Polarforschung 77 (1), 7 – 15, 2007 (erschienen 2008)

Linking Variation in Penguin Responses to Pedestrian Activity for Best Practise Management on Subantarctic Macquarie Island

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Abstract: From 2001–2005, a project was undertaken on subantarctic Macquarie Island to investigate the variation in responses to pedestrian activity by King *Aptenodytes patagonicus,* Gentoo *Pygoscelis papua* and Royal *Eudyptes schlegeli* penguins. The overall aim was to produce management-oriented information both for commercial tourism in the subantarctic and Antarctic, and for Antarctic Treaty Consultative Parties. A series of experimental and observational studies were employed to quantify aspects of physiology, behaviour and reproductive success of these three species of subantarctic penguins when exposed to pedestrian activity – the most common form of human activity on Macquarie Island. Key aspects of penguin ecology likely to yield information valuable to management were investigated, including: 1) the efficacy of current minimum approach distance guidelines for visitation to penguins; 2) the effect of visitor group size on penguin responses to pedestrian activity; 3) the role of habituation in penguin responses to pedestrian activity; 4) the phase of breeding / moult during which penguins are most sensitive to pedestrian activity; and 5) comparative responses to human activity between the three species examined. This paper describes key results from these five studies, and the application for management of human-penguin interactions on Macquarie Island and other subantarctic and Antarctic locations.

Zusammenfassung: Von 2001 bis 2005 wurde auf der subantarktischen Macquarie-Insel bei Königspinguinen *(Aptenodytes patagonicus),* Eselspinguinen *(Pygoscelis papua)* und Haubenpinguinen *(Eudyptes schlegeli)* die unterschiedliche Reaktion auf Fußgänger-Aktivitäten untersucht. Das allgemeine Ziel war, Management orientierte Informationen sowohl für den kommerziellen Tourismus in der Subantarktis und der Antarktis als auch für die Antarctic Treaty Consultative Parties zu formulieren. Es wurde eine Reihe von experimentellen Studien und Beobachtungsstudien angestellt, um Aspekte der Physiologie, des Verhaltens und Fortpflanzungserfolges der drei subantarktischen Pinguin-Arten zu quantifizieren, wenn sie Fußgänger-Aktivitäten ausgesetzt sind, der häufigsten Form menschlicher Aktivitäten auf der Macquarie Insel.
Die folgenden wichtigen Aspekte der Pinguinökologie, die wertvolle Informationen für ein Management beinhalten, wurden untersucht: 1) Wirksamkeit der Richtlinien zum Minimalabstand bei Besuchen in Pinguinkolonien. 2) Einfluss der Besuchergruppengröße auf die Reaktion der Pinguine bei der Begegnung mit Fußgängern. 3) Rolle einer Gewöhnung bei der Reaktion der Pinguine auf Fußgängeraktivitäten. 4) Phase der Brutzeit bzw. Mauser, während der die Pinguine am empfindlichsten auf Fußgängeraktivitäten reagieren. 5) Vergleich der Reaktionen der drei untersuchten Arten auf menschliche Aktivitäten.
Die Arbeit beschreibt die wichtigsten Ergebnisse dieser fünf Untersuchungen und ihre Anwendung für das Management der Mensch-Pinguin-Interaktionen auf der Macquarie-Insel und anderen subantarktischen und antarktischen Gebieten.

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Manuscript received 14 September 2007, accepted 01 November 2007

INTRODUCTION

As the number of people visiting the subantarctic and Antarctic increase, so do incidences of human-wildlife interaction. In these regions, Antarctic Treaty Consultative Parties conduct and support scientific research and commercial tourism is increasing dramatically (Council for Environmental Protection 2004, IAATO 2005a). At several locations, penguins can be exposed to considerable human activity, often during critical periods of breeding and moult (Kriwoken & Rootes 2000, Naveen 2003). Consequently, there is a need for effective and timely management of human-wildlife interactions that reflect the high conservation values of these areas.

Ideally, best practice human-wildlife interaction guidelines should be based on empirical studies, and appropriately cater for any variation in how animals may respond to human activity. Previous studies have reported varying results in how penguins will respond to human activity in populations (Woehler et al. 1991, Woehler et al. 1994, Patterson & Fraser 1998, Patterson et al. 2003), colonies (Giese 1996, Cobley & Shears 1999, McClung et al. 2004), and individual penguins (Culik & Wilson 1995, Nimon et al. 1995, Fowler 1999). Common elements from these studies strongly suggest that responses to human activity will be both species and location specific. Several other common elements known to influence how seabirds respond to human activity are also likely to be relevant for penguins, including the breeding phase during which interactions with human activity occur (Götmark 1992, Yorio & Quintana 1996, Bolduc & Guillemette 2003), the level of previous exposure to humans (Keller 1989, Yorio & Boersma 1992, Dunlop 1996, Bright et al. 2003), proximity to human activity (Giese 1998, Ikuta & Blumstein 2003, Fernández-Juricic et al. 2005), and stimulus type (Culik et al. 1990, Rodgers & Smith 1995, 1997, Lord et al. 2001).

