

A preliminary investigation into effects of flipper banding
on African Penguins *Spheniscus demersus*

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Index

- Acknowledgements
- Abstract
- Chapter 1: Review of the impacts of flipper banding on penguins, and an introduction to the African Penguin
- Chapter 2: Design and implementation of the Robben Island study
- Chapter 3: Banding the African Penguin – consequences to yearly return rates
- Chapter 4: The effect of flipper banding on foraging trip durations by African Penguins
- Chapter 5: The effect of flipper banding on the breeding success of African Penguins
- Chapter 6: A synthesis of the investigations into the issues of flipper banding African Penguins.

"I have often had the impression that, to penguins, man is just another penguin - different, less predictable, occasionally violent, but tolerable company when he sits still and minds his own business"

Bernard Stonehouse



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Abstract

Much of what is known about penguin movements and life history traits, including their population dynamics, and particularly the rehabilitation success after oil spills results from information derived from marking birds with flipper bands. However, flipper bands may negatively impact the welfare of penguins. While studies on the impact of banding have been undertaken for several penguin species, no such study has investigated the exclusive effect of banding on African Penguins *Spheniscus demersus*. I do so by comparing the difference in yearly return rates as well as foraging trip durations of 100 individuals injected with a subcutaneous transponder only, and 100 that have both transponders and a stainless steel flipper band. Each individual with a transponder is, in theory at least, recorded each time it moves into or out of the colony on Robben Island, South Africa. Radio antennae situated between the colony and the sea record the date, time and direction of movement electronically. A comparison of breeding success of banded and unbanded birds was also conducted at the penguin colony at Boulders Beach, Simonstown.

Fewer banded birds (65%) were recorded after one year than control birds (73%). This difference was not significant ($P=0.22$), but power to detect even a 10% difference in return rate is low ($P=0.23$). Ongoing monitoring of birds is required to test for long-term impacts. The majority of foraging trips were between 10 and 15 hours for both banded and unbanded birds (38.2% and 44.9%, respectively). Pooling all data, banded birds made significantly longer trips, but individual differences accounted for most of the variance in foraging trip lengths (4.8%), whereas the presence of a band only accounted for 0.1% of the variance. Despite this, the fact that a randomly selected group of banded birds spent on average an hour longer out of the colony than unbanded birds gives cause for concern.

There was no significant effect of banding on the likelihood of a nest successfully surviving the incubation period-or fledging stage. The probabilities of a nest successfully surviving the fledging period for birds with at least one band and without any bands were 0.71 and 0.63 ($P<0.05$), respectively.

The results, thus far, are inconclusive and there are sufficient indications of a possible impact to pursue monitoring of banded and control birds. Until this matter is resolved, a precautionary stance limiting the use of bands should remain in force while the long term effects of flipper banding African Penguins are investigated.

Chapter 1

**Review of the impacts of flipper banding on penguins,
And an introduction to the African Penguin**



Introduction

Determining life histories and demographic parameters requires a means to mark individuals. By being able to recognise individuals it is possible to study their survival and longevity, age of first breeding, mate and site fidelity, as well as their movements (Krebs 1989, Manly 1970, Calvo and Furness 1992, Manly *et al.* 1999). Marking individuals is not always easy and it is important that the means of marking is permanent for long-term studies. It is also crucial that it does not interfere with the welfare of the marked individuals (Krebs 1989, Manly 1970, Manly *et al.* 1999, Petersen and Branch 2004).

Birds are usually marked by affixing numbered metal bands or rings to their legs, sometimes augmented by colour bands to aid identification without capture (Marion and Shamis 1977). These bands should cause no hindrance to the bird's behaviour, longevity or social life (Marion and Shamis 1977, Calvo and Furness 1992). Sometimes the effects of banding are not intuitively obvious. For example, the colour of bands has been shown to influence sex ratios and even survival rate of Zebra Finches *Taeniopygia guttata* in laboratory tests (Burley 1985, 1986). Colour bands only affected mate choice where ultraviolet light was present, and thus the sensory capabilities and life style of the animals concerned need to be taken into account (Hunt *et al.* 1997).

Penguin banding

Marking penguins provides a new set of challenges. There has been a long series of trials and errors with respect to marking penguins, with experimental marking beginning as early as 1908 (Gain 1914). Their short, fleshy legs are not well suited to conventional bands. Bands placed on the tibia were difficult to read. Tarsal bands were exposed to a high degree of wear, often slipped off and could cause injuries (Sladen 1952, Cooper and Morant 1981). Researchers began experimenting with flipper bands. Early flipper bands were often lost at sea (Richdale 1951, Sladen 1952). Many different forms of band have been tried and initial designs were progressively improved upon.

The 1950s saw a series of flipper bands with clips or overlapping designs being used on Adélie *Pygoscelis adeliae*, Gentoo *Pygoscelis papua* and Emperor *Aptenodytes forsteri* penguins. These required experienced flipper-banders who had to attach bands carefully to minimise injury, and adjust band size to suit individual penguins (Sladen and Tickell 1958, Sladen and Penney 1960). In 1958/59, Sladen and Penney (1960) used a band of harder aluminium that no longer required a locking device. They reported a good survival rate for Adélie and Chinstrap penguins fitted with this band, despite some feather wear. Sallaberry and Valencia (1985) confirmed the benefits of a band with no fastening device. They removed bands with clips from Adélie, Gentoo and Chinstrap *Pygoscelis antarctica* penguins in Ardley Islands, when they noticed that approximately 65% had wounds as a result of the fastening clip rubbing against the thorax, causing erosion of the feathers and in some cases the skin. The replacement bands with no fasteners did not appear to cause wounds or feather wear (Sallaberry and Valencia 1985).

In the 1970s there was a shift from the use of aluminium to Monel, a nickel-copper alloy (Cooper and Morant 1981). Jarvis (1970) recognised the need to accommodate swelling of the flipper during moulting. Finally, in 1981, 316 grade (16–18% chrome, 10–14% nickel) stainless steel bands were introduced for African Penguins *Spheniscus demersus* decreasing the amount of band wear and injury to the bird (Cooper and Morant 1981). Stainless steel bands on Snares-crested Penguins *Eudyptes robustus* in New Zealand showed no sign of band wear even after nine years (see Cooper and Morant 1981). Similar bands used in South Africa were not worn after eight years of being fitted on the penguins (Cooper and Morant 1981).

In the past 30 years there have been minor changes to the design of the stainless steel flipper band. In South Africa each African Penguin band has a letter prefix followed by four or five digits. All bands have been made from grade 316 stainless steel and have been fairly consistent in overall length, but have varied in thickness, from 1.2 mm to 2 mm, and therefore in rigidity. Bands have been made by a range of manufacturers in the UK and in South Africa. The bands used on African Penguins in South Africa have conformed closely with the design specifications set by Cooper and Morant (1981).

The African Penguin

The African Penguin is listed as Vulnerable (BirdLife International 2004, Hockey *et al.* 2005). The population is at 10% of what it was at the beginning of the 20th century (Shannon and Crawford 1999, Crawford 2000, Whittington *et al.* 2000, Nel *et al.* 2003, BirdLife International 2004, Hockey *et al.* 2005). Reasons for this decline include egg and guano collection, competition with Cape fur seals *Arctocephalus pusillus* for food and breeding space, habitat loss, predation by feral cats *Felis catus*, Kelp Gulls *Larus dominicanus*, Sacred Ibises *Threskiornis aethiopicus* and fur seals, and reduction in their major prey species through competition with commercial fisheries (Crawford *et al.* 1995, Crawford 1998, Underhill *et al.* 1999, Crawford and Dyer 2000, Nel *et al.* 2003).

Oil pollution presents a further hazard to the African Penguin (Underhill *et al.* 1999, Crawford *et al.* 2000). Approximately 1 500 birds a year are taken to SANCCOB, Southern African Foundation for the Conservation of Coastal Birds, for rehabilitation from oiling. Of these, on average 74% are released back into the wild (Nel *et al.* 2003). Two of the largest oil spills to affect African Penguins were the *Apollo Sea* in 1994 and the *Treasure* spill in 2000. In both cases, the practice of penguin banding has clearly demonstrated the benefits of rehabilitation after oiling has occurred (Nel *et al.* 2003, Barham *et al.* 2007).

Previously it was thought that there was little use in rehabilitating oiled seabirds as other species of birds had benefited little from the expense and effort put into rehabilitation. Sharp (1996) called it “an expensive waste of time.” Little was known of the long-term effects oiling had on birds. However, after the *Apollo Sea* spill, of the oiled birds that had been rehabilitated and banded, 87% returned to their breeding colonies (Whittington 1999) and showed no significant difference in breeding success to birds that had never been oiled (Wolfaardt and Nel 2003). Since then, Barham *et al.* (2007) have shown that birds de-oiled after the *Treasure* Spill don’t breed as well as normal birds, but that birds that were ringed for other reasons than oiling, bred as well as unoiled birds. De-oiled penguins tended to lose large chicks, so they were unable to provide food when energy

demand was maximal. These birds showed an 85% survival rate after one year (Underhill *et al.* 1999), and 60% were sighted breeding as long as six years after the spill (Wolfaardt and Nel 2003). As a direct result of banding, it was possible to demonstrate the success of rehabilitation efforts. The population of African Penguins was an estimated 19% higher than it would have been without rehabilitation efforts (Ryan 2003).

The recognition of the success of rehabilitation efforts after the *Apollo Sea* spill allowed for the mobilisation of funds and people when disaster struck the penguin population in 2000, when the *Treasure* spill affected c. 20% of the population of African Penguins. The mammoth contribution of the efforts of SANCCOB during the *Treasure* spill saved the lives of as many as 36 000 penguins (Crawford *et al.* 2000).

Impacts of bands on penguins

The benefits of the knowledge gained by flipper banding of birds need to be weighed against any adverse effects on the bird. Much research has been done on the effects of flipper banding and the results vary. Ainley *et al.* (1983) described an increase of 28% mortality in Adélie Penguins in the first moult after banding. This was attributed to constricting blood vessels in the flipper during moult, and appeared to occur only in the first year after fitting the band. As a result, a larger band was used that could accommodate swelling of the flipper (Trivelpiece and Trivelpiece 1994). In contrast, Sladen and Penney (1960) reported good rates of survival in Adélie Penguins fitted with bands. In this case, it appears that inappropriate band design was the cause of mortality, rather than banding *per se*.

Culik *et al.* (1993) reported a 24% increase in energy required while swimming for seven Adélie Penguins in an artificial swim channel. The increase in energy expenditure has been attributed to an increase in drag and disturbance of wing flow character, physical impairment of the wing and rudder effects. Since there appeared to be no difference in swimming speeds of birds with bands to those without, it is possible that this increased energy expenditure will manifest itself in a decrease of foraging range which will in turn

decrease the number of prey encounters experienced by birds with bands (Trivelpiece and Trivelpiece 1994). The result would be a decrease to their overall fitness. Because only seven penguins were tested, and the degrees of freedom in the statistical analyses in this paper was given as $n = 115$ with bands and 157 without bands, there are potentially pseudo replication problems with the analysis of the data. The results therefore need to be treated with caution.

Bannasch *et al.* (1994) showed that the drag on Adélie, Chinstrap and Gentoo penguins without bands is extraordinarily low. In experiments on models of penguins performed in wind tunnels, separation of flow only occurred at the tail, indicating a predominately laminar flow over the surface of the bird and minimal turbulence in the boundary layer. The exceptionally well developed muscles below the surface of the skin account for the high degree of control over the positioning of feathers and surface tension of the skin, indicating the importance of the microstructure of the body surface in keeping drag and turbulence to a minimum (Bannasch 1986, Bannasch *et al.* 1994). Attaching an external device onto the streamlined body of the penguin is likely to increase turbulence in the boundary layer and thus increase drag. An increase of drag will result in higher power needs, and thus energy expenditure, which may decrease foraging efficiency and ultimately fitness (Bannasch 1986, Culik *et al.* 1993).

There are also concerns that the flashing effect of the silver band may increase the birds' risk from predators (Trivelpiece and Trivelpiece 1994). However, tests on differences in predation between black and silver bands on Adélie Penguins showed no increase in predation of birds with silver flipper bands (Trivelpiece and Trivelpiece 1994).

