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Long-term effects of flipper bands on penguins

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Changes in seabird populations, and particularly of penguins, offer a unique opportunity for investigating the impact of fisheries and climatic variations on marine resources. Such investigations often require large-scale banding to identify individual birds, but the significance of the data relies on the assumption that no bias is introduced in this type of long-term monitoring. After 5 years of using an automated system of identification of king penguins implanted with electronic tags (100 adult king penguins were implanted with a transponder tag, 50 of which were also flipper banded), we can report that banding results in later arrival at the colony for courtship in some years, lower breeding probability and lower chick production. We also found that the survival rate of unbanded, electronically tagged king penguin chicks after 2–3 years is approximately twice as large as that reported in the literature for banded chicks.

Keywords: life history; monitoring; conservation; seabird; banding; *Aptenodytes patagonicus*

1. INTRODUCTION

Individual identification of seabirds is usually required for studies of their ecology or behaviour. It also allows us to develop models to test how populations may be affected by the impact of fisheries and climatic variations, owing to changes in breeding success or survival (Ainley 2002; Croxall *et al.* 2002; Stenseth *et al.* 2002). In birds other than penguins, monitoring is possible most of the time by attaching a leg band that can be read by an observer. Penguins, however, owing to anatomical peculiarities of their leg joint, cannot be banded with traditional leg bands. As a result, flipper bands have been used widely since the 1950s. They are durable, cheap and easily read without human disturbance because recapture is not needed to identify band numbers. Flipper bands thus constitute the marking technique of choice in many banding programmes that are currently underway (Underhill *et al.* 1999; Wanless & Oatley 2000).

A serious problem is that some previous studies have suggested that flipper banding may have undesirable effects on penguins (Froget *et al.* 1998; Ainley 2002; Jackson & Wilson 2002). However, these studies did not address its long-term effects and, moreover, were undertaken during the summer when resources are most abundant and feeding constraints at sea on penguins are the lowest. These effects have therefore been assumed to be of short duration, i.e. to last for, at most, approximately 1 year, or the time needed for the birds to habituate to the bands (Barbraud & Weimerskirch 2001). Accordingly, although some investigators have stopped banding, large-scale banding programmes continue. For example, during the nine summer seasons between 1987–1988 and 1995–1996, *ca.* 36 000 penguins of 10 species were banded at localities throughout the Southern Ocean (Wanless & Oatley 2000).

2. MATERIAL AND METHODS

Since their breeding cycle lasts for more than 1 year, adult king penguins continue to visit the colony during the winter to feed the chick. Other species of penguins, with shorter breeding cycles, stay at sea during the winter. How flipper bands affect king penguin, *Aptenodytes patagonicus,* may therefore be investigated throughout the entire year, since its breeding cycle extends through the winter period. The growth of the chick is resumed only during the second summer after the onset of breeding by its parents (Barrat 1976). Our objectives were to examine differences in survival and reproduction between banded and unbanded birds. In a colony of 25 000 breeding king penguin pairs at Possession Island (46 25′ S, 51 45′ E), Crozet Archipelago, we employed automatic identification and data-logging systems to follow 100 adult king penguins for 5 years, 50 of which also received flipper bands. Identification is made with a transponder tag weighing 0.8 g (Texas Instruments Registration and Identification System) implanted under the skin of the bird's leg; the tag is activated electromagnetically, and because it requires no battery should provide information over the lifetime of the bird. Antennae buried on the three paths naturally used by the birds to go back and forth between the colony and the sea provide a permanently installed identification system. The journeys of the birds are undisturbed since there is no modification of any kind to the paths. The breeding cycle of the birds was established from their movements between the breeding area and the sea and using video recordings (see details in electronic Appendix A and Descamps *et al.* 2002).

3. RESULTS

The presence of the birds in the colony was characterized by a lower attendance of banded birds each winter, an effect that, over the years, also extended to the summer (figure 1). Penguin survival was investigated as a function of the decline in their presence. There was no significant size difference between birds that disappeared and those that returned, regardless of whether they were banded or not (i.e. there was no size-specific impact of banding) (bill length : fate (disappeared, returned) $F_{1,95} = 3.1$, $p = 0.74$, band $F_{1,95} = 0.70$, $p = 0.40$, interaction $F_{1,95} = 0.02$, $p = 0.89$; flipper length: fate $F_{1,95} = 0.67$, $p = 0.41$, band $F_{1,95} = 0.15$, $p = 0.70$, interaction $F_{1,95} = 1.97$, $p = 0.16$). The survival of banded birds over the 5 years of the study was identical to the survival of unbanded birds (Cox proportional hazards model, likelihood-ratio test = 1.53, d.f. = 1, $p = 0.22$) (table 1*a*; figure 2). However, a sample size of 283 animals per group would be necessary to detect a 10% difference in annual survival (with a significance of $\leqslant 0.05$ and power of 0.90). Moreover, given the long lifespan of king penguins (estimated to be *ca.* 20 years), it is possible that our 5-year analysis is not sufficiently long to show an effect of banding on survival.

