 Proportion of breeding southern royal albatrosses (*Diomedea epomophora*) on Campbell Island in 1997 that were banded in previous years

	Breeding birds visited at nests				
Area	N	banded	%	injured	%
North Col	64	19	30	1	5.3
Col	420	357	85	0	0
South Col	242	74	31	4	5.4
Moubray	551	204	37	2	1.0
Moubray-Lyall	595	93	16	6	6.4
Lyall	57	6	11	0	0
Faye	657	59	9	4	6.8
Paris	439	35	8	0	0
Honey	400	25	6	3	12.0
Total	3240	687	21.2	20	2.9

DISCUSSION

The problem

More than 35,000 southern royal albatross were banded on Campbell Island over an almost 60-year period. Recoveries of birds away from the island during this period were valuable in determining dispersal patterns of adults and juveniles to and from South American waters (Robertson & Kinsky 1972). Banded birds of known age and history were invaluable for studies of breeding and population parameters (pers. obs.). Unfortunately, 0.5% of birds banded as adults and 7% of chicks were injured by their bands. If these rates applied to all the birds originally banded on the island, 106 adults and 1698 chicks may have been injured.

Sources of error and variation in band recoveries

The 195 injured royal albatross and 225 bands that needed adjusting are probably minimal as there are several sources of error and bias in the banding and band recovery data.

Differential band wear and loss between band types may have influenced return and injury rates, particularly in older series. Aluminium bands were notoriously short lived; for example, bands on kittiwake (*Rissa tridactyla*) were illegible after 2-3 years (Spencer 1977). Aluminium bands on Campbell Island were longer lasting, as 20-30 years after banding they were thin and worn but often still legible. Undoubtedly they (and incorrectly fitted bands) fell off as there are a few records of bands found on the ground and others that were barely closed enough to stay on the leg (pers. obs.). Monel alloy bands in Britain were prone to corrosion from salt water and became illegible (Spencer 1977), however, monel bands found on Campbell Island in the 1990s were still legible and in good condition.

Variation in numbers and proportions of adults and chicks banded on Campbell Island and differing survival rates would influence rates of recovery between years. Although biennially breeding adult albatrosses typically have 90-97% annual survival rates, immature birds have lower survival rates; e.g., about 50% of wandering albatrosses (*D. exulans*) and 15-23% of grey-headed albatrosses (*Thalassarche chrysostoma*) survive to five years of age (Croxall *et al.* 1990; Weimerskirch *et al.* 1997; Tickell 2000). Since survival of juvenile southern royal albatross is also low (10% overall), most of the potentially 1700 injured chicks from all years would have died anyway. Many may not have fledged, as banding times varied from April to October, and inexperienced banders may have lowered fledgling success. Poor handling technique commonly caused chicks to vomit (unpubl. hut-book entries), and apart from the loss of food, stomach oil soaked their plumage and made them vulnerable to cold conditions; e.g., several vomit stained chicks were found dead after a snowstorm in 1984, two-three weeks after they were banded (G.A. Taylor pers. comm.). Legs of chicks were also accidentally broken during banding (J. Henderson pers. comm.).

It is possible that birds crippled by their bands had a lower life expectancy. For example, return rates of adult willow flycatchers that were injured by their bands were significantly lower than for the population at large (Sedgwick & Klus 1997). There was evidence for this on Campbell Island, as suggested by the low recovery rate of the 1979 cohort, although the link between high injury years and recapture probability was not high overall.

Banding effort at different localities also varied, whereas searching for banded birds was more restricted to the breeding studies at Col and Moubray, hence the recovery rates of birds at other areas was low. Cohorts from the study areas had high return rates; e.g., 39% of the 1987 chick cohort was seen subsequently. The recent more widespread searches found birds banded 20-30 years previously.

Under-reporting of injuries was likely because there was no reporting form that dealt with the state of the band, nor a code in the electronic recovery file which dealt specifically with the band or band injuries. Annotations on forms were the only clue to injuries having taken place. All types of band have caused injury, but no reason was given for the majority of the 691 band replacements over all years. In many cases (judging from the band series) they were replacing old aluminium and monel steel bands. Some (judging from scars typical of old injures) had bands removed, shifted to the other leg, or replaced with no associated comments on the banding forms. Even the more thorough data of 1994-98 probably omitted bands that were tightened during routine nest checks.