Subantarctic Macquarie Island (54°30' S, 158°57' E; Fig. 1) is one of the most significant conservation areas in Australia, reflected in its status as a World Heritage Area, an United Nations Educational, Scientific and Cultural Organization (UNESCO) Biosphere Reserve and a Tasmanian Nature Reserve (TASPAWS 2003a). Management of Macquarie Island is primarily the responsibility of the Tasmanian Parks and Wildlife Service (TASPAWS) and the Tasmanian Department of Primary Industries, Water and Environment (DPIWE). In addition, the Australian Antarctic Division (AAD) has maintained a strong presence on the island supporting and undertaking science programs, and has operated a permanently occupied station since 1949 (Fig. 1).

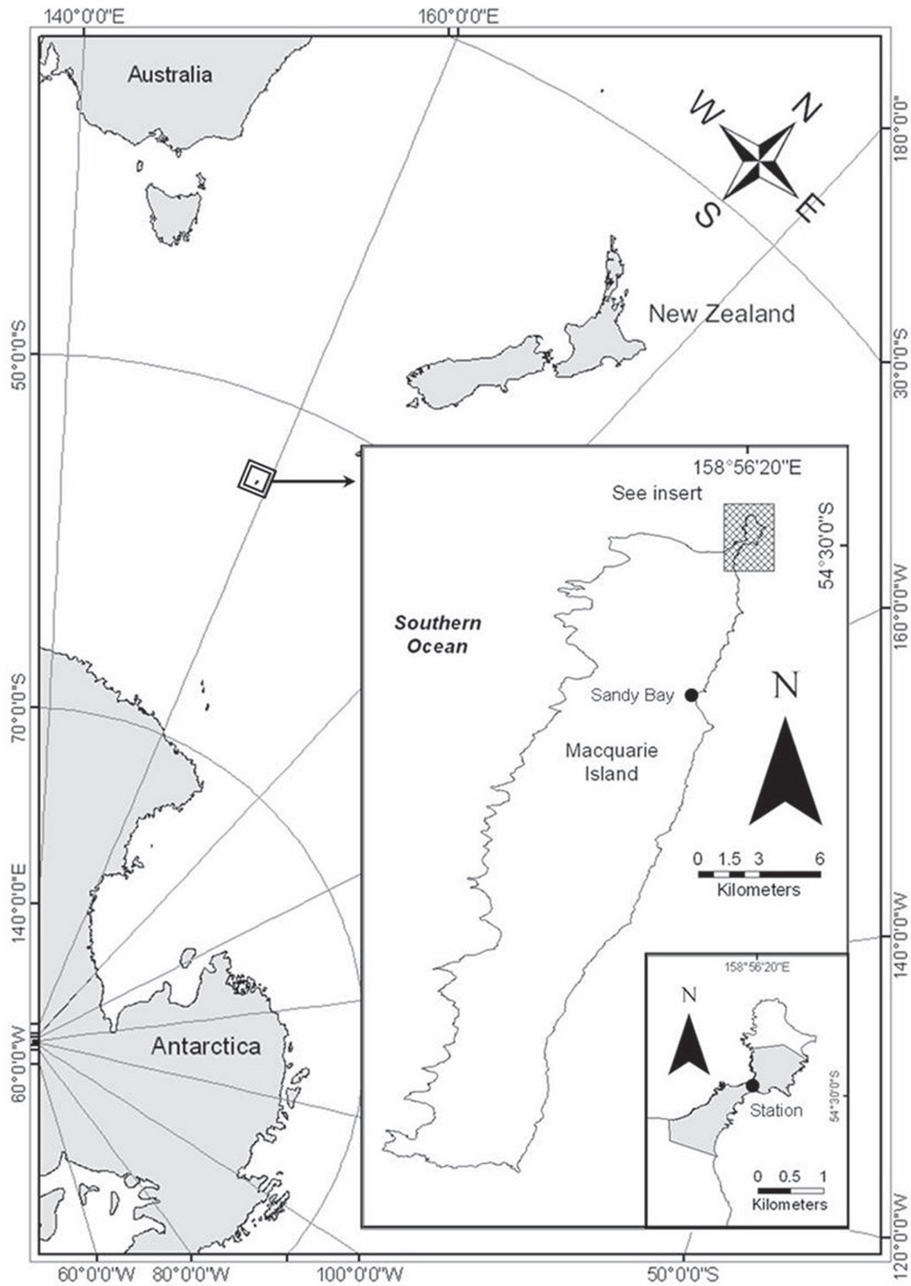

Fig. 1: Location of Macquarie Island. Shaded area within insert illustrates station limits.

Abb. 1: Lage der Macquarie-Insel. Das gerasterte Feld der Nebenkarten beschreibt das Umfeld der Station.