Feather wear, caused by friction as a result of bands, may compromise the penguins' insulation (Barham 2004). This is particularly problematic in Antarctic species and may not have as great an impact in temperate water penguins (Barham 2004, Petersen and Branch 2004). Badly fitted bands have also been known to cause wounds to penguins, especially if the edges of the band were not well smoothed or the band was not closed so that the joins were flush. Bands of lower quality tend to open, increasing the risk of birds

getting caught in fishing line or vegetation and starving to death (Stonehouse 1999, Jackson and Wilson 2002, Petersen and Branch 2004).

Some studies suggest that birds pry open the bands with their beaks (Wilson and Wilson 1989). The possibility that the bands cause irritation to the birds has been demonstrated in tests on the frequency and intensity of pecks on externally attached devices in African Penguins (Wilson and Wilson 1989). There is concern that even small effects may add up over the life time of the bird especially when multiplied over the high percentage of individuals in the population that are banded (Jackson and Wilson 2002, Petersen and Branch 2004).

Studies have been done on a number of a species of penguins to test if there is an effect of banding. These studies, summarised in Table 1, show no clear pattern on the effect of flipper banding, and highlight that there are interspecific differences. It is important to recognise the difference between double and single banding is not directly comparable to a comparison between single banding versus no banding. It may be that double banding impairs an individual where a single band does not and therefore the difference in the effect of double and single band is not equivalent to the effect of a single band. It is plausible that this is not an accurate measure of the effect of banding on a single flipper.

Table 1: Summary of studies investigating the effect of flipper banding on various penguin species, their duration and the effects found.

Species	Duration and Effect	Nature of effect	Authors and study site
Adélie Penguin	3 years	28% higher mortality in first year	AINLEY, D.G <i>et al.</i> 1983
<i>Pygoscelis adeliae</i>	Negative effect	subsequent 3% higher mortality	Cape Crozier, Ross Island, Antarctica AINLEY, D.G. 2002
	Negative effect		Ross Island, Antarctica
	6 years	statistically insignificant difference	CLARKE, J. & KERRY, K. 1998
	Negative effect	in return rates.	Béchervaise Island, Eastem Antarctica
	(272) 40 min swims	no difference in swimming speed	CULIK, B.M <i>et al.</i> 1993
	Negative effect	24% higher energy expenditure at 1.4 - 2.2 m/s	Ardley Island, Shetland Islands, Antarctica
	4 years		DUGGER, K <i>et al.</i> 2004
	No effect		Ross Island, Antarctica
Chin strap Penguin	1 year	8% higher return rate in single banded birds	TRIVELPIECE, S.G. & TRIVELPIECE, W.Z. 1994
	Negative effect	compared to birds with double bands	King George Island, Antarctica
<i>Pygoscelis antarctica</i>	1 year	25% higher return rate in single banded birds	TRIVELPIECE, S.G. & TRIVELPIECE, W.Z. 1994
<i>Pygoscelis papua</i>	Negative effect	compared to birds with double bands	King George Island, Antarctica
Gentoo Penguin	1 year	12% higher return rate in single banded birds	TRIVELPIECE, S.G. & TRIVELPIECE, W.Z. 1994.
African Penguin	4 years	no difference in nest success of banded birds	BARHAM, P.J <i>et al.</i> 2004
<i>Spheniscus demersus</i>	No effect	compared to rubber or birds without bands	Robben Island, South Africa
	6 years	no difference in return rates to breeding colonies	WOLFAARDT, A.C. & NEL, D.C. 2003
	No effect	between banded and unbanded birds	Dassen Island, South Africa
Magallanic Penguin	10 years	no significant difference between birds with	BOERSMA, D.P. & VAN BUREN, A.N. 2004
<i>Spheniscus magellanicus</i>	No effect	mouse-ear tags and with stainless steel bands	Punta Tombo, Argentina
Little Penguin	6 years		DANN, P <i>et al.</i> 2000
<i>Eudyptula minor</i>	Negative effect		Phillip Island, Victoria, Australia
King Penguin	2 years	45% return rate in double banded vs 76% single	FROGET, G <i>et al.</i> 1998
<i>Aptenodytes patagonicus</i>	Negative effect	banded birds. Delayed laying in double banded.	Possession Island, Crozet Archipelago
	5 years	Decreased breeding probability and chicks per	GAUTHIER-CLERC, M <i>et al.</i> 2004
	Negative effect	season in banded birds	Possession Island, Crozet Archipelago
Royal Penguin	1 year	No significant difference in survival or growth	HINDELL, M.A <i>et al.</i> 1996
<i>Eudyptes schlegeli</i>	No effect	rate of chicks.	Bauer Bay, Macquarie Island

The final report by Petersen and Branch (2004) of the Workshop on penguin flipper banding and other forms of marking highlighted the need for a study that concentrates on species-specific studies on the effect of flipper banding. Preliminary studies suggested no effect of banding on African Penguin survival or breeding success (Wolfaardt and Nel 2003, Barham 2004, Barham *et al.* 2007), but there has been no comparison with a control group of unbanded birds. Given the African Penguin's Vulnerable status and the fact that a large proportion of the population is banded, there is a need to look carefully into whether flipper banding has an effect on their survival and fitness (Petersen and Branch 2004).

This study assesses whether banding has an effect on the health and short-term survival of African Penguins. The study comprises two parts. First, differences in return rates and foraging trip lengths between African Penguins that have been newly fitted with an electronic subcutaneous tag, and those fitted with the tag and an external flipper band are investigated. Chapter 2 describes the materials and implementation of this study. Chapter 3 compares the return rates of banded and unbanded penguins one year after the birds were fitted with electronic tags and flipper bands. Chapter 4 examines the movements of banded and unbanded penguins to and from the colony as recorded by the electronic tags. The second part is a comparison of breeding success of previously banded and unbanded birds at Boulders Beach and is documented in Chapter 5. Chapter 6 draws together the findings from the literature, together with the results of the current study, and evaluates the extent to which flipper bands impact negatively on the African Penguin population.

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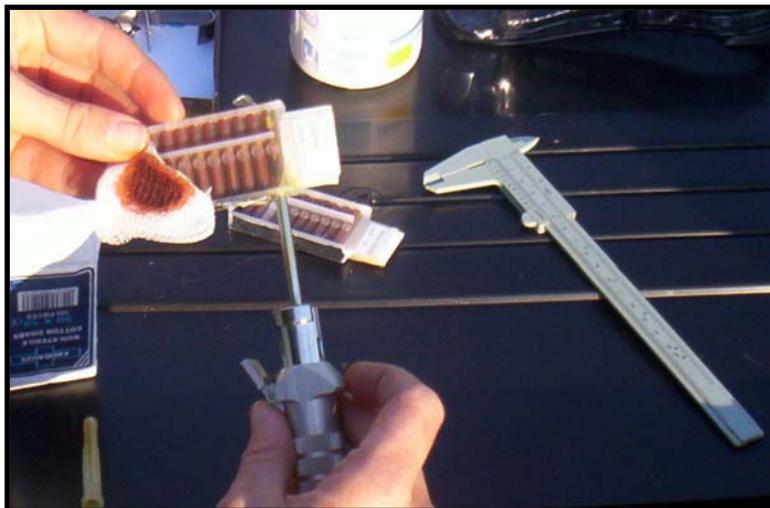
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Chapter 2

Design and implementation of the Robben Island study



Abstract

Much of this project was taken up in design and implementation. This chapter documents the various successes and failures experienced at each step in the process. It is hoped that this project will lay the foundation for a long-term investigation comparing the return rates and survival of banded and unbanded African Penguins fitted with transponders (transmitter responders) at Robben Island.

Included in this chapter is the design of the flipper band, the nature of the transponder and their methods of application. In addition, the reader system and means of data capture are described. The information is presented in two parts as a result of a change of design early in 2006, owing to various problems in the design of the 2005 system. Possibilities for future expansions and improvements on the project are also investigated.

Flipper Bands

Most previous banding of African Penguins has used bands manufactured by Lambournes, Solihull, UK. Finding a local company to produce the bands was thought to be best in the long term, if banding is to continue, because it would allow for more control over the design and quality control of bands, fewer delays and presumably less expense incurred. Schuurman Engineering in Cape Town was the company responsible for making the bands during the 2000 *Treasure* spill. At that time they needed to make a large number of bands in a short time, and while those bands were not ideal because the surface of the bands weren't well finished and some of the edges weren't smoothed properly (Petersen and Branch 2004), it was believed that with their previous experience they would be a good choice for making the bands for this project. Unfortunately, the division of the company responsible for making the bands was in the process of closing down. While they agreed to make the batch of bands to be used for this project, this was a one-off consignment. An alternative arrangement would need to be made if bands are to be made locally in the future.

The bands (Figure 1) were made from A4 sheets of 316-grade stainless steel, 1.3 mm thick and 13 mm wide. The sheets were pre-pin stamped on a computerised embossing machine by a company in Johannesburg (J. Schuurman pers. comm.) with 9 mm tall numbers ranging from R5001–R5500. Pin stamping is not an ideal means of numbering the bands, because the impression is not always consistently clear and the numbers are not distinct. It would be preferable to stamp each number as a whole. Unfortunately the pin stamping company also made an error in aligning the position of the numbers so that when the metal sheet was guillotined the numbers were not always centrally placed on the flat side of the band.

The numbering of these bands was not ideal for large-scale or long-term studies based on resightings using telescopes or binoculars, but it was adequate when used in conjunction with implanted transponders. The design of the project did not rely on resightings of birds with bands but rather on the transponder-reader records. The final cost for each band was approximately R13.00 in 2005. If flipper banding is to continue, it is imperative that only bands of the highest quality are deployed. If it is decided that bands should be produced locally a new company will need to be found and methods other than pin stamping investigated or an improvement in the consistency of the pin stamping technology will be required.

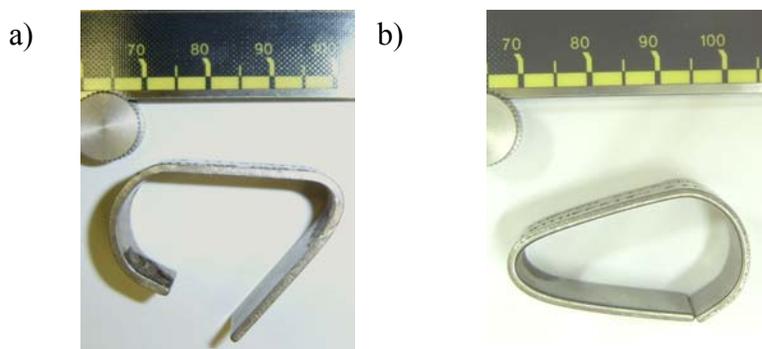


Figure 1: The R bands used in this study shown when open (a) and closed (b)

The bands were bent into an ovate shape that could be fitted onto the flipper. Theoretically they were designed to slip over the narrow part of the flipper and then be closed with one motion using water-pump pliers, with the ends abutting and a flush

finish. This was true for some of the bands used. However, in some instances the close was not flush, there was a gap or an overlap of ends and the band had to be further manipulated with pliers until a flush close was achieved.

Once the bands were shaped they were sent to a local tumbling company, Ceratex Engineering, where they were tumbled with glass to smooth the edges. This last process also dulls the appearance of the steel, making band numbers easier to read in sunlight.

The new bands were designed to be similar to the V-series bands produced by Lambournes in the mid 1980s, but the opening of the new bands was repositioned to minimise risk of injury. The opening of the V-series bands was on the inside of the flipper, adjacent to the body and therefore there was a high risk of injury. A workshop on flipper banding noted that the V-series bands were the best designed with regards to thickness of the metal and shape and the carefully prepared edges minimised wounds to the birds (Petersen and Branch 2004). In a study on band design the thickness and strength of the V-series band showed it to have four times higher resistance to band loss than the P, Z and S bands (Klages and Spencer 1996).

Transponders

The transponders were ordered from a Spanish company, Rumitag (www.rumitag.com). They were standard RFID (radio frequency identification) tags 32×3.85 mm, weighing 0.8 g, with a unique identification number. The tags were sealed in surgical glass and should last the lifetime of the bird; they are powered by the reader signal and require no battery. They could be read with a transponder reader (Texas Instruments Series Reader 2000) from a distance of c. 50 cm, but this distance could be increased to c. 1 m with the use of an antennae array. The tags were produced to survive temperatures from -40°C to over 70°C , although optimal working conditions were -25°C to 50°C . They could be read through almost any non-metallic material. Each tag was coated in Paraleyne to minimise migration within the body which has been recorded in previous studies with RFID tags in

Adélie Penguins (Dugger *et al.* 2005). They were housed separately in Betadine solution in cartridges of 10. In 2005 the cost of a single tag was R40.00.

