# IS FLIPPER BANDING OF PENGUINS A PROBLEM?

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Flipper bands allow individual identification of penguins and have helped to answer many key questions about penguin biology. Indeed, much of what we know about penguin natural history results from this marking technique, which makes identification of individual birds easy and has substantially contributed to the conservation and management of penguin populations. Flipper-banding studies demonstrated the remarkable rehabilitation success of oiled African Penguins *Spheniscus demersus* after the 1994 *Apollo Sea* oil spill in South Africa (Nel *et al.* 2003). As a result, strong and rapid mobilisation of resources to move and rehabilitate penguins in the 2000 *Treasure* oil spill was possible, preventing the potential loss of 36 000 penguins (Nel *et al.* 2003). However, evidence exists that flipper bands may adversely affect some penguin species, suggesting caution in band design and use (Cooper & Morant 1980, Jackson & Wilson 2002).

Any animal-marking technique has costs—whether financial, logistic or ethical. The question is how do those costs compare to the benefits? In the case of bands on birds in general, a wealth of evidence exists indicating that band loss is sometimes so high with some band designs, especially bands made of aluminium, that subsequent recoveries are useless for life-table analyses (Ludwigh 1967, Kadlec & Drury 1968). Moreover, laboratory studies show that even the colour of a band may influence the survival rate in some birds (Burley 1985). Despite the wide use of bands to mark individuals, only a few papers have critically evaluated band effects (Marion & Shamis 1977). Penguins, unlike other birds, are banded on a flipper instead of a leg, because leg bands are difficult to see, especially if the terrain is wet and muddy. For this reason researchers switched to the use of flipper bands (*cf.* Richdale 1957, Sladen 1958). However, some flipper bands have adverse effects (Jarvis 1970, Cooper & Morant 1981, Ainley *et al.* 1983, Sallaberry & Valencia 1985, Ainley 2002). An evaluation of the costs and benefits of different penguin marking techniques (e.g. materials, format and dimensions of bands, species and environmental conditions) is long overdue.

In January 2004, WWF–South Africa funded a workshop held in Cape Town, South Africa, which was co-hosted by BirdLife South Africa and Marine and Coastal Management, Department of Environmental Affairs and Tourism. The workshop brought together South African biologists, managers and conservationists to address the issue of flipper banding in penguins—particularly in relation to the African Penguin—and to compile a set of recommendations and guidelines to facilitate decisions about the circumstances in which flipper banding might be appropriate. The Cape Town workshop led to specific recommendations (Petersen & Branch 2004, Petersen *et al.* 2006) that have subsequently been adopted and applied in South Africa. Further presentations and debate on the subject occurred at the Fifth International Penguin Conference held in Ushuaia, Argentina, in September 2004.

## WHAT EVIDENCE IS THERE THAT FLIPPER BANDS CAUSE HARM TO PENGUINS?

### Effects on swimming and diving

Penguins swim with their flippers. They have very low drag coefficients while swimming (Bannasch 1994, 1995). On that basis, it has been conjectured that flipper bands may impede swimming in a number of ways. The band may block part of the wing profile, and as a result, part of the flipper may no longer contribute to thrust generation and propulsion. The entire flipper may become less efficient as changes in water circulation and distribution over it create surplus trailing vortices at its proximal end. Furthermore, the flipper band may disturb water-flow patterns over the body surface behind the flipper, thereby increasing drag and consequent energy costs. A band on one flipper may also cause asymmetry in the loading of the flippers and consequently in the kinematics of flipper action (Bannasch 1994). Whether penguins learn to compensate for wearing bands remains unstudied and unknown (see later text).

### Ecological effects

Seven studies on the effects of flipper bands on penguin ecology were summarized by Jackson & Wilson (2002). A synopsis follows. Survival of Adélie Penguin *Pygoscelis adeliae* adults banded with large aluminium bands was found to be as much as 28% lower in the first year after banding as compared with other years. Reduced survival caused the banded segment of the study population at Cape Crozier, Ross Island, to decrease 3% more rapidly than the unbanded segment, which was itself decreasing because of increased ice cover, albeit at a slower rate (Ainley *et al.* 1983, Ainley 2002). Similarly, survival of adult Adélie Penguins was lower (although not statistically significantly so) among flipper-banded birds (band design unspecified) compared to unbanded birds given microchip transponders at Béchervaise Island (Clarke & Kerry 1998). Yet another study of Adélie Penguins showed that bands could increase swimming costs by 24% (Culik *et al.* 1993). Return rates of double-banded King Penguins *Aptenodytes patagonicus* were 31.3% and 6.7% lower than those of single-banded birds (band design unspecified) in the first and second years after banding, respectively, and single-flipper-banded birds had annual survival rates 21.1% lower than those of birds fitted with subcutaneous transponders (Froget *et al.* 1998). Banded adult King Penguins spent significantly less time in, and returned less frequently to, their colonies than unbanded birds did; they also started courtship later, made longer winter foraging trips and bred less successfully (Gauthier-Clerc *et al.* 2001). However, among Royal Penguins *Eudyptes schlegeli,* no differences in chick growth, fledging success and adult overwinter survival were observed between flipper-banded adults and adults injected with a transponder (Hindell *et al.* 1996).