Four species of penguin breed on Macquarie Island; the King *Aptenodytes patagonicus,* Gentoo, *Pygoscelis papua,* Royal *Eudyptes schlegeli,* and Rockhopper *E. chrysocome.* All four species are exposed to varying levels of human activity during some stage of their breeding cycles. Human-penguin interactions on Macquarie Island originate from two main sources: the government-managed Australian Antarctic Program (AAP, formally known as Australian National Antarctic Research Expeditions, ANARE) including management programs from TASPAWS, and commercial tourism. As part of the government programs, between 10 and 40 people occupy the island year round, with the greater numbers present during October to March, corresponding with the summer science program. The majority of these people occupy the permanent station area (Fig. 1), where human-wildlife interactions can be classified as high in frequency and intensity. Compared to on-station, human-penguin interactions from government programs away from station can generally be classified as low in intensity and frequency. There is also an annual re-supply period of approximately one week, when up to 100 people are on the island per day undertaking science programs and transferring fuel, food, equipment and personnel to and around the island via helicopters, small boats and amphibious vehicles. In addition to the AAP, between two and eight tourist vessels currently visit the island per season, with 40 to 100 people arriving ashore per trip. Commercial tourism produces low frequency but high intensity interactions for those penguins visited. For both the AAP and commercial tourism on Macquarie Island pedestrians are the most frequent source of human-penguin interaction, similar to other subantarctic and Antarctic locations. Many breeding colonies are situated close to common transit routes for AAP and TASPAWS personnel traversing the island, with other colonies, for example at Sandy Bay (Fig. 1) and within station boundaries, specifically utilised for commercial tourism.

Managing people near penguins on Macquarie Island is currently achieved via a permitting system, primarily based on temporal and spatial restrictions, and adherence to a set of behavioural guidelines (TASPAWS 2001, 2003a, 2003b, AAD 2002, 2004). One of the main guidelines is a 5 m minimum approach distance (TASPAWS 2003b), with the purpose of maintaining a buffer between people and penguins, and is applied to all species across all breeding phases. The 5 m guideline is commonly used on other subantarctic and Antarctic locations by tourism operators (IAATO 2003), and other Antarctic Treaty Consultative Parties (Antarctica New Zealand 2000, Umweltbundesamt 2002). The effectiveness of this guideline for preventing greater than minor or transitory impacts (the threshold indicated within the Macquarie Island Draft Management Plan) has not been empirically tested on Macquarie Island, and it remains unclear if it is appropriate to apply this guideline across all species and breeding phases, or whether habituation may be confounding penguin responses to human activity. Addressing the effectiveness of this guideline, and the impacts of government programs and tourism on wildlife, are identified as research priorities for Macquarie Island within the Draft Management Plan (TASPAWS 2003a).

RESEARCH APPROACH

To provide context for this paper, we provide only a brief overview of the research approach used for common methodological elements across the five studies. Greater detail of methods used in the research can be found in Holmes et al. (2005, 2006), and Holmes (2005, 2007).

For each study, both experimental and observational studies were employed. Experiments followed a simple, repeatable methodology to allow the responses of penguins to be examined in light of key variables considered to influence their responses to people, and allowed sufficient sample sizes to be obtained (n = 20 to 27 individual penguins per sample group) (Holmes 2005). Experiments were primarily used to empirically measure the behaviour, and for one study physiological responses (heart rate: Holmes et al. 2005), of penguins to a standardised pedestrian approach, using the current 5 m minimum approach distance (TASPAWS 2003b), lasting no more than 5 min per approach. We aimed to gain as much experimental control as possible, by conducting experiments during a specific weather and time window, and kept pedestrian jacket colour (red) constant. All experiments followed a before (pre-approach), during (approach) and after (post-approach) format, allowing for responses to be statistically analysed using repeated measures procedures. No humans were present during the pre- and post-approach stages. Post-approach recordings were split into consecutive time periods to identify when behaviour (and heart rate) were comparable to pre-approach recordings. Behaviours analysed are presented in, Holmes et al. (2005, 2006) and Holmes (2005, 2007). Behavioural analyses were undertaken using The Observer 5.0 (Noldus Information Technology 2002). Responses to pedestrian approaches were considered against theoretical backgrounds such as the predation-risk hypothesis, whereby wildlife may perceive anthropogenic stimuli as a relative predation threat, and respond accordingly (Frid & Dill 2002, Beale & Monaghan 2004b, Blumstein et al. 2005). In addition to manipulative experiments, an observational study was also undertaken to examine the breeding success of Gentoo penguins breeding in areas of high and low human activity, relative to other environmental factors likely to influence chick production, using a simple linear (regression) model (Holmes et al. 2006).

KEY RESULTS

Testing the 5 m minimum approach distance guideline

The 5 m minimum approach distance guideline for pedestrians near breeding wildlife is a common tool used throughout the subantarctic and Antarctic (Umweltbundesamt 2002, IAATO 2003, TASPAWS 2003b), however, only limited validation of the efficacy of this guideline has been undertaken (Giese 1998, Pfeiffer & Peter 2004). On Macquarie Island, incubating Royal penguins displayed significant increases in vigilance and heart rate when exposed to a single person approaching to 5 m, however, no penguins fled the nest (Holmes et al. 2005). These responses typified a preparedness to flee, similar to a flight-or-fight response (Ball & Amlaner Jr. 1980) and akin to the predation-risk hypothesis (Frid & Dill 2002), and were significantly stronger than during predator overflights or aggressive interactions with skuas (Fig. 2). This suggested Royal penguins perceived a single person