Trials on captive birds

To test the reaction of African Penguins to the injection of transponders and to perfect the procedure, a trial run was done on captive birds held at SANCCOB, the Southern African Foundation for Conservation of Coastal Birds. SANCCOB has a number of birds that, for various reasons, cannot be re-released into the wild and live in what is known as a 'home pen' on the premises. Each of these birds is already identifiable by a stainless steel flipper band and can easily be caught again, making them ideal for testing the long-term reliability of the transponders.

In February 2005, 10 birds from the SANCCOB home pen that were not breeding at the time were chosen for the trial. Transponders were inserted midway between the shoulder blades by a veterinarian, as has been done in other studies using transponders on penguins (e.g. Chiaradia and Kerry 1999). At the point of insertion, a number of small downy feathers were plucked to clear the skin surface, which was swabbed with Betadine antiseptic. The insertion needle also was cleaned with Betadine before being used on each bird. The transponders were loaded into the large-bore needle without being handled, and were injected subcutaneously with the bevel face down and needle pointing towards the bird's head (Figure 2). Gentle pressure was applied to the wound with a wad of cotton wool for c. 30 s to stop bleeding and ensure correct positioning of the transponder (N.J. Parsons pers. comm.). The use of sutures and staples to close the wound was tested and deemed unnecessary due to the small nature of the wound.

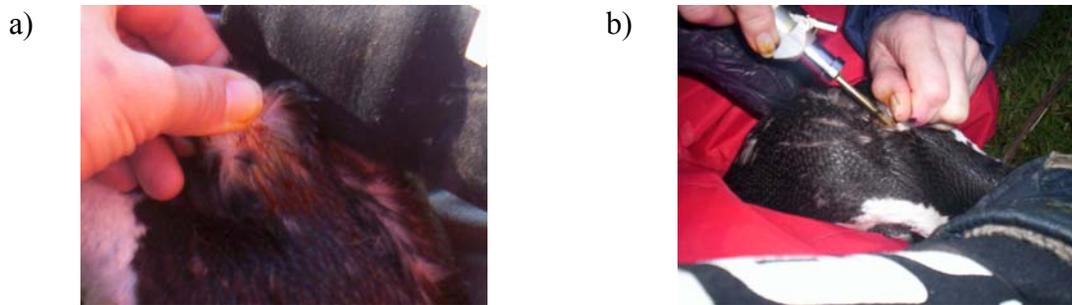


Figure 2: Inserting the transponder; a) some downy feathers are plucked and the surface of the skin swabbed with Betadine and b) the needle is inserted bevel side down.

Despite fears that inserting the transponder would illicit a fear response in African Penguins (Petersen and Branch 2004), the trial birds showed no lasting behavioural response to the injection. The birds showed stress as a result of being handled, but once they were under the control of an experienced handler there was no further reaction even when the needle was inserted. A handheld reader was used to ensure the transponder was working. The birds were inspected within a week and all wounds had healed. Because these birds are under constant care from SANCCOB any unusual behaviour or deleterious effects of the fitting of transponders would have been noticed. In March 2006, and again in April 2007, all the transponders were working when tested with a handheld reader. The handheld reader has a limited reading range so it was not able to give an indication of tag migration.

Study Site

The study was conducted at Robben Island, (33°47'S 18°22'E) (Figure 3a), South Africa, 11 km from Cape Town harbour, currently the second largest African Penguin colony (du Toit *et al.* 2004). It is accessible by a 30–45-minute ferry ride from Cape Town. Ferries run daily, weather permitting. This site was chosen in part because of the ease of access and in part because penguins on Robben Island use distinct pathways *en route* from their nests to the sea and back again (Shaw 2005). African Penguins are diurnal feeders and thus go out to sea each morning and return in the evening (Wilson *et al.* 1986). In 1997 Marine and Coastal Management (MCM) capitalised on this characteristic by building a

weighbridge on one of the most well worn paths at the time (L. Upfold pers. comm.). Sixty-five adult penguins were fitted with transponders in 1997 and also flipper-banded. A transponder reader and wooden weighbridge were placed in a naturally narrow part of the path (Figure 3b), with the weighbridge designed to encourage only one penguin to walk through at a time (L. Upfold pers. comm.). A fence was built on either side of the weighbridge using garden fencing ca 0.5 m high to discourage penguins from walking around the funnel. This project was subsequently abandoned after repeated failure of the automated recording systems (B.M. Dyer pers. comm.) but the fence remained in place, so that virtually all penguins using this pathway passed over the wooden platform of the weighbridge.

This pathway proved to be ideal for this study because the penguins were already habituated to the modifications made to their pathway eight years previously. In addition, the previous study required a link to a power source and a nearby utility box, which could be used for this project. The funneling fence was mostly still intact, but was extended and repaired where necessary.

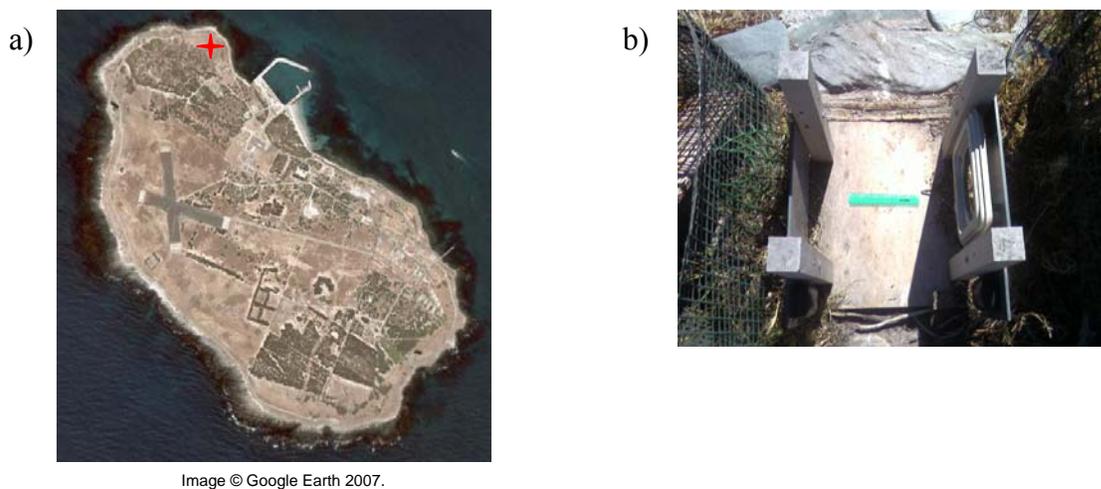


Figure 3: a) Robben Island showing location of reading station (cross) and b) the reading station (with medium gate antennae and optical sensors) photographed from above with a 15 cm ruler for scale.

Field Application

A test run was done on site at Robben Island on 28 April 2005 to test the practicalities of catching and injecting penguins in field conditions. Since the new bands had yet to be completed, L-series bands were used, which were available from SANCCOB. Ten birds were given transponders, and half of these also were banded.

To minimise disturbance associated with the recording station, birds were caught on the same path but landward of the recording site. After originally attempting to catch birds in a fenced trap, they were eventually caught by herding them under trees and bushes, where they huddled until captured. Once caught they were put in SANCCOB penguin carry boxes in groups of no more than three and taken away from the path so as not to disturb further groups of birds from using the path. Catching typically was conducted in the early morning and evening, when the largest number of birds would be on the path either heading seaward to feed or landward to their nests (Wilson 1985).

A total of 200 birds was processed in 2005, the 10 of the trial run and a further 190 in July. At the end of April 2006 a further 54 birds were processed in the same manner, bringing the total sample to 254. Only unbanded adult penguins were caught and each penguin was first checked for the presence of a transponder using a handheld reader to prevent injecting multiple transponders into the same individual. The transponder was inserted using the technique employed at SANCCOB. Occasionally, if the tag was not felt to have penetrated deeply enough, it was massaged into the bird. Only trained veterinarians or veterinary nurses injected the transponders and only experienced penguin handlers held the birds to minimise stress to the birds. Every alternative penguin was flipper banded in addition to receiving a transponder. A trained penguin flipper bander using water pump pliers did the banding.

Culmen depth and length were measured to the nearest 0.1 mm using Vernier calipers. Culmen depth was taken at the base of the beak, and length was measured as defined in

Cooper (1972). These measurements were taken by one person throughout the project to minimise errors. There was no significant difference in the bill depth or bill length between banded and unbanded birds ($n = 122$; $p = 0.35$ and $n = 122$; $p = 0.27$, respectively). Although Cooper (1972) used culmen length and depth to sex African Penguins, there was no clear bimodality in measures and thus sexing could not take place with any degree of accuracy (Figure 4).

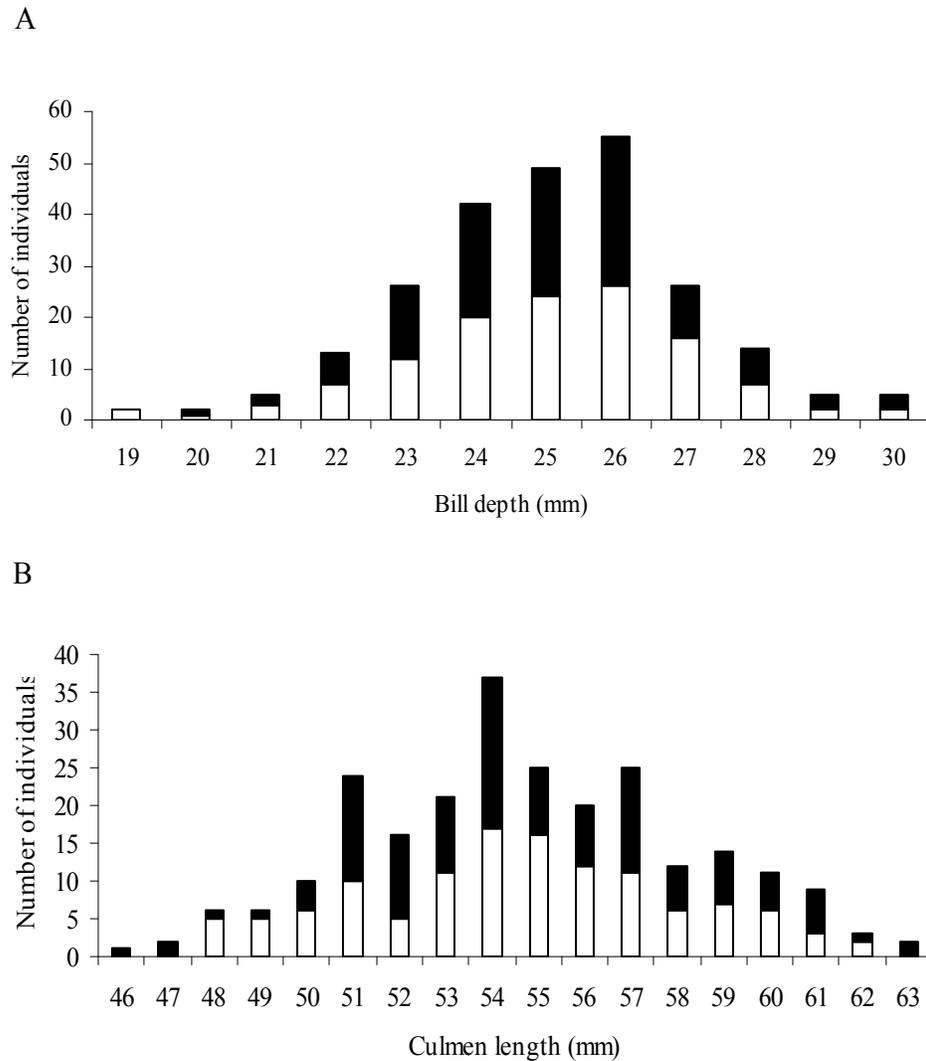


Figure 1: Bill depth (a) and culmen length (b) of 244 African Penguins equipped with transponders (black bars) and transponders and bands (white bars).

Birds were harnessed with a non-elastic string secured underneath their wings, and weighed with a 5 kg spring balance. Masses varied greatly because some birds were

caught on their way to feeding and others after they had just fed and the results were therefore not included in the analysis. Before being released, each bird was sprayed on the chest with Porcimark, a pink alcohol-based animal die, to avoid recapture. The total handling time was less than 3 min, although birds were kept in ventilated SANCCOB holding boxes for up to 45 min prior to marking.