Another possible reason for under-reporting was that, until the late 1980s, Campbell Island staff did not usually have appropriate equipment to remove bands. For example, an embedded band seen in November 1985 was not removed and replaced until March 1992. Most casual observers would not attempt to catch an injured bird without the training or equipment to operate on it, hence injuries probably went unreported. Conversely, if limping birds were more likely to be seen and captured and uninjured birds ignored, injury rates could be overestimated. Hence the higher injury rate of 3.9% before 1994 compared with 2.5% in 1994-98, when more systematic searches of birds sitting on eggs took place. A contributing factor to the decrease though was that the more recent recoveries included cohorts with lower injury rates.

Causes of band injury

Banding technique

It is not known whether royal albatrosses are more prone to injury than other albatrosses. Possibly their relatively fleshy legs are easily irritated by the edges of open bands. Many thousands of Campbell albatross (*Thalassarche impavida*) and grey-headed albatross were also banded on Campbell Island (NZNBBO)) and, although many bands are partially open, few have been reported as being injured. I have observed only one embedded band.

The main cause of injuries seems to have been very poor banding technique in some years or by some people. The year with the worst banding history was 1979, as 54% of the 166 birds seen from that cohort of 1283 chicks were injured and 15% more bands were incorrectly applied or had opened in the interim period, allowing potential for future injury.

Poor banding technique was a result of the lack of training and supervision given to banders. Training was a mixture of a verbal briefing before departure to the island and written instructions. For the most part, though, it relied on common sense, the experience of meterological staff who returned for a further year, and the exchange of information between staff during the annual change-over. Most were keen, careful and inspired by their contact with wildlife, but others were less careful, and in ignorance did not close bands properly (or handle the birds carefully). This may have been a result of a 'ring and fling' style of banding, since if the band is only closed with one squeeze of the pliers, it will inevitably spring open with a large gap. Adept banders could apparently process several hundred birds per day (Kerr 1976) and at times they competed for the greatest totals (unpubl. hut-book entries). However, more than 100 chicks banded in an eight-hour day seems unreasonably fast. At that rate, a two-person team (one holding a bird and one banding) would process one bird every five minutes, including travel between the dispersed nests.

The lack of feedback to island staff about recoveries of birds they had banded, or access to band histories, affected their enthusiasm for doing the job well (Dilks & Dunn 1978). Banding pliers were not always available and staff improvised their own equipment and protective clothing (Dilks & Dunn 1978). For example, heavy leather gloves with plastic inners (Moubray hut book entry, 1982) were sometimes used, which would have eliminated the manual dexterity required for applying a band correctly.

'Ring and fling' banding may have been age-specific. In the 1970s-1980s up to 150 adults and 2000 chicks were banded annually. The smaller number of adults may have been banded more carefully in the study areas (resulting in low injury rates), whereas widespread banding of chicks may have resulted in carelessness. However, during the 1960s similar numbers of adults and chicks were banded (up to 2000-3000 of each per year), yet injury rates were still higher amongst chicks than adults.

Band characteristics

The change in band construction from aluminium to monel alloy and stainless steel saw an improvement in quality and longevity of bands in other banding studies. Aluminium bands tended to corrode and wear quickly, especially in salt water or sand environments (Marion & Shamis 1977), resulting in band loss and underestimates of bird survival (Ludwig 1967; Ludwig *et al.* 1995). Leg injuries occurred occasionally (Marion & Shamis 1977) and in some cases birds died after feathers and skin froze to their bands (MacDonald 1961). Aluminium bands with sharp rims caused more injuries (e.g., calluses, skin overgrowth, severe swelling, leg loss and death from infection) to parrots than rounded stainless steel bands. Re-banding with stainless steel bands allowed parakeets to recover successfully from previous injuries (Meyers 1994). However, the use of stainless steel bands is not a cure-all and injuries have been reported (Calvo & Furness 1992); e.g., turkey vultures (*Cathartes aura*, Henckel 1976), willow flycatchers (Sedgwick & Klus 1997), and snowy plovers (*Charadrius alexandrinus*, Amat 1999).