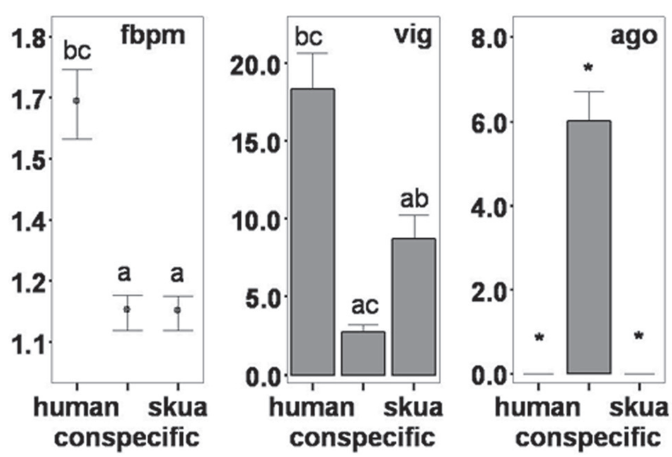

Fig. 2: Royal penguin *Eudyptes schlegeli* mean ±SE heart rate (beats per min) as a function of individual resting heart rate (fbpm), vigilant acts / min (vig) and agonistic acts / min (ago) when exposed to first 15 sec of interaction between single person standing at 5 m (*n* = 26), agonistic interactions with a conspecific (*n* = 15) and skua overflights below 15 vertical meters (*n* = 15). Letters indicate statistical difference between stimuli. Stars indicate no statistical testing done as no agonistic responses were recorded during human approaches or skua overflights. Taken from Holmes et al. (2005) and reproduced with permission of Elsevier.

Abb. 2: Haubenpinguin *Eudyptes schlegeli:* mittlere Herzschlagrate (±SE), Schläge pro Minute, als eine Funktion der individuellen Ruhe-Herzschlagrate (fbpm), Aufmerksamkeitsrate / min (vig) und Aggressivitätsrate / min (ago), wenn die Pinguine die ersten 15 Sekunden einer stehenden Person im Abstand von 5 m (n = 26) ausgesetzt sind, aggressive Interaktionen zu arteigenen Individuen (n = 15) und Skua-Überflüge niedriger als 15 m (n = 15). Die Buchstaben zeigen statistisch gesicherte Unterschiede zwischen den Stimuli. Sterne zeigen an, dass keine statistischen Tests gemacht wurden und keine Aggressivität während der Annäherung von Menschen oder Skua-Überflügen festgestellt wurden. Daten aus Holmes et al. (2005) mit Genehmigung von Elsevier.

visiting the nest as a greater threat than the naturally occurring stimuli tested. The responses observed during visitation can be described as minor or transitory, and on their own can be considered an acceptable impact as defined in the Macquarie Island Draft Management Plan (TASPAWS 2003a), and the Madrid Protocol (Cohen 2002). Nevertheless, the context provided by the relative response of penguins to natural versus human stimuli demonstrated that using the 5 m guideline still warrants a reasonable level of caution.

How does visitor group size influence response?

For wildlife managers, visitor group size represents one of the more easily manipulated facets of visitor management (Beale & Monaghan 2004b, Geist et al. 2005, Holmes 2005). In Holmes (2005), groups of five people elicited significantly higher rates (frequency and duration) of vigilance from guarding Gentoo penguins than did single person visits, suggesting that penguins associated a higher level of perceived risk with larger visitor groups (e.g. see Frid & Dill 2002). Wildlife managers could control this level of perceived risk by either a) reducing visitor group sizes, or b) increasing minimum approach distances for larger groups of people approaching penguins. However, it remains unclear what represents a greater interruption to breeding birds: one visit by five people at once, or five separate visits by a single person. There are further research opportunities available to determine at what set-back distance would a group of five people elicit the same level of response as that from a single person at 5 m.

Habituation and the effect of previous exposure to human activity

Habituation is a key variable likely to confound both management and research of human-wildlife interactions (Keller 1989, Knight & Cole 1995, Dunlop 1996, Cobley et al. 2000). On Macquarie Island, the majority of Gentoo penguins breed away from station limits (Fig. 1), where they typically have limited prior exposure to visitation and are regarded as sensitive to human activity (Holmes et al. 2006). In contrast, during some years, small numbers of Gentoo colonies are occasionally located within station limits (Fig. 1), where they are exposed to almost daily pedestrian activity plus vehicle movements, and raise questions regarding habituation and the effect of previous exposure to human activity. Results from a study in 2002-2003 (Holmes et al. 2006), indicated that when presented with the same pedestrian stimulus, guarding Gentoo penguins breeding away from station limits showed significantly stronger behavioural responses than counterparts breeding within station limits, with the former continuing to demonstrate an altered behavioural pattern even after the stimuli was removed. This result demonstrated the site-specific nature of responses to human activity, and emphasised the importance of previous exposure when considering how best to manage visitation to penguin colonies. The responses of penguins regularly exposed to visitation should not be considered typical of those irregularly exposed, as the latter may in fact be more sensitive. While evidence of habituation was observed in this context on Macquarie Island, the proximate mechanisms leading to such a response are not well understood (i.e. how regularly, and what stimulus intensity must animals be exposed to in order to facilitate habituation?). As such, habituation should not be considered an inevitable outcome for all species regularly exposed to higher levels of human activity and therefore, should not be considered as a goal of wildlife management (e.g. see Nisbet 2000), without significant caution.