A subsequent visit to the island in June 2006 was made to mark birds using the pathway in order to determine whether they used other pathways. These birds were marked with Porcimark on the white feathering on either side of the neck, allowing observers to notice a marked bird from either direction. Earthwatch volunteers working in the penguin colony in the subsequent two weeks recorded the pathways used by marked penguins and noted that marked penguins were found on pathways other than the one on which they were marked.

Data collection

The recording station used a single medium gate antenna supplied by Runitag on the narrow wooden walkway. The antenna was designed to operate in temperatures ranging from -30°C to 60°C . As a bird walked through the walkway the low frequency reader detected the transponder's unique number. Two optical sensors determined the direction of movement. A successfully logged event occurred only once the bird had passed through both sensors. If more than one bird with a transponder walked through the gate at the same time, the reading failed. A successful reading recorded the number of the transponder, the direction of movement and date and time of event.

The system in 2005 had the reader connected to a personal computer (PC) housed in a near-by utility box via a standard RS232 cable. Any readings were stored in RAM until the data were manually downloaded on the PC. The data was then stored as a text file in which 2000 entries would require 62 KB of memory (G. Laubscher pers. comm.). Unfortunately the island's electricity ran off a generator and there were frequent power outages. In the event of a power failure, all the data stored in RAM were lost and the

computer had no means of automatically booting up again after the power failure, so no new data were recorded. To reduce loss of data, trips were made to the island on a weekly basis; however, the loss of data was substantial. In November 2005 a UPS (Uninterrupted Power Supply) was installed to minimise the effect of the power outages. The UPS supplied power for up to 90 minutes after a power failure, but the system continued to be unreliable. Large temperature fluctuations experienced in the utility box resulted in recorded times being inaccurate and eventually the computer itself also malfunctioned.

In 2006 the decision was taken to replace the system with one not reliant on a PC at the site. The new system stored data in a micro controller with an on-board flash memory. The direction and transponder number were stored with a time stamp. Connecting a portable laptop with a serial cable to the logger enabled retrieval of these data. This system only used 22 KB of memory for 2000 events. The UPS was still used, so that even in the event of a power failure the reader would continue to run and no data lost. The continuous running of the system also meant more accurate time keeping. While there remained some clock drift due to the temperature fluctuations, this amounted to no more than one hour per month (A. Markham pers. comm.).

The use of optical sensors to determine direction remained a problem. When birds walked in groups, the direction of movement of a bird with a tag may be incorrect as a result of confusion with untagged birds. This occurred mainly at times of peak penguin traffic in the mornings and evenings, and thus the direction could be inferred from knowledge of penguin habits. The problem will be solved by using two antennae that can either be connected to two readers which each record the time of an individual bird, or with one, more complex reader, that will recognise direction.

The opportunities for expansion with this system are extensive. The use of cellular technology, specifically GPRS (General Packet Radio Service) streaming data to a location on the mainland would decrease the need for trips to the island and allow real-time data collection. It would also enable malfunctions to be detected rapidly. This could be combined with the use of a web cam for visual images of the penguins crossing the

bridge. This would aid studies of visual recognition because the image could be correlated to a known individual (Burghardt *et al.* 2004). Despite the problems experienced with the MCM weighbridge system, it may be possible to redevelop a means of weighing each individual as it passes through the reader. The project could also be extended substantially by the use of readers at other pathways, although the availability of power sources and the expense of readers may limit this.

There are a number of ways in which the project could be expanded and improved to enable the long-term study of the impacts of penguin flipper banding. In addition, the technological advancements in the transponder reader and transfer of data may allow for expansion of field studies that do not require an external marker to be fitted to the penguin, thus decreasing reliance on flipper banding and enabling extensive electronic collection of data which could be used for a variety of studies, such as foraging trip length in relation to offshore food abundance.

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Appendix 2.1:

AMS Solutions (implementation of the original antenna system on the island):

Tel: 021 557 0160

Email: amssol@amssolutions.co.za

Web Address: www.amssolutions.co.za

Address: P.O. Box 132, Table View 7439, South Africa

Companies involved in the manufacturing of flipper bands or transponders.

Ceratex Engineering (for tumbling):

Tel/Fax: 021 933 0375

Email: info@ceratex.co.za

Web Address: www.ceratex.co.za

Address: P.O. Box 1082, Parow 7499, South Africa

Rumitag (supplier of electronic tags):

Tel: (+34) 93 470 0188

Web Address: www.rumitag.com

Address: C/Esmeragda, 19-21 Sat. 1a, Esplugues de Llobregat
08950 Barcelona, Spain

Sea bird rehabilitation centre

SANCCOB:

Tel: 021 557 6155

Fax: 021 557 8804

Web Address: www.sanccob.co.za

Address: P.O. Box 11116, Bloubergrandt, Cape Town, 7443

Chapter 3

Banding the African Penguin – consequences to yearly return rates.



Abstract

Several studies have indicated there are negative effects associated with fitting flipper bands to penguins for research purposes, but no impact was found in studies on *Spheniscus* penguins. This study considers the effect of banding on return rates of African Penguins on Robben Island, South Africa. In 2005, 200 birds were fitted with subcutaneous transponders. Each alternate bird also was fitted with a stainless steel flipper band. There were no biases in mass or bill dimensions between experimental and control groups. Each time a penguin fitted with a transponder walks past the antennae situated on the island, the direction of movement, date and time were recorded, along with the individual number of their transponder. After one year, the return rate of banded (65%) penguins was lower than that of unbanded (73%) birds. This difference is not significant, but the power to detect a significant difference was low ($P < 0.4$ even if the actual difference in survival rates was 10%). Continued monitoring of the survival of the birds in this study is essential.

Introduction

Flipper banding has been the primary means of gathering data on penguins during the 1900s (Stonehouse 1999). A dichotomy exists between the benefits of data gained as a result of attaching a flipper band to penguins and the possible consequences to the individuals that arises from doing so. A workshop on penguin flipper banding, held in Cape Town in 2004, highlighted the need for a project to be designed to test the effects of flipper bands on the African Penguin (Petersen and Branch 2004). This view was underpinned by the results of a number of papers reporting negative effects of flipper bands on a variety of other species of penguins. Banded Adélie Penguins experienced decreased survival in a study over 15 years at Cape Crozier (Ainley *et al.* 1983, Ainley 2002) and a statistically insignificant decrease in survival at Bechervaise Island over 3 years (Clarke and Kerry 1998). Gauthier-Clerc *et al.* (2001, 2004) reported a decrease in survival of banded King Penguins. However, in studies on the Royal Penguin and in a study of another *Spheniscus* penguin, the Magellanic Penguin, no negative effects

associated with flipper banding were detected (Hindell *et al.* 1996, Boersma and Van Buuren 2004).

Given the significant differences in size and lifestyle of penguins, as well as in the design and quality of bands been used in different studies, it would be rash to predict a uniform effect of flipper banding for all species in all environments. No study to date has assessed the effect of flipper banding on African Penguins independent of the effects of oiling. Wolfaardt and Nel (2003) showed a small but non-significant decrease in breeding success of banded and previously oiled African Penguins on Dassen Island in years of food shortages, but no differences between banded and unbanded birds when food was readily available. In another study, breeding success was not statistically different among Robben Island African Penguins with stainless steel flipper bands, no flipper bands or a new rubber flipper band over a period of four years (Barham *et al.* 2004). In both these studies, the birds with flipper bands were fitted with the bands after rehabilitation from oiling. Thus any effect shown may be as a result of long-term effects faced by oiling and rehabilitation rather than effects of the band itself. This may differ according to the type of oiling event and speed of rehabilitation; Barham *et al.* (2007) have shown that the breeding success of penguins oiled during the *Treasure* spill was lower than that of birds affected by previous spills or those that have not been oiled at all. Thus the decision of whether to continue banding is a complex one, fraught with conflicting lines of evidence.

This study is designed to investigate the specific effects of banding by comparing the apparent survival of African Penguins banded for this study and injected with subcutaneous transponders, with a control group that had subcutaneous transponders only.

Methods

Robben Island (33°47'S 18°22'E) is 11 km from Cape Town harbour and is the second largest penguin colony in South Africa (du Toit *et al.* 2004). The penguins on Robben Island create very distinct pathways en route between their nesting sites and the sea

(Shaw 2005). This makes the use of a short-range transponder reader viable to monitor the comings and goings of birds to the colony. A weighbridge set up for a previous project, run by Marine and Coastal Management between 1997 and 1999, provided an ideal natural funnel for use in this project. The penguins were already habituated to the modifications on the path made in 1997. These modifications included the further narrowing of the pathway in the area of the weighbridge and fencing off of the areas immediately adjacent to the bridge.

Between 9 and 23 July 2005, 200 adult African Penguins were caught on the pathway on the landward side of the bridge; these birds were almost certainly breeding in the area served by this pathway at the time. They were injected with subcutaneous transponders (Chapter 2) and every alternate bird was fitted with a 316-grade stainless steel flipper band designed locally to be similar to the V-series bands created by Lambournes in the UK, and used on African Penguins in previous studies (Klages and Spencer 1996). On capture, each penguin was checked for a transponder to prevent double tagging. A single medium gate antenna and two optical sensors picked up the individual number of the transponder, the time of movement and its direction.

African Penguins breed throughout the year, but most breeding on Robben Island occurs between March and September, with moulting between November and January (Underhill & Crawford 1999). For the 200 experimental penguins banded in July 2005, a bird recorded by the transponder reader between March 2006 and September 2006 is said to have survived the year including the premoult fast, moulting and at least one breeding season. The drop out rate was determined from the date at which the bird entered the study until the last date the individual was recorded within the study period.

The proportion recaptured is a minimum estimate of survival. African Penguins do not breed in every year (Whittington *et al.* 1996) and do not use any single path exclusively (pers. obs.), so a failure to recapture a bird does not necessarily indicate mortality. A chi-squared goodness of fit test was used to compare the numbers of banded and control birds recaptured after one year. A power analysis was done to estimate the capacity of the

study, given the current sample size, to detect significant difference in return rates over 5 years assuming a 5, 10 and 15% negative effect associated with banding. The power to detect a significant difference in return rates was estimated by comparing the observed proportions of returning birds (Zar 1984). The analysis assumes an 80% recapture possibility and 90% survival, based on the best estimates for African Penguins from Whittington *et al.* (1996). It must be noted that this survival estimate was calculated using banded individuals (Whittington *et al.* 1996) and could introduce a bias if banding does indeed decrease survival.

Results

Of the 200 birds banded in 2005, 73% of the unbanded birds and 65% of the banded birds were recorded moving past the transponder reader in the following breeding season. While a larger number of unbanded birds were re-sighted, the difference was not significant ($\chi^2_1=1.50$, $P=0.22$). Assuming the observed difference (73:65) is the underlying distribution, the power to detect this difference in one year is low (0.23). Figure 1 shows recapture estimates over five years for banding effects of five, ten and a 15% difference and assuming 80% recapture probability on a 90% survival estimate.