Correct application of the R-band requires that both ends of the band be overlapped alternately during closure until the ends spring back into a butted and flush position. It is possible that the large R-band is too weak to remain closed indefinitely; e.g., some bands that were apparently satisfactory in the mid-1980s (G. Taylor, pers. comm.) subsequently required adjustment. R-bands used on takahe (*Porphyrio hochstetteri*) also sprang open by 1-2 mm after a year or more (D. Eason, pers. comm.), and on kiwi (*Apteryx*) R-bands tended to open by 2-3 mm over several years, although no leg injuries were noted (H.A. Robertson, pers. comm.). A similar-sized band used on Canada geese (*Branta canadensis*) often sprang open, requiring adjustment, and some birds were badly injured by their bands (M. Imber, pers. comm.).

The advent of stainless steel for durable bands created technical difficulties in their production and led to increased springiness (Spencer 1977). To keep the weight down for smaller birds, manufacturers reduced the gauge of steel to a minimum commensurate with mechanical strength, while increasing temper. This in turn increased springiness whereby the ends of the bands can open by small amounts over time, and this is more likely with large bands (Spencer 1977). Similarly, most stainless steel bands used in New Zealand are made from the same gauge, regardless of size of the band. A thicker gauge of steel for large bands would presumably make the band circle stronger and less likely to open.

The current R-band used on royal albatross may actually be too small for some birds as it is difficult to close on the large males, and the even smaller O-band crippled some birds. It is not known why the R-band circumference was reduced in circumference by 14 mm, but as all three types (aluminium, monel and stainless steel) were different sizes and all caused injuries, it is not clear what size is optimal. The NZNBBO supplied larger RA-bands for use on the larger individuals in 1998. However, these had even greater springiness than R-bands, so they are unlikely to reduce injury rates.

Bands may have contributed to leg injuries of the endangered kakapo (*Strigops habroptilus*), so as a precaution they were replaced with internally injected transponders (D. Eason, pers. comm.). While useful in confined areas or study sites and in small populations, transponders are less useful when the visibility of the tag is important. Most marks of wild birds make it a simple exercise for uninitiated members of the public to send records or the bands of dead birds to the bander or banding institution (Spencer 1977). For example, the reporting of band recoveries away from Campbell Island, either washed up on beaches or caught by fishing boats, would be markedly reduced without a visible band.

Banding issues in general

There are few examples of metal band injury problems in the literature compared with the number of studies that rely on banding (Henckel 1976; Calvo & Furness 1992; Sedgwick & Klus 1997; Clarke & Kerry 1998; Amat 1999). This may be because injury rates are generally very low, or workers seek to fix any problems without publicising them too widely or the issue is ignored. Most people regularly involved in banding studies are aware that problems occur, but by taking appropriate care to limit them, the knowledge gained through banding for the greater population is seen to outweigh the rare detrimental effects on individual birds.

A basic premise of banding is that each bird must be released uninjured and with minimal stress (McClure 1984), and the band must not be a potential hindrance or irritation to the bird (Marion & Shamis 1977; Calvo & Furness 1992). Any marking procedure that injures the bird is morally unacceptable (Ryder 1977). Only patient and considerate people should band, "all others become useless in the field" (McClure 1984). Albatrosses need to be handled with care to prevent injury to both parties. If banders wait patiently and allow birds to settle after they have approached them, or return on another occasion if necessary, even nervous birds can be banded on the nest (Fig. 2d). In this way, the birds are less agitated or likely to abandon the nest than if they are removed and restrained to band them.

CONCLUSION

The scope of albatross banding on Campbell Island could not have been achieved without the voluntary work by meterological staff stationed on the island, and it led to valuable findings on dispersal (Robertson & Kinsky 1972) and current work on population dynamics (PJM unpubl.) However, lack of training or supervision of banders led to years of poor banding technique which in turn left a legacy of injured birds that are now found throughout the island. For ethical and animal welfare reasons the problem should be rectified, a task that would take at least three summers of fieldwork. Over a five-year period, systematic searches in study areas for all banded birds and repair of any faulty bands resulted in a marked decrease in the incidence of injuries, whereas rarely visited areas had injury rates of 6% (up to 16%). Untreated, the injured birds from the late 1970s to early 1980s will gradually die out over the next 20-30 years. Fortunately, the quality of banding on Campbell Island increased after the early 1980s and only two crippled birds were found, although many chicks were yet to return to the island. The large R-band has a level of springiness that necessitates it be checked periodically for closure. Most recent banding focused on study areas and as birds tend to return to natal areas, band checking will be more manageable in the future.