Despite greater behavioural sensitivity observed among Gentoo penguins with limited prior exposure to human activity (i.e. those breeding away from station limits, or off-station), a simple linear model of colony reproductive success (average chicks raised per pair against pedestrian activity and 15 environmental variables), found that for 42 colonies off-station, low levels of pedestrian activity had no significant relationship to breeding success when compared to other environmental and site variables (Holmes et al. 2006). This model showed that off-station, reproductive success during 2002-2003 had a significant positive relationship with colony size, and significant negative relationship when the colony was situated: a) in short grassland (e.g. *Luzula crinata, Acaena* sp.); b) near colonies of other penguin species; and c) close to Southern elephant seal *Mirounga leonina* harems (adjusted $R^2 = 0.61$, $n = 42$). When the model was applied to the three colonies located on-station (i.e. with higher human activity), breeding success was higher than predicted by the model for two colonies, suggesting that different factors were operating to influence breeding success there, compared to off-station sites (Fig. 3). These results may also be interpreted as suggesting some advantage for Gentoos breeding on-station during the study period, possibly due to reduced activity of predator species that are sensitive to human activity (i.e. giant petrels *Macronectes* spp.; Woehler et al. 2003, Creuwels et al. 2005), or less food availability for predators (both giant petrels and Subantarctic skuas *Catharacta lonnbergi*) within station limits – although caution is required given the low number of on-station colonies tested (Holmes et al. 2006). Determining the effect of human activity on land-based predators of penguins remains an important avenue of investigation.

The role of breeding phase

The sensitivity of penguins to visitation is likely to vary with different stages of breeding, likely reflecting differences in parental investment through time (Trivers 1972, Andersson et al. 1980), and the different energetic demands of each breeding stage. Royal penguins approached during incubation, guard, crèche and moult (Holmes 2005), were the most sensitive during incubation, and moult. Incubating and moulting penguins responded at the greatest distances to a standard pedestrian stimulus (Fig. 4), with the behaviour of the latter affected for up to 15 min after the visit occurred. Reducing potentially harmful effects of human activity during the more sensitive periods of incubation and moult can be achieved by minimising visitation, or by promoting greater set-back distances to birds during these phases. Determining the effect of human activity on seabirds during key pre-laying activities of nest prospecting and recruitment remains an important direction for research.

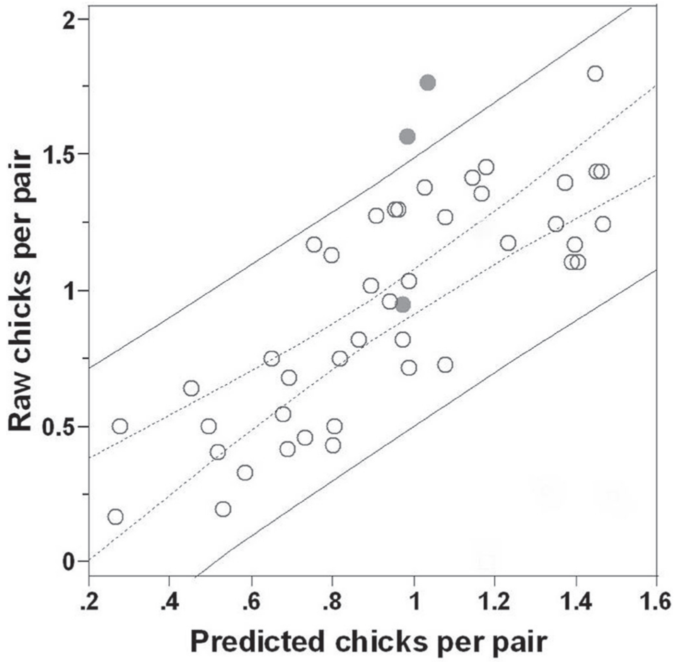

Fig. 3: Raw Gentoo penguin *Pygoscelis papua* colony reproductive success (mean chicks raised per pair per colony, *n* = 45) plotted against 95 % confidence intervals (CI) predictions from simple linear (statistical) model explaining breeding success off-station (adjusted R^2 = 0.61, *n* = 42). Open circles = colonies off-station (i.e.. low human activity, n = 42), closed circles = colonies on-station (i.e. high human activity, n = 3). Dashed lines are the 95 % CI for the mean, and straight lines are 95 % CI for individual values, from predicted values from the model. Taken from HOLMES et al. (2006) and produced with permission of Springer.

Abb. 3: Eselspinguin *Pygoscelis papua:* Reproduktionserfolg in den Kolonien (mittlere Zahl von aufgezogenen Küken pro Paar und Kolonie, *n* = 45), abgetragen gegen die 95 % Konfidenzinterval (CI). Vorhersage ausgehend von einem einfachen linearen (statistischen) Modell, das den Bruterfolg außerhalb der Stationen erklärt (R^2 = 0,61, *n* = 42). Offene Kreise = Kolonien außerhalb der Stationen (d.h. geringe menschliche Aktivität, n = 42), gefüllte Kreise = Kolonien in Stationsnähe (d.h. hohe menschliche Aktivität, n = 3). Gestrichelte Linien beschreiben das 95 % Konfidenzintervall für den Mittelwert, und durchgehende Linien das 95 % CI für individuenbezogene Werte, abgeleitet von den Modellvorhersagen. Daten aus HOLMES et al. (2006) mit Genehmigung von Springer.