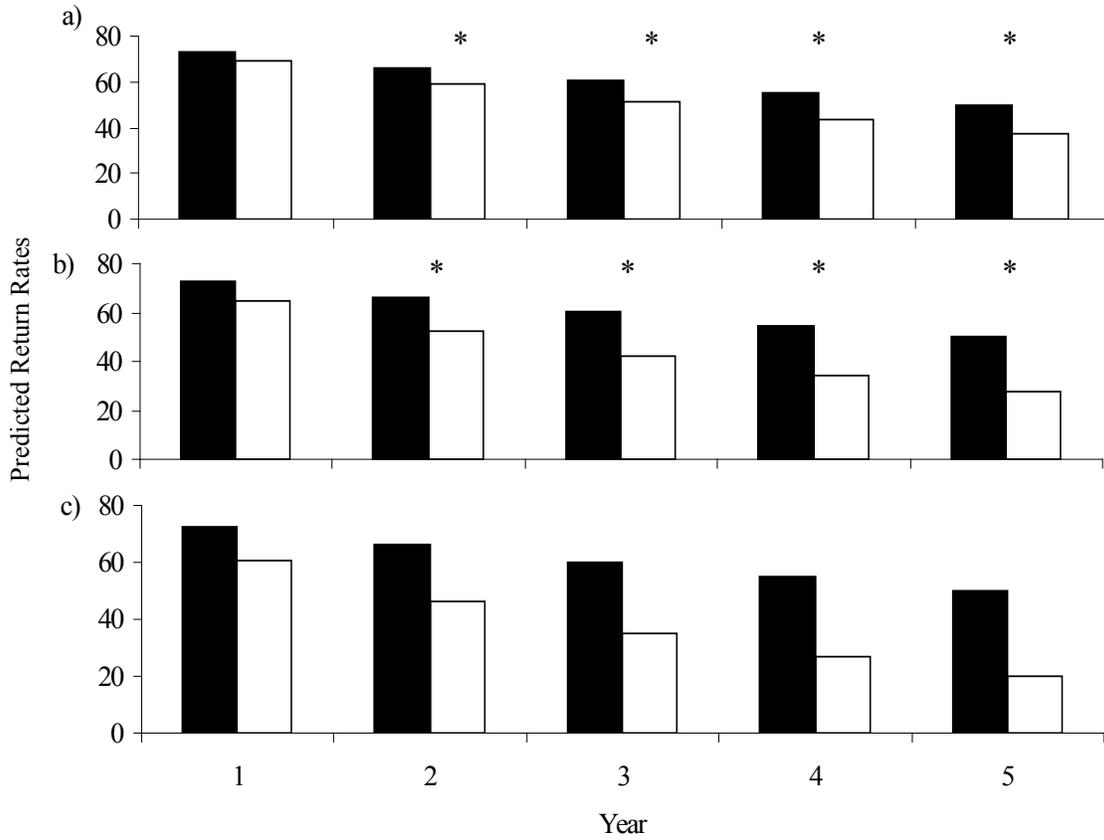


Figure 1: Estimated return rates over 5 years assuming that banding decreases survival by a) 5, b) 10 and c) 15% per year (see methods for details). Statistical difference ($P < 0.005$), calculated using chi-squared test is denoted by an asterisks (*)

The drop out rate of banded and unbanded individuals is shown in Figure 2. The initial drop out rate was high for both banded and unbanded individuals. There was no significant difference between the drop out rate of banded and unbanded groups at any stage during the period of the study.

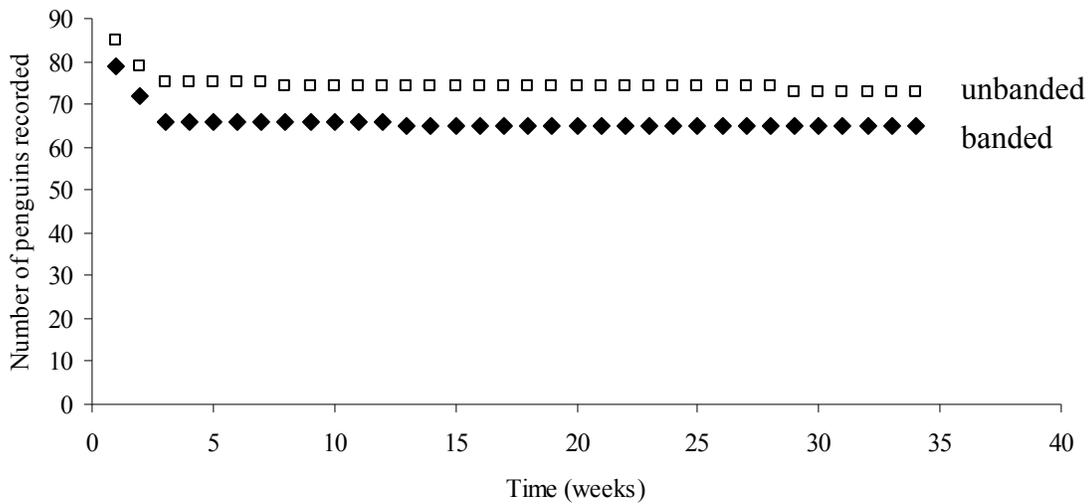


Figure 2: The drop out rate of banded (black diamond) and unbanded (grey square) individuals.

Discussion

This study compared the apparent survival of 200 African Penguins, 100 fitted with both bands and transponders and 100 with transponders only for one year. This interval spanned parts of two breeding seasons and the annual moult. Birds fitted with bands and transponders showed no significant difference to those without bands in returning to use the path. Given that the study did not rely on seeking out birds for resighting, there was no bias towards birds with bands over those with only transponders, as both were equally likely to be detected by the transponder reader. However, the small sample size limits the strength of conclusions that can be drawn from these results.

The initial large drop out rate for both banded and unbanded birds was unexpected. It is possible that as a result of the disturbance and handling, individuals did not continue to return to the same pathway after initial capture. Birds that dropped out also may not have been breeding at the start of the study. The initial drop out rate was similar for both banded and unbanded individuals. The initial period was characterized by multiple reader failures prior to the installation of the new reader system, but these birds were not seen again even once the new system was installed in 2006. It must be presumed that they were no longer using this path or did not return to the island in the 2006 season. An

alternative explanation of the large initial drop out rate was that substantial proportions of individual penguins using the pathways on any given day are from the pool of non-breeding birds, especially those of pre-breeding age, which are exploring the breeding grounds, investigating for potential mates and nest sites. The extent to which non-breeding birds visit the breeding colonies (as opposed to remaining on the shoreline) is unknown. It is possible that such a bird, having had a single “bad” experience in a particular section of a colony, avoids it in future. Hockey and Hallinan (1981) reported that adults looking for a nest site are sensitive to even low levels of disturbance, which might explain the rapid initial loss of both banded and unbanded individuals.

It is possible that the effect of the band will be amplified over the lifetime of the bird and this will not be detected over one year as found in a study on King Penguins where a small non-significant effect was found in the first year, but a strong negative effect was found over the long term (Froget *et al.* 1998). Hindell *et al.* (1996) stated that although there is no band effect on Royal Penguins over a year of breeding, they speculated that in years of decreased food availability banded birds will be at a greater disadvantage or that after their first breeding after banding, they may not be able to rebuild their body reserves for subsequent breeding attempts. Subtle differences in survival and fitness will be more likely to be detected over time.

Similarly Wolfaardt and Nel (2003) showed a small not non-significant decrease in breeding success of de-oiled and banded African Penguins on Dassen Island in years of low food availability. Clarke and Kerry (1998) in a study on Adélie Penguins showed similar result. However, it now appears more likely that the depression in breeding success in the Dassen Island study was a consequence of the effect of de-oiling rather than a consequence of the effect of banding (Barham *et al.* 2007). My study on Robben Island occurred during a breeding season when food was in particular short supply.

The availability of the sardine *Sardinops sagax* and anchovy *Engraulis encrasicolus*, the mainstays of the diet of the African Penguin, has been shown to strongly influence breeding success at Robben Island (Crawford *et al.* 2006), and is likely to influence the

number of birds of sufficient body mass returning to the colony to breed. The 2006 breeding season was considered to be below average for African Penguins at Robben Island (T.M. Leshoro pers. comm.). It is likely that this was a result of limited food availability in the region, and an eastward shift of the distribution of sardine along the South African coastline, decreasing the population of sardines in the areas where penguins from Robben Island hunt (van der Lingen *et al.* 2005). Penguins while breeding have a limited feeding range and food needs to be available within c. 20 km of the colony (Petersen *et al.* 2006). However, even in this year of decreased food availability there was no significant difference in the number of banded and unbanded birds returning to the colony.

The sample size of 100 would only show a significant difference during the second year if there is a 10% or greater effect of banding on the birds. The sample size is not large enough to detect a 5% effect even after 5 years. While a larger initial sample size would strengthen the results over the short term, only with a longer-term study will we know for certain whether the wearing of a band will be enough of a burden to decrease the survival of African Penguins on Robben Island. It is possible that the energetic cost of wearing a flipper band will result in decreased survival of African Penguins over the long term, as has been shown in Adélie Penguins (Ainley *et al.* 1983, Ainley 2002, Clarke and Kerry 1998) and King Penguins (Froget *et al.* 1998). It is important to come to conclusions about the African Penguin in their own right, because it is possible that they may have sufficient reserves in their energetic budget to be able to remain unaffected by the addition of a flipper band, as Hindell *et al.* (1996) hypothesized for Royal Penguins. However, this can only be known once a long-term study has been carried out.

Alternatively, the impact of wearing a flipper band may be a once-off impact on survival and should the individual survive and adapt to the initial change it is unlikely to be impacted by the band in the long term. It is possible to conclude from this study that the wearing of a band for a single year showed no significant decline in resightings between unbanded and banded birds however the strength of this result would be greatly increased

with a larger initial sample size. A cautionary stance regarding the impact of banding on the African Penguin should be taken until a long-term study has been completed.

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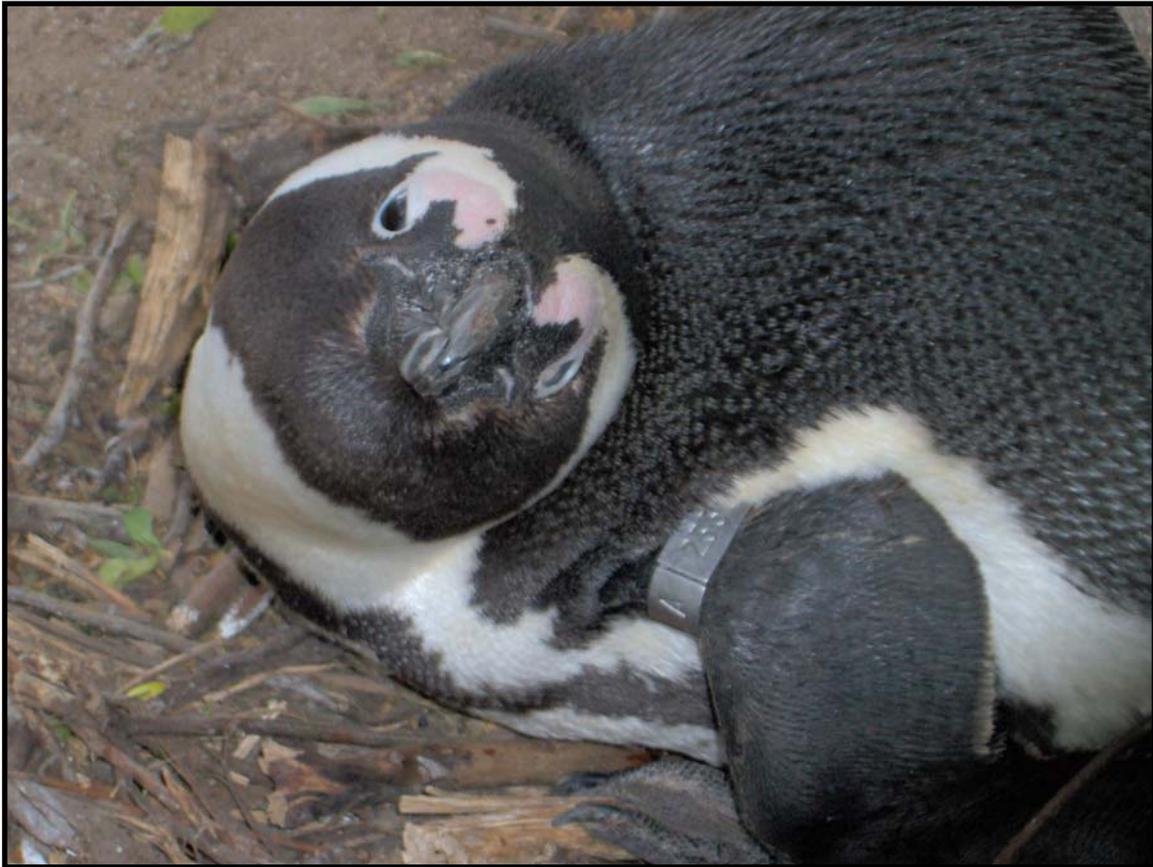
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Chapter 4

The effect of flipper banding on foraging trip durations by African Penguins



Abstract

Flipper bands have been inferred to greatly increase drag on swimming penguins, potentially decreasing foraging efficiency. One way to assess whether foraging efficiency is compromised is to compare foraging trip durations of penguins with and without bands. A total of 254 adult African Penguins on Robben Island, South Africa were injected with transponders, half of which were also fitted with flipper bands. The movements of these birds were then monitored remotely as they traveled between their nests and the sea. Only trips between 6 and 96 hours were used in the analysis to minimize the influence of experimental error. These accounted for 89.3% of the total number of trips (n=6211). Most trips lasted 10-15 hours for both banded (38.2%) and unbanded (44.9%) birds. Foraging trips of banded birds were longer (18.6 ± 13.1 h) than those of unbanded birds (17.6 ± 13.2 h). However, this difference was not significant once the difference between foraging trip lengths of individuals was taken into account, which accounted for 4.8% of the variance. Thus the largest influence on foraging times was individual differences rather than banding. Foraging trip length changes during the breeding cycle, being longest during incubation, shortest when provisioning young chicks, and then gradually increasing as the chicks grow. These differences may account for the large inter-individual differences recorded.