It is unlikely that there will ever again be such a large-scale banding operation carried out by untrained amateurs in New Zealand, but the problems on Campbell Island illustrate the need for good supervision and training in banding programmes (Buckley *et al.* 1998). It is also important to allow resources and time for band maintenance (tightening, adjustment and replacement of old bands). Too often, at the end of a banding study, birds are left for many years or indefinitely without ever having their bands checked.

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Appendix 1

An analysis of the connection between band injury rates and recapture probability contributed by Richard Barker, Department of Mathematics & Statistics, University of Otago, Dunedin, New Zealand

A model was created for 1994-98 data to test for the connection between band injury (and adjustment) rates and recapture probability. Because there were so few birds with injuries that had been first banded as an adult, they were ignored. Whether or not a bird appeared in the 1994-98 recapture statistics depended on when it was banded, since fewer birds would be seen from earlier cohorts than from more recent cohorts. An initial analysis indicated that this effect could be modelled by a quadratic effect of time since banding. The probability of recapture in 1994-98 was allowed to depend on site of banding (Col, Moubray or other) and random year effects after accounting for the effect of time since banding. It was assumed there was no site effect for the probability that a bird was injured by its band (or the band required adjustment) given that it was recaptured. This was modelled as depending on an effect due to time since banding and a cohort effect. It was further assumed that the random cohort effects (for recapture or for injury) were sampled form a bivariate normal distribution with means 0 and correlation r.

Model

If X_{ij} is the number of birds recaptured in 1994-98 from n_{ij} birds released following banding as chicks in year i and at location j, then X_{ij} is modelled as a binomial random variable with parameters n_{ij} and p_{ij} where

$$\ln\left(\frac{p_{ij}}{1-p_{ij}}\right) = \beta_{0j} + \beta_1 T_i + \beta_1 T_i^2 + e_i$$

If Y_i is the number of birds recaptured in 1994-1998 that were injured or had their bands removed, then Y_i was modelled as a binomial random variable with parameters $X_{i\cdot} = X_{i1} + X_{i2} + X_{i3}$ and π_i where

$$\ln\left(\frac{\pi_i}{1-\pi_i}\right) = \alpha_0 + \alpha_1 + t_i$$

The pair (e_i, t_i) were modelled as bivariate normal random variables with means 0, standard deviations σ_e and σ_t, and correlation ρ.

The program WinBUGS (Spiegelhalter 2000) was used to fit the hierarchical model described above using Markov chain Monte Carlo (McMC) methods. Using vague prior distributions for the parameters α_0, α_1, β_{0j} (j = 1,2,3), β_1, β_2, ρ, σ_e, and σ_t, McMC was used to generate 100,000 values from the posterior distributions of the above parameters after discarding the first 5,000 (a burn-in sample).

Summary statistics for the posterior distributions of parameters in the hierarchial model are:

			Percentiles		
Parameter	mean	sd	2.50%	median	97.50%
α_0	-2.865	0.432	-3.786	-2.842	-2.076
α_1	-1.177	0.475	-2.158	-1.164	-0.268
β_{01}	-0.870	0.218	-1.297	-0.872	-0.434
β_{02}	-1.288	0.216	-1.712	-1.290	-0.854
β_{03}	-2.238	0.216	-2.662	-2.240	-1.805
β_1	0.371	0.169	0.026	0.373	0.698
β_2	-1.124	0.181	-1.498	-1.118	-0.784
σ_e	0.711	0.135	0.494	0.695	1.020
σ_t	1.657	0.375	1.072	1.608	2.520
ρ	-0.471	0.220	-0.806	-0.503	0.039

The Department of Conservation plans to remove bands from southern royal albatrosses on Campbell Island over three summers, beginning in 2004/05. In the Col study area the bands will be replaced with transponders to maintain a long-term marked population, but over the rest of the island, bands will be removed and not replaced.