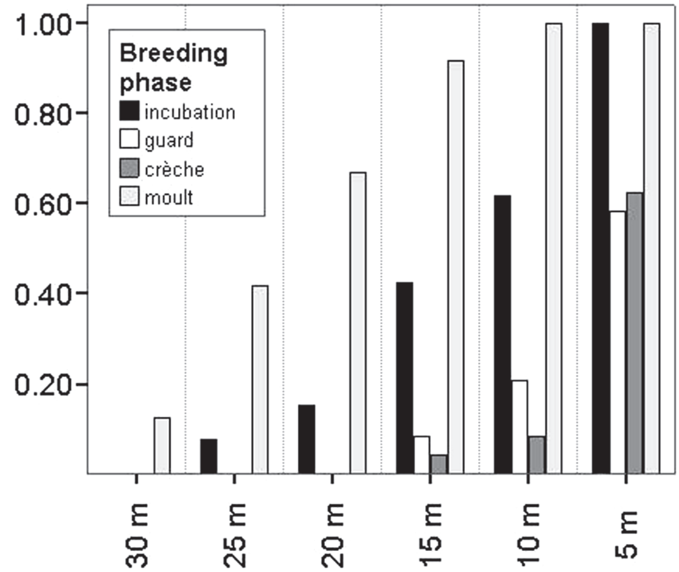

Fig. 4: Distance at which Royal penguins *Eudyptes schlegeli* first became alert, reflected as a cumulative proportion for each breeding phase, when approached by a single pedestrian from 30 to 5 m during different breeding phases. From HOLMES (2005)

Abb. 4: Distanz, bei der Haubenpinguine *Eudyptes schlegeli* zuerst aufmerksam werden; widergespiegelt als kumulativer Anteil für jede Brutphase, wenn sich ein einzelner Fußgänger von 30 auf 5 m während der unterschiedlichen Brutphasen dem Nest nähert (aus HOLMES 2005).

Comparing species responses

Responses to visitation are rarely homogenous across different avian species (BLUMSTEIN et al. 2003, BLUMSTEIN et al. 2005). When guarding King, Gentoo and Royal penguins were exposed to the same human approach stimulus, only Gentoos significantly altered their behavioural pattern after the stimulus was removed, suggesting that Gentoos on Macquarie Island are more sensitive to human activity than either Kings or Royals (HOLMES 2007). Gentoos were also more likely to perform some ritualised behaviours (i.e. low threat /display behaviour), however, the only recorded incidence of abandoning a chick was recorded in King penguins, suggesting that caution should always be exercised, regardless of species. Results from this study also suggested that greater efficacy of self-regulated visits can be achieved through identification of behaviours likely to indicate a change in the natural activity of each observed species, including vigilance (e.g. neck extensions and rapid head turning) for all species, and low threat/display behaviour in Gentoo penguins (HOLMES 2007).

APPLICATION OF RESULTS TO BEST PRACTICE HUMAN-WILDLIFE INTERACTIONS

The results obtained from this project have the most relevance for management of both government expeditions and commercial tourism on Macquarie Island, and have potential to contribute more widely to management elsewhere in the subantarctic and the Antarctic, including scientific, logistic and commercial activities.

Direct comparisons of the potential impacts from government expeditions and tourism on wildlife in the region (as done elsewhere in the Antarctic, RIFFENBURGH 1998) are not straight forward, given the characteristics of human-interactions from each group differ widely, hence, wildlife will respond differently. On Macquarie Island, away from the station, interactions with wildlife from government expeditioners can be classified as low in intensity and frequency, while on-station, interactions are relatively high in intensity and frequency. In contrast, tourism on Macquarie Island is presently irregular in frequency but high in intensity for those wildlife visited.

Direct application of results from the present studies will be somewhat limited with respect to commercial tourism, given that a normal tourist visit on Macquarie Island (i.e. between 40 to 100 people ashore at a time, for one to eight hours, using a boardwalk and platform to view a Royal penguin colony at Sandy Bay; Fig. 1) differs significantly from the pedestrian stimuli tested (i.e. a single person, or group of five people, approaching once for <5 min). Low annual visitor numbers, compared to the Antarctic Peninsula, pre-emptive planning efforts and a strategic approach, mean that tourism on Macquarie Island appears currently well managed (KRIWOKEN et al. 2006). However, the responses of wildlife to commercial visits on the island have not yet been tested, and were not a part of this project. A quantitative monitoring protocol, plus studies to assess how tourism activity influences wildlife, will be critical for effective future management of tourism on Macquarie Island (Tasmanian Resource Planning and Development Commission 2005), particularly if industry interest in Macquarie Island continues to grow (N. Carmichael, Executive Officer for Macquarie Island, TASPAWS, pers. comm. 2005), as is occurring elsewhere in the subantarctic and Antarctic (Naveen 2003, IAATO 2005a).