Introduction

Recent studies have highlighted the importance of understanding the cost of research techniques and weighing them up against the benefits and usefulness of the research and knowledge gained (Jackson and Wilson 2002). Much of what is known about penguin biology is as a result of flipper banding, but some recent studies suggest that flipper banding may have significant impacts on penguin survival, through impacts on insulation and locomotion (Jackson and Wilson 2002, Petersen and Branch 2004, Petersen *et al.* 2006a). Many studies have compared breeding success (Gauthier-Clerc *et al.* 2001, 2004, Wolfaardt and Nel 2003, Froget *et al.* 1998, Hindell *et al.* 1996) and survivorship (Ainley *et al.* 1983, Ainley 2002, Clarke and Kerry 1998, Wolfaardt and Nel 2003, Boersma and

Van Buuren 2004) of penguins fitted with flipper bands compared to those fitted with a subcutaneous transponder.

The attachment of external devices for research purposes impairs performance and presumably increases energy expenditure (Wilson *et al.* 1989, Culik *et al.* 1993, Ryan *et al.* 2007). In a laboratory-based study, using model penguins, Bannasch (1994) reported an increase in energetic costs associated with the attachment of a flipper band. Dugger *et al.* (in press) showed that although the foraging trips of banded birds were longer, the birds that are away for longer bring back more food. Studies based on analysis of departure and arrival times do not allow a distinction between the amounts of time spent hunting, and the amount of time commuting to hunting grounds or resting on the sea surface. However, there is a strong correlation between foraging trip duration, foraging range and the total distance traveled (Wilson 1985, Petersen *et al.* 2006b).

To date, studies on African Penguin flipper banding have focused on the effect of banding on breeding success, but the conclusions have been complicated by the fact that many banded birds have been rehabilitated after oiling (Wolfaardt and Nel 2003, Barham *et al.* 2007). The ability of a parent to forage efficiently has been shown to greatly influence the effective rearing of their offspring (Chappell *et al.* 1993) and thus if there is an effect of banding on foraging durations in the African Penguin this must be taken into account when deciding whether banding should be continued or not. However, no study to date has focused on the whether or not flipper banding influences foraging trip durations of African Penguins that have not been oiled or rehabilitated. This study addresses that gap, and aims to show whether there is an impact of flipper banding on the foraging times of African Penguins on Robben Island. However, even this study is likely to only monitor individuals that are breeding because they will be making frequent trips between their nests and foraging grounds.

Methods

Robben Island (33°47'S 18°22'E) was a convenient study site because it is 11 km from Cape Town harbour and it was, at the time of the study, the second largest penguin colony in South Africa (du Toit *et al.* 2004). Most importantly, the penguins on the island created very distinct pathways en route from their nesting sites to the sea (Shaw 2005). This made the use of a short-range transponder reader viable to monitor the coming and goings of birds to the colony. A weighbridge set up for a previous project provided an ideal natural funnel for use in this project, and penguins were already habituated to the modifications on the path (Chapter 2).

In July 2005, 200 adult African Penguins were caught on the pathway inland from the bridge and were injected with subcutaneous 32 mm transponders (Chapter 2). Every alternate bird also was fitted with a 316-grade stainless steel flipper band. Each penguin was measured (bill, weight.) and checked for a transponder to prevent double tagging. A single medium gate antenna and two optical sensors detected the individual number of the transponder, the time and direction of movement.

Between March and September 2006, individuals moving past the antenna were recorded with the direction of movement, time and their unique number. This coincides with the peak-breeding season of the African Penguin (Crawford *et al.* 1995). African Penguins are diurnal feeders; most foraging trips involve departure in the morning and return in the evening (Wilson 1985, Petersen *et al.* 2006b). The fact that the data were recorded electronically means that birds leaving before light or returning after dark were not missed by observers, resulting in observation times much greater than it would be if recorded manually. These foraging trip lengths included the time that is taken for the birds to walk to the beach, however long they spend idling on the beach, the amount of time they spend moving to and from a fishing ground, in addition to the amount of time spent on foraging. The foraging trip durations can therefore not be translated directly into foraging effort. They do, however, provide a clear indication of the amount of time spent

away from the nests and this is crucial, especially during the height of the breeding season.

A foraging trip was defined as a recording of an individual penguin moving towards the sea, and later moving inland again. An island stay was recorded when a trip inland was followed some time later by a trip towards the ocean. There were occasions when the records indicated successive movement in the same direction. This occurred when several birds, in addition to the bird with the transponder, passed through the recorder together, and can be ascribed to an unforeseen design error in the transponder reader system. Successive recorded movements in the same direction may also occur when birds make use of an alternate path, as observed on occasions. To prevent these errors from influencing the results, only trips that consisted of successive outwards and inwards recordings of passage time were used in the analysis. Foraging trips were only included if they were between six hours and four days (96 hours) although initial analysis included trips of longer than 96 hours, they did not affect the results and were excluded from subsequent analysis to ensure that only trips that were definitely foraging trips, and not as a result of birds not being read when they walk through the pathway, were included in the final analysis. Trips shorter than six hours are likely to have been brief excursions to the sea for bathing or drinking; there were also numerous short trips during which birds appeared to move backwards and forwards past the transponder reader, possibly because they were disturbed between the reader and entering the sea. Because we wanted to take inter penguin variability into account, the analysis was restricted to those penguins for which at least 25 foraging trips were available, but this choice of cut off was investigated to determine whether it modified the main conclusions. A multiple regression analysis was used to determine statistical significance of band status, individual differences and bill size (gender) using GenStat.

Results

Foraging trips that were between 6 and 96 hours accounted for 89.3% of birds' trips. This includes the vast majority of the trips, while excluding those that are likely to be artifacts

of the study design. The percentage of trips that were between 10 – 15 hours accounted for the majority of the banded (38.2%) and unbanded (44.9%) birds’ trips. In total, 6211 foraging trips were available for analysis. Of these, 231 (4.2%) were more than four days (96 hours) in length and 359 (6.5%) were shorter than six hours. Ninety-nine penguins made at least 25 trips. Of the 4918 trips between 6 and 96 hours in length made by these 99 penguins, 3645 (74.1%) were between six and 18 hours in duration; there were smaller peaks for trips of two days and three days duration (Figure 1). The mean duration of 2827 trips made by 54 unbanded penguins was 17.6 hours (median 12.9 hours, SD 13.2 hours) and of 2091 trips by 45 banded penguins was 18.6 hours (median 13.5 hours, SD 13.1 hours), suggesting that the trip lengths made by banded penguins averaged one hour longer than unbanded penguins.

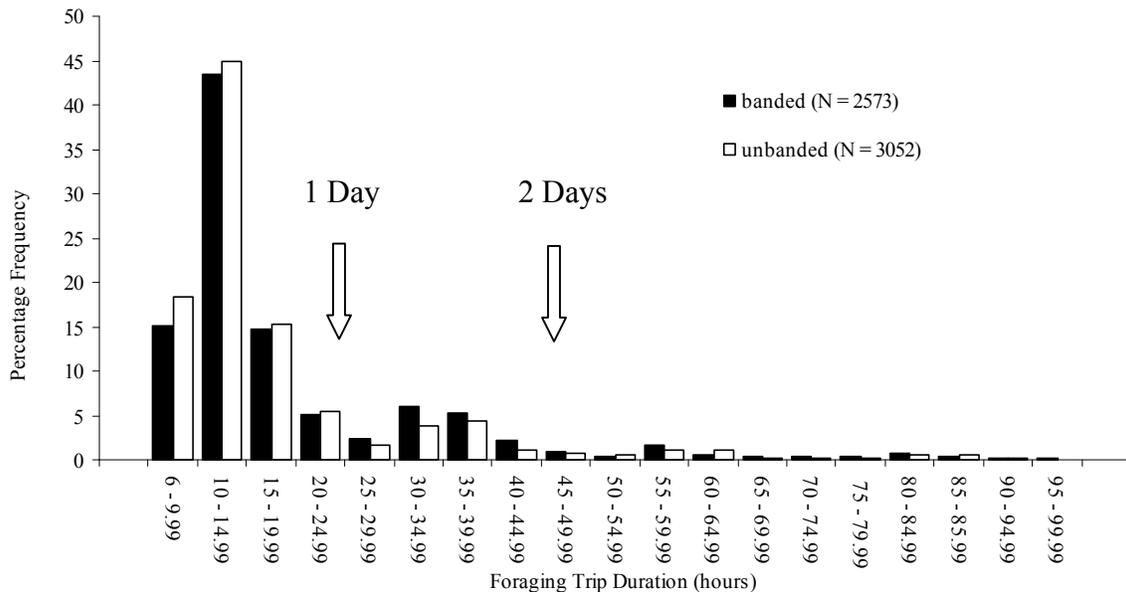


Figure 1: Percentage frequencies of foraging trip lengths for banded and unbanded penguins with transponders.

However, this difference does not take into account the fact that individual penguins potentially have different mean trip lengths. Fitting a model that included only individual penguin as explanatory variable accounted for 4.8% of the variance in trip length. The model that included only whether a penguin was banded or not accounted for 0.1% of the variance, suggesting a difference of 0.93 hours ($t=2.42$, $df = 4916$, $P=0.008$). However, when both individual penguin and banding status were included into the model, the effect

of band was no longer significant. The one-tailed test that foraging trips of flipper-banded birds were longer than those of unbanded birds was not significant ($t = -0.37$, $df = 4916$, $P = 0.85$).

Discussion

Although there have been a wide range of studies done on the effects of the flipper bands on different species of penguins, they have varied in their conclusions. It is also difficult to come to an overarching conclusion about flipper bands for penguins from studies that have used different methods and have been on a variety of species. The picture is further complicated by the fact that different studies have used a variety of bands – and that differences in the bands may result in differing effects on the penguins. It is possible that many of the band designs are sub-optimal, and that the negative impacts can be mitigated or eliminated by improved flipper band design. Ballard *et al.* (2001) pointed out that much of the discrepancies reported on the effect of flipper banding may be a result of variability at the level of individual penguins, and this is often not taken sufficiently into account.

The results show that banded penguins spend, on average, an hour longer at sea than unbanded birds. However, the vast majority of the difference in foraging time can be accounted for by individual difference (4.8%) rather than band status (0.1%). Indeed once the individual is accounted for, the difference of having a band or not is no longer significant. The inherent difference between individuals influences foraging time to a greater extent than whether the individual is wearing a band or not. However, this does not negate the fact that there is a difference in foraging trip duration of banded and unbanded individuals, and this could be as a result of decreased foraging efficiency. This could be tested further by measuring the amount of food available to chicks when adults return after foraging trips by conducting diet samples.

The average trip length differs considerably from the average trip durations of approximately 45 hours obtained by Heath and Randall (1989) at Algoa Bay. These birds

were, however, fitted with packages of 1.4–1.6% of the birds' body weights and therefore a direct comparison cannot be made. These results may be artificially inflated as a result of large external devices.

Although there is no certainty about the state of breeding of the individuals in this study, it is likely that individuals making regular repeated trips to and from the island would be those that are breeding (Wilson 1985). Birds that fail during incubation will have longer average trips than those that breed successfully since only birds that are provisioning for chicks will be under pressure to return rapidly to the colony (Wilson 1985). Studying birds that are of sufficiently high fitness levels to breed may result in small, cumulative impacts of the flipper bands that may only be of importance over the lifetime of the bird remaining undetected. The proportion of birds breeding is likely to be the most sensitive parameter for detecting if there is an effect of flipper banding.

The difference between foraging lengths could compromise the ability of banded individuals to breed successfully over the long term since the ability of a parent to forage efficiently has been shown to greatly influence the effective rearing of their offspring (Chappell *et al.* 1993) and these banded birds will be spending less time at the nest, and longer commuting and foraging. Foraging trip lengths recorded in this work do not take into account the fact that the penguins spend varying amount of time idling en route to the beach and on their return to their nests. It is presumed that both banded and unbanded birds will spend similar amounts of time idling.