Two aspects of reproduction were investigated. The first was a change in the timing of breeding, and specifically

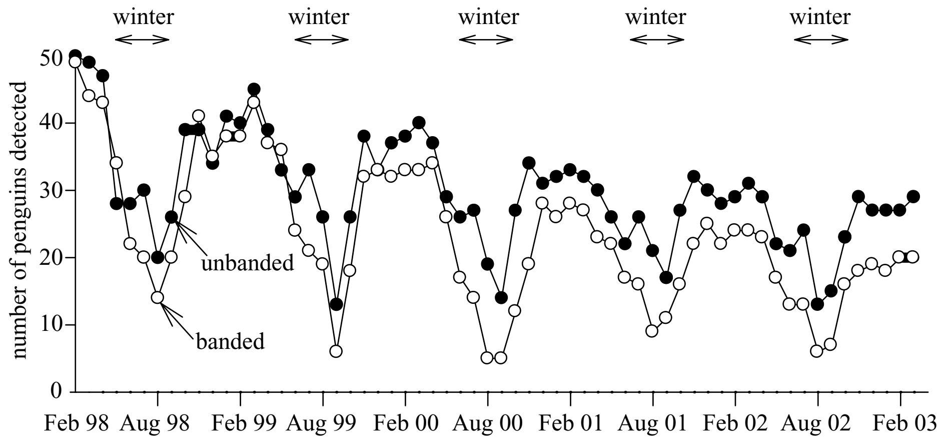

Figure 1. The numbers of banded (open circles) and unbanded (filled circles) birds detected by month over 5 years.

Table 1. (*a*) Annual return rate, (*b*) arrival for courtship and (*c*) reproductive success of banded ($n = 49$) and unbanded birds ($n = 50$).

parameter	banded	unbanded
(*a*) annual return rate (*n*, percentage)		
1998/1999	45 (92%)	45 (90%)
1999/2000	37 (82%)	40 (89%)
2000/2001	30 (81%)	35 (87%)
2001/2002	27 (90%)	32 (91%)
2002/2003	20 (74%)	29 (91%)
(*b*) arrival for courtship (mean date, s.e., *n*)		
1998/1999	30 November (4 days, 33)	11 November (2 days, 30)
1999/2000	7 December (5 days, 26)	29 November (4 days, 31)
2000/2001	12 December (3 days, 22)	19 November (1 day, 25)
2001/2002	14 December (7 days, 26)	12 December (8 days, 32)
2002/2003	5 December (6 days, 21)	14 December (5 days, 30)
(*c*) reproductive success (number of birds with a fledged chick, percentage)		
1997/1998	10 (20%)	15 (30%)
1998/1999	7 (15%)	9 (20%)
1999/2000	4 (11%)	9 (22%)
2000/2001	4 (15%)	11 (34%)
2001/2002	3 (11%)	10 (31%)

in the arrival dates of birds returning for courtship activities. Banded birds had a different pattern of return from unbanded birds (repeated-measures mixed model: group × time interaction $F_{4,163} = 4.45$, $p = 0.002$). Banded birds returned consistently to the colony for courtship in early to mid-December (table 1*b*; see figure 3 in electronic Appendix A). Unbanded birds had a more variable pattern of return (table 1*b*). In 1998/1999 and 2000/2001, unbanded birds arrived in early and mid-November while in the other seasons, unbanded birds arrived at times similar to the arrival times of banded birds (early to mid-December; table 1*b*).

Considering all birds that survived through one breeding season or longer after banding (i.e. 1998/1999 season or longer), the probability of breeding in any one year was 0.73. Using this probability to predict the breeding pattern for both groups over the four post-banding breeding seasons (1998/1999, 1999/2000, 2000/2001, 2001/2002), we found that neither group followed the predicted pattern ($G = 11.1$, d.f. $= 4$, $p = 0.03$). Unbanded birds tried to breed every year, whereas banded birds had a good probability of not trying at all (analysis of standardized residuals, $\alpha = 0.05$). Specifically, unbanded birds had a breeding probability of 0.83 whereas banded birds had a breeding probability of only 0.62.

The other aspect of reproduction examined was 1-year-old chick production. Banded birds produced fewer chicks per season than unbanded birds (table 1*c*; paired $t = -5.67$, d.f. $= 4$, $p = 0.005$). Banded birds produced a mean of 0.14 chicks per adult per season; unbanded birds produced a mean of 0.27 chicks per adult per season, or almost twice as many. Over the four breeding seasons, banded birds produced a total of 28 chicks whereas unbanded birds produced a total of 54 chicks (table 1).