The results from this project will, however, be highly relevant for managing AAP expeditioner and TASPAWS staff interaction with penguins on the island given: a) the experimental stimuli used more closely resembled typical expeditioner activity; and b) at present, AAP expeditioners interact with wildlife more often than commercial tourists, given expeditioners typically have greater access and spend more time on the island.

The specific management recommendations that emerge from this project centre around the validity of the 5 m approach distance guideline, and the various factors that influence its efficacy as a management tool. Under certain conditions (i.e. a single person approaching incubating Royal penguins once), approaches to 5 m appear valid, as they result in behavioural changes that are minor and transitory, but key factors clearly influence the effectiveness of this guideline. During more sensitive breeding phases of moult and incubation, greater set-back distances would also allow penguins to maintain a normal activity, and would reduce the likelihood of moulting birds flushing. These precautionary measures appear particularly warranted for Gentoo penguins, given their apparent higher sensitivity to visitation compared to Royal and King penguins on the island. For all species examined, greater set-back distances should alleviate the behavioural modification associated with visitation by a group of five people, however it is unclear how appropriate this would be for larger groups (e.g. 30 to 40 people). In such circumstances, it may be necessary to maintain even greater distances if the goal of management were to ensure "normal" or uninterrupted behaviour as a result from visitation. During this project, empirical evidence indicated that approaches to 30 m (the current guideline recommended in the Australian Antarctic Territory; AAD 2004a) resulted in no measurable change in penguin behaviour (Holmes 2005, 2007, Holmes et al. 2005, 2006). While this gives managers confidence that a guideline of 30 m could be highly effective at minimising disturbance there may be certain impracticalities in applying such a set-back distance. The current threshold for acceptable human impacts is no greater than minor or transitory (TASPAWS 2003a), a precautionary approach that results in human activity eliciting no measurable behavioural response from wildlife would seem more likely to contribute to more sustainable interactions in the future (Holmes et al. 2005), akin to the precautionary principle described in the Macquarie Island Draft Management Plan (TASPAWS 2003a) and implicit in the Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol) (Rothwell & Davis 1997, Scott 2001, Cohen 2002).

With any management recommendations generated by empirical studies, there will be practical issues (e.g. safety and logistics, legal constraints, social and management expectations) to consider before they can be applied. For example, site characteristics that allow greater set-back distances to be implemented (e.g. open, flat terrain), may not feature at certain wildlife breeding sites where vegetation and topography mean that visitors have no safe choice but to approach wildlife more closely. In such cases, the key results from this project can still be drawn upon. For example, closer approaches, with larger groups, and during more sensitive breeding phases, will increase the likelihood of negative impacts to breeding animals. A more strategic approach for managing human-wildlife interactions would allow such practicalities to be integrated with these results, and could result, for example, in visitors only being directed to colonies that can facilitate appropriate set-back distances, with limited access to sites where this may be unachievable.

Distinguishing between breeding and non-breeding penguins will also be critical to the management of human-wildlife impacts. Non-breeding penguins can sometimes display an apparent curiosity toward human visitors, however, these responses should not be considered typical of breeding wildlife. Further, visitation to non-breeding penguins that are situated near breeding groups may indirectly impact upon adjacent birds, as was suggested by results obtained from King penguins (Holmes 2007). Emphasising appropriate visitor behaviour when near wildlife (i.e. crouching, limiting movements), as identified elsewhere (Wilson et al. 1991, Martin et al. 2004, Fernández-Juricic et al. 2005), plus recognising indicators of altered behavioural patterns (Holmes 2007), will also provide important tools to help minimise impact. Finally, wildlife breeding near areas of regular human activity should not be considered representative of those breeding in areas of low human activity, and importantly, they should not be considered habituated and therefore immune to the effects of human activity (Holmes et al.,2006).

Results from this project also have relevance for the management of tourism activities on the Antarctic Peninsula. Visitor numbers to this region are increasing, and applying a strategic approach to tourism management faces considerable complexities, given the involvement of many sovereign nations (Tracey 2001, Antarctic Southern Ocean Coalition 2005, Downie 2005). Timely and relevant planning and management is required for sustainable Antarctic Peninsula tourism. Site-specific guidelines represent one such undertaking supported by both Antarctic Treaty Consultative Parties and the key tourism industry body, the International Association for Antarctica Tour Operators (IAATO 2005b, United Kingdom et al. 2005), and yields great potential for more relevant on-ground management of popular tourist landings. Results from this project support a site-specific approach to tourism management, given the site-specific nature of penguin responses to human activity recorded (Holmes et al. 2006).

Elsewhere in the Antarctic and subantarctic, Antarctic Treaty Consultative Parties will continue to support and undertake science. Results from this project would prove useful for these parties when considering the impact of their activities on wildlife, including undertaking environmental impact assessments (Kriwoken & Rootes 2000), and instituting minimal impact approaches to logistics and research activities. However, this project focussed only on visitation as one source of potential impact, and there are several other anthropogenic sources of impact within these regions that warrant close consideration, including: vehicular activity (Giese & Riddle 1999, Harris 2005); disease (AAD 2004b); transfer of alien species (Lewis et al. 2003, Frenot et al. 2005, Whinam et al. 2005); and the construction and operation of infrastructure. This project should therefore be seen as part of a broader investigation and ongoing review of the effects of human activities on wildlife.