Part of the problem of flipper bands rests in the nature of the bands themselves (Cooper & Morant 1981, Boersma & van Buren 2004), and many of the above authors (Clark & Kerry 1998, Culik *et al.* 1993, Froget *et al.* 1998, Hindell *et al.* 1996) failed to specify the design of the band employed, making comparisons difficult. Bands that have sharp edges or that become loosened (certainly an attribute of aluminium bands), can readily result in physical damage or in penguins becoming ensnared in vegetation in some instances. The latter has been a specific problem at Robben Island in South Africa, where the birds breed in dense vegetation. Flipper bands must allow for the swelling that occurs during moult (Jarvis 1970, Cooper & Morant 1981, DeNapoli & Urquhart 2000). Feather wear is one of the problems caused by flipper banding, which may result in bare skin, broken skin or an open wound, in order of severity.

After the review by Jackson & Wilson (2002), several more studies, most yet to be published, but presented or discussed at the Fifth International Penguin Conference in Ushuaia in September 2004, have provided further insights into the problem:

- A study of Magellanic Penguins *Spheniscus magellanicus* that used various marking techniques considered the ecological cost of wearing a flipper band over an extended period of time (Boersma & van Buren 2004). In 1993, 50 pairs of Magellanic Penguins were double-banded with aluminium bands made by Gey Band and Tag Company. These were the bands used in the study reported by Ainley *et al.* (1983), discontinued in that locale in the 1970s, but then used for a time in the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) studies on the Antarctic Peninsula. Another sample of 50 pairs were double-banded with stainless steel bands designed by DPB and made by Lambournes, and 50 pairs were tagged with two Monel 1005-3 mouse ear tags (2×10 mm) made by National Band and Tag Company. The ear tags were attached to the outer web of the left foot. By January 1994, several aluminium tags had opened or turned around on the flipper, and eight birds had died. The difference was not statistically significant between double-banded and web-tagged birds. The authors concluded that not all bands are equal: penguins with aluminium bands had lower survival and more injuries than penguins with stainless steel bands or web tags.
- In a study of African Penguins on Robben Island, South Africa, data collected over four years from three experimental groups of *c.* 20 nests each (unbanded, conventional metal flipper bands and experimental rubber silicone bands) showed little difference in breeding success between the groups (Barham *et al.* 2004).
- Wolfaardt & Nel (2003) showed that when breeding (especially feeding) conditions were average or better, African Penguins that had been rehabilitated and banded after the *Apollo Sea* oiling “fared as well, and sometimes better than, control birds. However, in studies conducted during periods of food shortage or unfavourable breeding conditions the *Apollo Sea* birds were less successful at raising chicks than control birds [were]” (unoiled and unbanded). Thus, flipper banding may have little or no adverse effect on African Penguins when food supplies are adequate, because birds that were doubly disadvantaged by oiling and banding did not show any reduction in breeding success. Wolfaardt & Nel’s data show that when food was limited, birds that had been oiled, rehabilitated and released with bands performed poorly relative to control birds, although the affects of oiling and rehabilitation could not be separated from the effects of flipper banding. These results suggest that any negative effects of flipper banding are only likely in years when food is short and penguin condition is thus poor. Further research is necessary to separate any long-term effects associated with oiling from those of banding. These results for African Penguins paralleled those for King Penguins at Iles Crozet (Gauthier-Clerc *et al.* 2004) and support the hypothesis that adverse effects associated with bands may be manifested only during periods of reduced prey availability.
- Finally, Dugger *et al.* (in press) collected data from two groups of Adélie Penguins (one group fitted with flipper bands and transponders, and the other with only transponders), with new samples tagged in each year, over four austral summers (2000/01 to 2003/04) on Ross Island, Antarctica. They found that stainless steel flipper bands (DPB design) reduced apparent annual survival by 10%–13% in all four seasons. The study also noted high annual variability, including years of very high survival, equivalent to the highest measured in unbanded penguins, among banded birds in 1996 and 1997 (no transponder data available). However, since the 2000/01 breeding season (the first year of the band-effect study), two very large icebergs grounded offshore to almost entirely occupy the feeding area of the large Cape Crozier colony, erecting a wall separating it from the other colonies in the western Ross Sea. Because of the resulting increased severity of breeding conditions, in addition to the band effects on apparent survival, the study detected decreased breeding population size and philopatry, poor reproductive success and decreased breeding propensities—all of which could have led to lower survival. This study also found little support for an earlier hypothesis that band effects, at least for the Boersma design, take place only in the first year after banding (although aluminium bands were used in the early study; Ainley *et al.* 1983, Ainley 2002). The new band design takes into account the increase in flipper size during the moult period, thus perhaps alleviating problems of increased mortality in the first year after banding. Some data indicate that it is possible that penguins learn to offset costs of wearing a band (as noted earlier). For example, Dugger *et al.* (in press) found that foraging trips were longer on average for banded than for unbanded birds, but birds undertaking longer trips brought back more food in three of the four seasons examined.