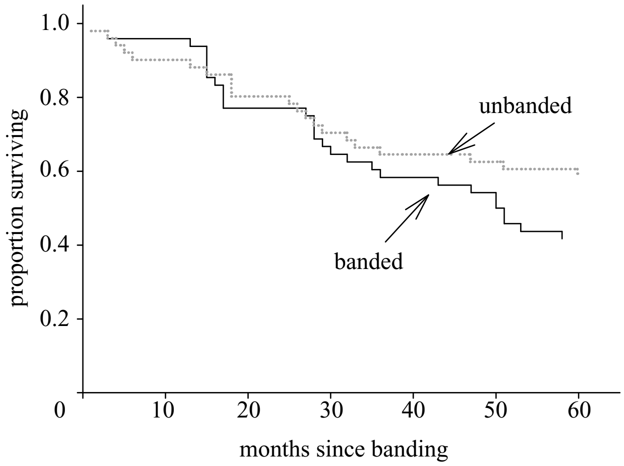

Figure 2. Survival curves of banded and unbanded king penguins using a Cox proportional hazards model with right censoring. Months after banding are based on the initial banding month of February 1998 (e.g. 10 = 10 months after banding, or December 1998).

Four banded birds each produced two chicks. Ten unbanded birds each produced two chicks and one unbanded bird produced three chicks. It is important to note that only one bird of any breeding pair was banded in our study. This would suggest that the impact of banding might have been even greater if both birds of each pair had been banded, as is usually done in multi-year investigations of penguin breeding success.

The question arises as to the bias that might also be induced in population studies of penguins by flipper banding of chicks. We therefore fitted two cohorts (100 chicks in 1998 and 200 chicks in 1999) of 10-month-old chicks with transponders before fledging. Because an effect of flipper bands on adults had already been observed, it would not have been ethically acceptable to band chick cohorts. Up to 81% of the fledged young returned to the colony after three winters and 74.5% after two winters, in the cohorts of 1998 and 1999, respectively.

4. DISCUSSION

The results showed that unbanded adults arrived earlier at the colony for courtship in two out of five seasons, had a greater probability of breeding each year and produced a total of 54 chicks versus 28 for banded birds over four seasons. The survival rate of unbanded king penguin chicks after two or three winters was approximately twice as large as that reported in the previous studies on banded chicks in subantarctic islands (47% in Brodin *et al.* (1998) and 5.6–39% in Weimerskirch *et al.* (1992)).

The impact of banding may be especially pronounced for king penguins because their breeding cycle includes the winter months when resources are less abundant than in summer, particularly near the colonies, and birds must expend more energy searching for food. The observed negative effects of banding may thus be partly owing to the increased energy cost for swimming that results from decreased hydrodynamic efficiency. Putting a single flipper band on Adélie penguins *Pygoscelis adeliae* has been found to result in more than a 20% reduction in near-surface swimming efficiency for several hours after banding (Culik *et al.* 1993). Whether or not the effect lasts for longer and how a flipper band affects swimming efficiency at depth as penguins forage has yet to be examined. Indeed, the drag effect of a flipper band could be critical when the bird is foraging at depths (200–300 m) where flipper power is required for the pursuit of prey (Sato *et al.* 2002). The adverse effect of flipper bands on king penguins during the winter may also be caused by their long travel distance to and from the pack ice, which corresponds to *ca*. 3500 km of swimming, and/or to the greater depth at which they then forage (Charrassin & Bost 2001). Furthermore, the breeding seasons require body reserves for survival through fasting in the colony, and king penguins attempt to synchronize their breeding cycle with the availability of lantern fish, their main prey, whose maximal abundance occurs in summer (Olsson 1996). The delayed returns of banded birds to the colony for breeding and the higher proportion of non-breeding banded birds could therefore be owing to a longer feeding period being required to attain a sufficient body condition for breeding fasts. In addition, since the synchronized return of the king penguin population to the colony would facilitate the opportunity for an ideal free mate choice (Olsson 1998), the arrival delay shown by banded birds may negatively affect their ability to find the best mates (those in best condition for breeding) and the birds would then be less successful.

It should be noted that king penguins are not the only penguins that have to face high variability in the marine environment within and between years. South American species experience El Niño and La Niña events (Boersma 1998). Tropical and subtropical penguins, moreover, are about one-third of the mass of king penguins, which would probably exacerbate any mass-specific negative effects of flipper bands.

In addition to the use of banded penguins as sensitive indicators of climatic changes (Barbraud & Weimerskirch 2001), other projects involving large-scale banding have objectives encompassing the conservation of species (Underhill *et al.* 1999; Goldsworthy *et al.* 2000). The long-term effects that we report here, however, raise important questions about the ethics and effects of banding in the broader issue of bias in scientific studies. The potential for disruption of the breeding cycle leading to reduced chick production and chick survival are clearly not in the interest of penguin conservation, particularly in the case of endangered species. Scientifically, we may have to reconsider our present knowledge on the life-history traits of penguins, such as breeding success and chick survival, which over the years has been drawn almost entirely from flipper-banded birds. For new investigations, long-term validation studies of any new type of penguin band should be made before ambitious studies on population demographics are launched. As we demonstrate here, small implanted electronic tags may be used, enabling their identification on their unchanged paths, with the added benefit of greatly reducing investigator disturbance near colonies. This method also provides an autonomous, automatic way of monitoring animal populations, which introduces earth-science-like observatories into the life sciences.

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