While it may be possible that the effects of flipper banding may manifest over a life time of an individual, it has been argued that the largest effect of flipper banding will occur within the first year of banding (Peterson and Branch 2004). It is possible that the difference in average foraging time between banded and unbanded birds may decrease after the first year, and thus only the continued monitoring of foraging times is likely to increase the understanding of the effects of flipper banding of African Penguins and separate the difference that results from individuals as opposed to flipper banding. The fact that banded birds spent, on average, one hour longer foraging than unbanded birds,

necessitates a cautious approach to banding in the future. Even though this result was not significant once individual difference was taken in to account, it indicates that there is some effect of banding and highlights that the importance of continuing this study in order to test for long term effects of banding. In the meantime only small numbers of individuals such as those released once rehabilitated at SANCCOB should continue to be banded.

The magnitude of the individual differences between penguins was not foreseen at the start of this study. The power of the study to measure the impact of flipper band on foraging trip duration could be increased by removing bands from penguins with both bands and transponders, and by adding bands to penguins with only transponders. This would help to remove the effect of individual variation between birds. However, it does increase the amount of handling of individual birds. Nevertheless, if done judiciously, a carefully designed study, involving recapture of penguins with transponders and adding/removing bands is feasible, would improve the results. It would be best if such a study took place over more than one breeding season, with banding status altered twice per year, but taking into account the breeding status of the penguins at the time of changeover.

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Chapter 5

The effect of flipper banding on the breeding success of African Penguins



Abstract

Recent concern over the impact of flipper banding precipitated this study on the breeding success of the African Penguin at Boulders Beach, South Africa. Breeding success for banded and unbanded birds was compared in 2006. The study included 100 nests with varying degrees of vegetation cover; proximity to the disturbance; burrow depth and either soil or clay substrate, half of which had at least one banded adult, and the other half had no banded adults. No significant differences in nest success were found between the different nest types, and while success was higher in unbanded nests, this difference was also not significant. It is suggested that once an individual has reached the level of fitness required to breed, the chance of success is equivalent for unbanded and banded birds.

Introduction

Recent studies of the effect of attaching a metal band to the flipper for the lifetime of a penguin have resulted in much debate into the cost *versus* the benefit of research conducted in this way. Some researchers have reported that flipper bands increase the drag experienced by an individual when swimming by as much as 24% (Culik *et al.* 1993). Penguins are altricial, providing parental care to their young from hatching to fledging; thus an adult penguin's ability to forage efficiently plays an important role in its ability to successfully rear its young (Chappell *et al.* 1993). Only birds of a certain fitness level are able to attempt breeding. If flipper bands hamper the effectiveness of foraging, either by increasing energy expenditure during swimming (Culik *et al.* 1993) or decreasing maneuverability (Bannasch 1994), the possible effect on the reproductive success of penguins needs to be investigated.

In a double vs. single banding study on King Penguins a delayed onset of breeding in the double banded birds was shown, thought to be caused by an increased foraging effort (Olsson and Brodin 1997, Froget *et al.* 1998). It is recognized that the difference of effect of double banding as opposed to single banding may not compare linearly to the difference between a single band and no band at all. However, a similar delay in the onset

of breeding and a lower success rate were found in banded birds compared to those fitted with subcutaneous electronic transponders in a study over five years on King Penguins (Gauthier-Clerc *et al.* 2004). On the other hand, a separate study has found that Royal Penguins with bands experienced no differences in breeding success compared to those fitted with subcutaneous transponders (Hindell *et al.* 1996). It is possible that any effect of banding may be species specific and may also vary depending on the quality of the bands used.

The African Penguin is listed as Vulnerable (BirdLife International, 2004). It is endemic to southern Africa and breeds at 29 localities between central Namibia and Nelson Mandela Bay (formerly Algoa Bay), South Africa (Hockey *et al.* 2005). Its population decreased from more than one million adult birds in 1910 to 0.2 million in 2000 (Hockey *et al.* 2005). While research into the population fluxes and breeding success are important in determining the management of the species, it is important that the methods used do not interfere or cause harm to the birds.

Studies on the effect of banding on breeding success have been conducted at Robben Island and have shown no differences in the success of banded and unbanded adults (Barham *et al.* 2007). A study conducted at Dassen Island on the breeding success of African Penguins rehabilitated and thus banded after the 1994 *Apollo Sea* oil spill also showed no differences in breeding success between the rehabilitated birds and non-banded control birds, after a period of six years (Wolfaardt and Nel 2003). However, breeding success is highly variable in African Penguins from year to year. In the latter study, banded birds were less successful breeders than unbanded birds in years of poor food availability, but the reduction in breeding success was not statistically significant. It is hypothesized that any negative effect from banding on breeding success might be exaggerated in years of limited food availability if banding affects the body condition of birds which will also influence the proportion of banded birds that attempt to breed (Wolfaardt and Nel 2003, Robinson *et al.* 2005). This study attempts to investigate whether there is an influence of banding on breeding success by controlling for differences in nest types and disturbance levels within the Boulders Beach reserve.

Methods

Study Site

Boulders Beach (34°12'S 18°27'E) is approximately 40 km south of Cape Town and forms part of the land managed by Table Mountain National Park (TMNP). The colony began with just two pairs of birds nesting in 1985 (du Toit *et al.* 2004). The initial rapid growth of the colony has slowed in recent years (Crawford *et al.* 2000, du Toit *et al.* 2004, Petersen *et al.* 2006 Underhill *et al.* 2006). The annual census conducted in 2006 estimated a total of approximately 1075 nests within the park and its immediate surrounds, a decrease from the peak of 1227 nests in 2005 (Underhill *et al.* 2006, Monique Ruthenberg pers. comm.). The colony consists of a central core area that is actively managed by the TMNP and surrounded by a penguin-proof fence designed to limit the expansion of the colony inland, and a peripheral area that extends laterally along the coast in both directions. This study was limited to nests within the central core to control for the higher amount of disturbance experienced by nests outside the park. Previous studies have shown that nests outside the park have lower breeding success than those within the park boundaries (Murison 1998, de Vos 2005). This effect has also been observed in Magellanic Penguins (Gochfeld 1980).

Study Design

The main breeding season for African Penguins is between March and October with a peak in May (Murison 1998, Crawford *et al.* 2000). Nest monitoring began on 15 March and ended on 2 August 2006. Nests were chosen where an adult was seen incubating at least one egg. Newly initiated nests were included in the study up until 18 May. All nests were monitored throughout the study period regardless of failure. Second breeding attempts were not included in the study although they were noted.

For each banded bird found incubating on a nest, an unbanded bird incubating on a nest of similar characteristics was also marked and monitored. Nests were marked with a red

plastic tag attached with galvanized wire to a dowel stick hammered into the ground next to the nest. Unbanded birds were marked temporarily with Porcimark at the beginning of the study to ensure that both partners were unbanded. A total of 53 pairs of nests were monitored. Three pairs of nests were subsequently excluded after alien vegetation clearance in the close vicinity of the nests resulted in desertions. The study therefore concluded with 50 nests at which one parent was banded and 50 nests at which both parents were unbanded.

The nests varied in the degree of protection they provided with some in burrows that gave protection on three sides and others in scrapes with varying degrees of vegetation cover or no cover at all. The extent of nest cover has been shown to significantly influence breeding success in Magellanic Penguins (Frere *et al.* 1992, Stokes and Boersma 1998), Yellow-eyed Penguins *Megadyptes antipodes* (McKay *et al.* 1999) and in African Penguins (Seddon and van Heezik 1991). The nests were therefore characterized on the basis of four criteria: 1) the substratum; 2) the percentage vegetation cover; 3) the degree of burrowing and 4) the distance from any of the pathways. A single person undertook all scoring to minimize any potential bias.

Substratum was defined as either clay or sand. The clay soil is derived from granite and low nutrient soil (de Vos 2005) and is resistant to erosion but susceptible to flooding after heavy rains. It allows for burrowing, which is not possible in the highly mobile sand.

Vegetation cover was scored out of three, with 0 being minimal to no vegetative cover, 1 as moderate cover and 2 as full cover. The vegetation in the area consists of thickets of Strandveld dominated by alien trees, Manatoka *Myoporum serratum*, Rooikrans *Acacia cyclops* and the native Wild Olive *Olea africana* (Murison 1998, du Toit *et al.* 2004).

Nest design was scored out of three. Burrows protected on three sides as well as overhead were scored as 2; a scrape scored 1 and open nests with no excavation scored 0. It is important to note that nest excavations continued throughout the breeding period, especially once the chicks were born, however only initial scores were used in the study.

Distance from the pathways was also scored out of three. Where the nest was 0–2 m from a pathway it scored zero, or highly disturbed, where it was 2–7 m from the pathway it scored 1 or moderately disturbed, and where it was more than 7 m from the pathway it scored 2 or minimal disturbance. The pathways included all public access walkways and the two boardwalks within the park. With more than 40 000 tourists, on average, visiting the colony annually (Petersen *et al.* 2006) the amount of disturbance from human proximity to nests is likely to substantially influence nesting success (Murison 1998). However, it also means that birds are less likely to be disturbed by research. To minimize the disturbance caused by nest checks, only one person moved within the colony during the weekly nest checks, except in the initial stages when nests with banded birds were being sought, and two people moved through the colony.

Because only nests that were occupied by an adult incubating at least one egg were used in the study, a comparison of egg production between banded and unbanded birds is meaningless. The initial number of eggs was recorded, as well as the number of hatchlings resulting from those eggs (hatching success). The African Penguin has average an incubation period of 40 days, thus any eggs that continued to be incubated for more than six weeks were presumed to have failed. The number of chicks that reached the stage where at least 50% of the down had been replaced with feathers (fledgling success) was also recorded. It proved difficult to monitor birds past this stage because they had often formed crèches with individuals of a similar age. Final analysis was done using the number nests with at least one successful fledgling resulting.

Breeding success was determined using an extension of the Mayfield (1975) method developed by Underhill (submitted for publication). To put the results in context, they have been compared against rates of success in a previous study conducted at Boulders Beach in 2005 (de Vos 2005).

Results

Nest success was measured in two ways: a nest either survived the incubation period (taken as 40 days) to produce at least one hatching or the clutch was lost; or a nest with at least one hatchling survived 74 days to produce at least one fledging. The effect of flipper banding (i.e. one parent having a flipper band) on the success of the incubation period was not significant ($t_{95} = 0.50$, $P=0.31$, one-sided test). According to the model, the probabilities of a nest successfully surviving incubation with and without a flipper-banded adult were 0.680 and 0.722, respectively. However, the 95% confidence intervals on these probabilities overlapped and were large (0.599, 0.771) and (0.650, 0.804), respectively. Similarly, the effect of flipper banding on the success of the fledging period was not significant ($t_{62} = -0.66$, $P=0.74$, one sided test) and in fact went in the opposite direction to what was predicted. The modeled probabilities of a nest successfully surviving the fledging period with and without a flipper-banded adult were 0.712 and 0.633, respectively. However, once again the 95% confidence intervals on these probabilities were large (0.614, 0.840) and (0.509, 0.786), respectively, with considerable overlap between them. Productivity for nests with at least one banded individual was 1.1 and for those with two unbanded adults, was 1.07.

In addition there were no significant differences between nests situated in the open, those in shallow burrows or those in full burrows, either during the fledging period or incubation period (all tests have $P>0.05$). Similarly, there was no significant effect of vegetation cover, or of distance to the pathway, indicating that, at this colony, penguins were habituated to the presence of humans near their nests (Appendix 1).

While banded birds were slightly more successful when vegetation cover was at its fullest, the unbanded birds were more successful at intermediate levels of vegetation cover, and when there was no cover at all. These relationships were not statistically significant. Banded birds were more successful where nests were 0 – 7m from the pathway, but not when they were greater than 7m from the path. This relationship was not significantly different. Banded birds were more successful when nests were in clay,

whereas unbanded birds were more successful on sandy soil but this was not statistically significant (Figure 1). Breeding success in 2006 did not differ significantly from that in the 2005 season (de Vos 2005).