As of 2006, 12 studies (nine published) were available on six species of penguins for which data on flipper-band effects existed (Table 1). One species (Adélie) was studied in the Antarctic, two (King and Royal) in the sub-Antarctic and three (Magellanic, African and Little *Eudyptula minor*) in temperate climes (Dann *et al*. 2000, studies cited earlier). Deleterious effects were found under some conditions for four of the six species. However, researchers need to better understand differences among band types, among regions and among species.

Different species of penguin differ in the water and climatic conditions they experience. In addition to these variables, the studies mentioned differed in band material and design. Because the type of band, its construction and dimensions, and the experience of the banders are often not reported (Gauthier-Clerc *et al.* 2004), comparisons within or among species are difficult. Moreover, band design has evolved, making comparisons between old flipper bands and new ones inappropriate (e.g. Dugger *et al.,* in press). Individual penguins also vary in body size and thus bands vary in their fit among individuals. Ballard *et al.* (2001) found, for instance, that individual variation explained the largest difference in foraging behaviour in a study of the effects of instrument attachment in penguins.

## INTERNATIONAL POLICIES AND RECOMMENDATIONS

Two international workshops on the subject of penguin flipper banding, both under the auspices of the Scientific Committee on Antarctic Research (SCAR) Bird Biology Subcommittee were held in Monticello, Minnesota, USA, in July 1993 (Fraser & Trivelpiece 1994), and in Cambridge, UK, in July–August 1996 (Fraser 1997, SCAR 1997). Both recommended that flipper bands no longer be considered the marking method of choice for penguins, and that they be used with caution. In Shanghai, China, in July 2002, the SCAR Life Sciences Standing Scientific Group (LSSSG) adopted Recommendation XXVII, LSSSG 14, which had been drafted by the SCAR Group of Experts on Birds (formerly the Bird Biology Subcommittee). That recommendation reads "caution should be taken when designing research programmes that require the external marking of penguins, especially when using current designs of metal flipper bands for demographic and other long-term studies, and to implement alternative methods of marking penguins immediately."

## COMPARISONS AMONG MARKING TECHNIQUES

The eight marking techniques for penguins that currently exist can be grouped into six categories:

- Remote tracking
- Flipper bands
- Subcutaneously implanted transponders
- Dyes or bleach
- Web tags, punches or other marks
- Photographic identification

Remote tracking is generally used for shorter periods than banding, but it yields high-quality information and precise, continuous data on movements (Wilson *et al.* 2002, Boersma *et al.* 2002). Hydrodynamic effects are substantial, but owing to the very high cost of the instruments and research, only a small number of birds are affected for short periods.

Flipper banding is relatively inexpensive, but in the past it involved a large number of birds and yielded mainly demographic data. Tarsal and leg bands are not recommended for penguins because of low visibility, high wear and loss of feet and other injuries (Sladen 1958, Cooper & Morant 1981).

Subcutaneous transponders have the potential to generate large amounts of accurate data, provided recorders can be installed to achieve adequate reception and the instrumented birds are persuaded to move past the recorders (e.g. on walkways) (Clarke & Kerry 1998). However, these tags are expensive and may be appropriate only in certain types of colonies. Implantation of transponders is briefly invasive and, without proper procedure, may lead to infection.