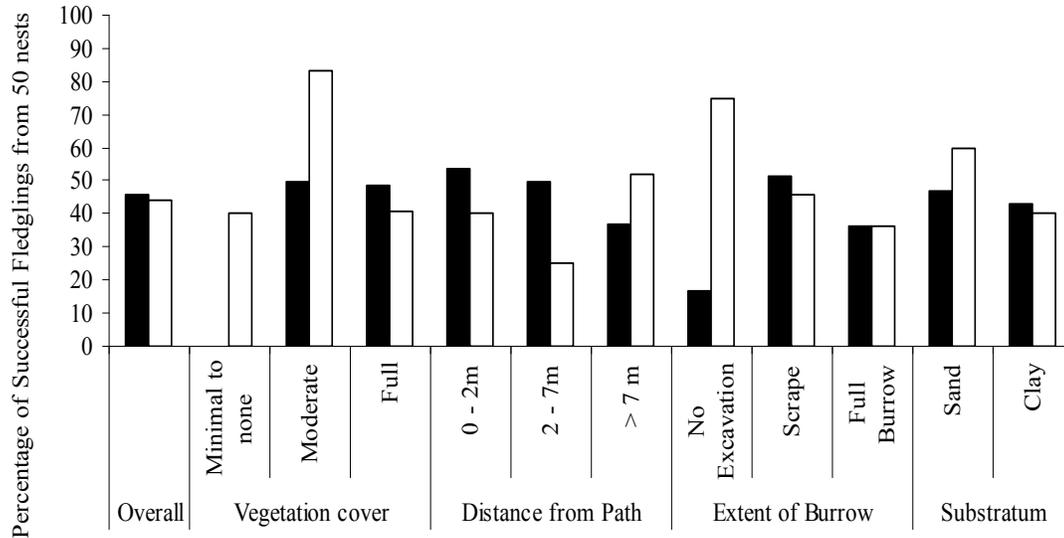


Figure 1: The percentage of successful fledglings from 50 nests with at least one banded adult (black bars) and 50 nests of two unbanded (white bars) penguins at Boulders Beach, Simonstown. Including the break down of success for each of the four nest characteristics.

Discussion

The breeding season in 2006 was considered to have below average success rates for Boulders Beach penguins (Underhill *et al.* 2006, Monique Ruthenburg pers. comm.) possibly as a result of decrease in available food as a result of the impact of the fishing industry that operates off the west coast (van der Lingen *et al.* 2005). Petersen *et al.* (2006) have shown that African Penguins from Boulders Beach had to travel further and longer than penguins from other colonies to forage. A decrease in availability of sardines and Cape Anchovies, the penguins' primary food sources, would thus negatively influence their capacity to forage (Nagy *et al.* 1984, Crawford and Dyer 1995, Crawford and Jahncke 1999, Crawford *et al.* 2000, Crawford *et al.* 2006). However, there was no significant difference in the overall breeding success in the 2005 season to that of the

2006 season. This may mean that the previous season was also below average as a result of decreased food availability. Although significant differences were found between fledgling success of nests with variable degrees of vegetation cover and extent of burrowing in the 2005 study conducted at Boulders Beach (de Vos 2005), such differences were not found to be of statistical significance in this study, where the sample size was appreciably smaller.

It has been predicted that during periods of decreased food availability, such as experienced in 2006, birds with flipper bands will be likely to be less successful than those birds unencumbered by flipper bands (Wolfaardt and Nel 2003, Robinson *et al.* 2005). However, this study has found that there was no statistically significant difference in fledging success between nests of banded birds and those of unbanded birds.

It is acknowledged that only birds of a sufficient level of fitness will attempt breeding regardless of whether they are banded or not, and thus there may be an effect of banding that is not seen in studies on breeding success because only the fittest of the banded birds breed. This study was designed to look at the breeding success of those penguins that were fit enough to breed. It is possible that there are a higher proportion of banded birds that do not reach the fitness level required to begin breeding. It is during breeding and the subsequent stage of parental care that the birds are under most pressure to forage effectively and efficiently. It must nonetheless be considered when deciding on the impact of flipper bands for the whole population, which includes those individuals that are not breeding. What is needed is a study that examines whether there is a difference in the proportions of banded and unbanded penguins that do not breed in a given year.

Given that few penguins have been banded since the *Treasure* oil spill in 2000, nests that contained banded birds were limited in number. For each nest of banded birds, a nest of unbanded birds with similar characteristics and in close proximity was also found. This was to minimize any results that may have been as a function of nest characteristics rather than the successfulness of the bird.

It has been shown that in dense populations, better nesting sites are selected first by better-experienced and fitter birds. Younger or less fit birds must make do with the nesting sites that are left over (Tenaza 1971, Volkmann and Trivelpiece 1981, Davis 2001, Frere *et al.* 1992). Because it is a long time since birds were banded, the banded sample would have been composed of older birds (at least six years old), some of which might have been geriatric, others in the peak of breeding condition, with few young birds. It may be that birds that are banded may not get the best quality nesting sites. It is also possible that because nests of unbanded individuals with similar properties to those of banded individuals were chosen for the study, the comparative unbanded birds are those of lower fitness or are younger on average and thus have lower quality nest sites, although this cannot be quantified. If this is the case, the results are not representative of the entire population. However, the nests that were chosen covered a wide range of characteristics known to influence successfulness of breeding attempts including; substratum type (Stokes and Boersma 1991, 1998), nest type (Paredes and Zavalaga 2001), degree of cover (With and Webb 1993), and proximity to disturbance from tourists (McKay *et al.* 1999). None of these factors were shown to have statistical significance to breeding success.

It is also important to acknowledge that there are many aspects that influence the breeding success of individuals, including nest site selection; proximity to disturbance; design of the nest; and timing of breeding (Seddon and van Heezik 1991, Stokes and Boersma 1991, Frere *et al.* 1992, Stokes and Boersma 1997, McKay *et al.* 1999). Burrows that provide protection from three sides as well as overhead have been shown to have a moderating effect on external temperature changes in the case of Magellanic Penguins *Spheniscus magellanicus* (Frere *et al.* 1992) and this may also be the case in African Penguin nests, where excessive heat may result in nest desertions. Burrows are not possible in sandy soil and even in clay soil are at risk of collapse. The external environment also influences success, since high temperatures may result in nest desertions by birds that risk dehydration (Randall 1987) and heavy rains may flood nests causing nest desertion and fatalities in young chicks (Barham *et al.* 2006).

It is worth noting that 24% of the banded nests contained birds that were banded during the *Treasure* oil spill in 2000. Recent evidence has suggested that, on Robben Island, these birds had a lower breeding success than other birds affected by previous oiling events (Barham *et al.* 2007) and despite that there was no significant difference in breeding success of banded and unbanded birds.

In conclusion, a lack of significant difference between nest success of banded and unbanded birds suggests that once birds have reached the level of fitness required to breed, the presence of a band is unlikely to hamper breeding success. This study did not measure the degree to which a band may affect the ability of individuals to reach a level of breeding fitness. It also did not measure whether banded birds are being left with the less desirable nesting sites. This study does show that bands do not negatively influence the success of African Penguins that have reached breeding fitness level, even in years of low food availability and decreased breeding productivity at Boulders Beach.

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Chapter 6

Synthesis



Concern about the effects of flipper bands on penguins (Jackson and Wilson 2002) prompted this study to assess whether bands have an impact on African Penguins *Spheniscus demersus*. While previous studies have touched on aspects of this question (Cooper and Morant 1980, Whittington 2003, Wolfaardt and Nel 2003, Barham *et al.* 2007), this is the first investigation to test whether flipper bands have an impact on this species independently of other factors such as oiling and rehabilitation. This dissertation reports the initial findings after a little more than one year of monitoring marked birds. Continued research is required to form responsible management decisions.

Summary of key findings

I failed to find a significant impact of flipper bands on the survivorship of African Penguins at Robben Island, but the tendency was for fewer banded birds to return to the colony, and the power to detect even a gross impact such as a 10% reduction in survival is low over one year. Foraging trip durations of banded birds averaged longer than those of unbanded birds, although this pattern apparently was influenced by individual differences between birds. Increased foraging trip durations suggest that banded birds have to spend longer at sea to feed efficiently, and may be expected to influence the ability to breed successfully through reduced provisioning rate to chicks. However, the breeding success of pairs with at least one banded bird was not significantly different from that of unbanded pairs at Boulders Beach in 2006. This was despite 2006 being a below average year for penguin breeding in general, which is when one would expect any negative effect of banding to be at its greatest (Wolfaardt and Nel 2003, Robinson *et al.* 2005). However, the banded birds in this study differed from those in the transponder study at Robben Island in that they were not newly banded, and thus had survived any initial impact of bands.

Future Research Directions

The results presented here are of necessity preliminary, given the need to complete the dissertation within the period of research funding. Clearly the most important priority for

future research is to continue monitoring the fate of the banded and control groups of transpondered birds at Robben Island. Linked to this, increasing the sample size of transpondered birds will greatly increase the power to detect a significant impact of bands on apparent survival (return rate) of penguins. Fortunately both these measures are taking place. Passive monitoring of marked birds at Robben Island is ongoing, and a further 100 birds were marked in 2007, and it is planned to mark 300 more in 2008. Having multiple cohorts of marked birds will further improve our understanding of the effects of bands on penguins by allowing for inter-year comparisons.

Several other questions may be worth investigating. Probably the most useful would be to link foraging trip durations to the stage of breeding. Foraging trip length varies with stage of breeding, being longest during incubation, shortest when provisioning small chicks, and gradually increasing again as chicks grow (Wilson 1985). Being able to control for this source of variation in foraging trip length would increase the power to detect any differences attributable to bands. The apparent differences in foraging trip length between banded and unbanded birds are intriguing and warrant further investigation. Do individuals making longer trips bring back more food? Or are they spending longer trying to collect the same amount of food?

It would also be ideal to monitor breeding success of birds that form part of the transponder study at Robben Island. However, this was attempted during the present study, but proved extremely difficult due to the dense vegetation and the low tolerance to disturbance exhibited by birds on Robben Island. Breeding success was monitored on Boulders Beach to overcome some of the problems associated with Robben Island. It is worth investigating the possibility of using transponders to conduct a similar study on foraging trip lengths at Boulders Beach where breeding success is more easily monitored. This may require slightly different technology and study design because birds at Boulders Beach are less constrained to commute along narrow pathways, potentially preventing the use of short range transponder antennae.

Chick growth rates may prove to be a more sensitive measure of adult foraging performance than breeding success. Comparing growth rates of chicks from banded or unbanded adults would allow one to detect if there are any sub-lethal impacts on breeding success of banded adults. Other factors to consider include the influence of gender of the banded bird on foraging trip durations and chick growth. One might expect smaller females to exhibit greater effects from bands. However, this would require genetic sexing of birds, given the poor discrimination of sexes based on morphology (see Chapter 2).

Finally, the timing of breeding and moult may be altered as a result of banding, if banded birds are unable to accumulate the energy reserves necessary for these activities at the same rate as unbanded birds. This may also be reflected in differences in body condition after a given a period with the band. Similarly, the body condition of banded and unbanded individuals at the same stage of moulting could be compared. This negates any bias of a study that only compares individuals of a sufficient fitness to breed. However, handling moulting birds is very disruptive, because penguins are very sensitive to disturbance at this stage of their life cycle (Petersen and Branch 2004).

Recommendations

The injection of subcutaneous electronic transponders opens up a whole new field of research that would not be possible with flipper banding as the only means of marking. It allows for the electronic and consistently repeatable collection of data that would not be practical with flipper bands as the exclusive means of marking. The sheer volume of data that can be gathered with transponders greatly increases our knowledge of the movements and habits of African Penguins. However, the purchase of transponders and the associated readers is expensive. The short distance at which the transponders can be read also limits their usage. The collection of data requires that an individual must be in close proximity to a reader, and this is not always feasible, especially in other locations where the penguins do not necessarily use well-marked, narrow pathways.

The main drawback to using transponders is that it is not possible to recognise a marked individual without an electronic reader, constraining the types of research that can be undertaken. It is difficult to find the nests of birds with transponders, and the short range at which transponders can be read with handheld readers is likely to increase disturbance of birds in the field. Flipper bands can be read from a distance without physically disturbing any individuals. Another advantage of flipper banding is that when an individual wearing a band dies, it is possible for the band to be noticed by a member of the public and reported to the ringing office. Dead penguins with transponders cannot be “recovered” in this way. However, the speed with which technology is advancing means that improvements in transponder technology and their associated antennae can open up new exciting methods in scientific studies of this nature (Petersen and Branch 2004).

While both techniques have their strengths and weaknesses, it is most important to recognise that transponders and flipper bands are appropriate for different types of research, and one cannot necessarily replace the other. If flipper banding is to be discontinued, an alternative means of external marking may be required for certain types of research, such as those that require survival estimates based on recoveries, immigration/emigration studies and nest/mate fidelity studies. The evidence to date, while equivocal, tends to suggest that flipper bands do have some impact on the foraging performance and perhaps survival of African Penguins. Accordingly, a precautionary approach should remain in place, preventing large-scale banding of African Penguins until the long term effects of flipper banding has been investigated thoroughly.

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