**TABLE 1**
**Summary of studies assessing the effects of flipper bands on penguins**

| Reference | Species | Study site | Study duration | Effect found |
|---|---|---|---|---|
| Ainley *et al.* 1983, 2002 | Adélie Penguin | Cape Crozier, Ross Island, Antarctica | 15 Years | Negative effect on survival |
| Barham *et al.* 2004 | African Penguin | Robben Island, South Africa | Ongoing | Unresolved, unpublished |
| Clarke & Kerry 1998 | Adélie Penguin | Béchervaise Island near Mawson Base, Eastern Antarctica | 3 Years | Negative but statistically insignificant effect on survival |
| Culik *et al.* 1993 | Adélie Penguin | Ardley Island, Shetland Islands, Antarctica | 40-Minute swims of one penguin | Negative effect on energetic cost |
| Bannasch 1995 | Laboratory model–based | | | Theoretical model predicts energetic costs |
| Dugger *et al.* (in press) | Adélie Penguin | Ross Island, Antarctica | 4 Years | Inconsistent negative effect on survival; no effect on foraging |
| Wolfaardt & Nel 2003 | African Penguin | Dassen Island, South Africa | 6 Years | No effect on breeding success or survival, except possibly during food scarcity |
| Boersma & van Buren 2004 | Magellanic Penguin | Punta Tombo, Argentina | Ongoing | No effect on survival, unpublished |
| Froget *et al.* 1998 | King Penguin | La Baie du Marin, Possession Island, Crozet Archipelago | 5 Years | Negative effect on breeding phenology |
| Gauthier-Clerc *et al.* 2001, 2004 | King Penguin | Possession Island, Crozet Archipelago | 5 Years | Negative effect on breeding phenology |
| Dann *et al.* 2000 | Little Penguin | | Ongoing | Initial results indicate negative effect, unpublished |
| Hindell *et al.* 1996 | Royal Penguin | Bauer Bay, Macquarie Island | 1 Year | No effect on breeding success |

All of the foregoing methods allow for the identification of individual birds. Dyes and bleaches are most useful for marking whole cohorts, or large groups of birds, rather than individuals, but they have been used to individually mark small groups of birds. This marking method has the disadvantage of lasting, at best, only until the bird moults, and it may conceivably increase mortality by making the individual more attractive to predators.

A potentially useful technique presented at the Fifth International Penguin Conference was a digital-image recognition system at least for species of the genus *Spheniscus,* which show individual variation in plumage markings. For example, each African Penguin carries a unique pattern of black spots on its chest that does not change through moults. Preliminary testing of a computer recognition system has begun. Theoretically, a system could be developed to identify and record the movements of up to 100 000 individual penguins, possibly obviating the need for any further banding of individuals of this species (Burghardt *et al.* 2004). As in the case of transponders, the penguin must appear at a location, and in a frontal orientation.

None of the marking methods evaluated to date will provide all the information required for all past and current studies.

## STUDIES OF THE EFFECTS OF MARKING

Three approaches could be used to investigate and quantify adverse effects of flipper bands on penguins. The choice of procedure depends on the effects to be studied. Regardless of procedure, the statistical method to handle data analysis should be considered before the study is begun. It is important to control for species, band design, band material and band application. Ethical consideration should be taken into account given current evidence of effects of metal flipper bands.

First, annual survival and return rate can be compared for birds with and without flipper bands and transponders. Some birds should be marked with a transponder only and others with both a transponder and a flipper band. Adequate controls for the effect of the transponder are also needed. Sufficiently large numbers should be marked for statistical rigour, and comparisons made over a series of successive years to allow for differences in environmental conditions.

Second, comparisons can be made between double-banded and single-banded birds. Such an approach may be the only viable option for juveniles, among those species in which juveniles visit colonies, as resighting of these birds is less predictable. Careful thought needs to be given to proper experimental controls to address the greater resighting rate of double-banded birds, and the possibility that one band may have no detectable effect, whereas two bands may have an effect.

Thirdly, some comparisons, perhaps using temporary marking such as dyes, can be made between banded (and dyed) and unbanded (and dyed) birds, without the use of transponders. However, it is probably only practical to do this to assess effects on breeding biology, considering too that breeders may constitute a biased sample because they may be in better condition than nonbreeders. In a study of King Penguins, researchers were unable to detect any statistical differences between banded and unbanded birds after they had commenced breeding. Foraging trip durations, incubation and brooding shifts were all similar between banded and unbanded individuals. However, fewer banded birds returned at the beginning of the next breeding season (Gauthier-Clerc *et al.* 2001).

## CONCLUSIONS

Penguins are charismatic, but are also species of great conservation concern. They are regarded as indicator species whose status reflects the wellbeing of marine ecosystems (e.g. as used in the CCAMLR Ecosystem Monitoring Program). Numbers of many species have decreased over the past century and 10 of 17 penguin species are now threatened with extinction (BirdLife International 2004). Contributing to the decline is a plethora of threats, including competition with commercial fisheries, oiling, competition with and predation by other species and, for some species, degradation or loss of breeding habitat resulting from guano scraping during the 19th and 20th centuries.

The emerging body of evidence suggesting that at least some flipper bands negatively affect penguins has highlighted the need to consider carefully whether and under what circumstances flipper bands should be used. Critical assessment of evidence for and against banding, using similar band designs and materials, with rigorous experiments are vitally needed to determine band effects, not only for the sake of conducting good science, but also and equally importantly, for the sake of the animals we hope to conserve.

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