Similarly, on Macquarie Island, this project addresses only one key environmental issue there. There have been notable successes in tackling some exotic pests, specifically the eradication of cats *Felis catus* (Copson & Whinam 2001), and the development of a plan to eradicate Ship rats *Rattus rattus,* European rabbits *Oryctolagus cuniculus* and the House mouse *Mus musculus* (TASPAWS 2003a, Department of Environment and Heritage 2005). Competition with fisheries and fisheries interactions, including illegal, unreported and unregulated (IUU) fishing (Fallon & Kriwoken 2004), represent issues somewhat more complex, and extend beyond the terrestrial environment of Macquarie Island, to overlap with the management of the Southern Ocean (Robertson et al. 2000, Goldsworthy et al. 2001). On a global scale, climate change will be one of most difficult challenges natural resource managers will face in the future (Jones et al. 2003 Frenot et al. 2005). In contrast, there are far fewer confounding factors that will impede the effective management of human-wildlife interactions on Macquarie Island. The results from this project provide a valuable direction towards implementing best practice management of human activities near wildlife.

Management arrangements are typically dynamic over time, and major, future changes to access and logistic support to Macquarie Island could considerably change the nature of human activity there (TASPAWS 2003a). For example, while the majority of wildlife interactions currently occur as a result of government expeditioner activity, a reduction in government support and an increase in commercial interest could change this dramatically, thus presenting different challenges for those managing human-wildlife interactions. How this changes the nature of human activity on Macquarie Island will be integral in the future interpretation and application of results from this project.

THE ROLE OF SHORT AND LONG-TERM STUDIES OF HUMAN – WILDLIFE INTERACTIONS

During this project, parameters easily identified or controlled by managers were targeted for investigation to evaluate potential variation in the responses of penguins to pedestrian activity. However, other intrinsic parameters may have also significantly influenced such responses. For example, age, fitness, health, sex or quality of individual seabirds are known to significantly influence their reproductive success and behaviour (Sæther 1990, Weimerskirch 1992, Forsland & Pärt 1995, Martin 1995), and it is reasonable to predict that these factors may also influence how penguins will respond to human activity.

Long-term studies will remain a crux component of our understanding of the consequences of human – wildlife interactions in the subantarctic and Antarctic (Riddle 2000). Two critical roles for such studies are to provide: a) context for interpreting wildlife responses to human activity against a background of natural variability; and b) information on the cumulative effects of human activity on wildlife. While projects like the one presented here cannot replicate long-term data sets within limited time restrictions, they do play a significant role in providing evidence towards the proximate mechanisms that may lead to such long-term outcomes (Higham 1998, Constantine 2001, Engelhard et al. 2001, Engelhard et al. 2002, Lusseau 2003a, 2003b, Beale & Monaghan 2004a, Beale & Monaghan 2004b).

In many cases, pedestrian activity near penguin colonies may appear to result in no greater than minor or transitory impacts, and hence, would be considered acceptable under guidelines applicable to both Macquarie Island and the Antarctic region more broadly (Cohen 2002, TASPAWS 2003a). However, it remains unclear if these minor or transitory impacts can cumulate into more harmful outcomes for penguins over periods longer than one or two breeding seasons. Typical parameters measured during long-term studies (i.e. population numbers, breeding success) may only identify impacts once an outcome greater than minor or transitory is reached. For example, if human activity was found to depress recruitment into a penguin population, then it is possible that the existing breeding population may maintain stable levels for some years without new penguins being recruited. Only when this existing breeding population declined would an impact be registered using parameters such as population counts and breeding success (Woehler et al. 1991, Woehler et al. 1994). Further, once such an impact was recognised, population counts and breeding success measures would not aid in identifying the proximate mechanisms that led to this outcome. Consequently, it is the combination of both long-term studies and targeted experimental studies, such as those within this project, which will yield the most informative result to detect and manage potentially harmful human impacts on wildlife and meet the high conservation management goals in the subantarctic and Antarctic.

ACKNOWLEDGMENT

The authors wish to thank Hans-Ulrich Peter, Simone Pfeiffer, Christina Büßer and other members of the Polar and Bird Ecology Group at Friedrich-Schiller-University in Jena for bringing the "Human Impact on Terrestrial Habitats in the Antarctic” workshop to fruition. Thanks to members of the 53rd and 54th ANARE to Macquarie Island for their assistance in the field, particularly Helen Achurch, Bryan Ries, Alistair Dermer, Sue Robinson, Martin Schulz and John Lynn, and to Richard Coleman, Leslie Frost and Glen McPherson for advice. Thanks to Simone Pfeiffer and Jochen Plötz for manuscript improvements. This project was financially and logistically supported by an Australian Antarctic Scientific Advisory Committee grant, with ethics approval from the Australian Antarctic Animal Ethics Committee (ASAC project 1148) and the University of Tasmania Animal Ethics Committee (Approval No. A0006949). Macquarie Island access permits were issued by the Tasmanian Parks and Wildlife Service, and scientific permits were issued by the Nature Conservation Branch of the Tasmanian Department of Primary Industries, Water and Environment (DPIWE) (Permit No. MI

02188). This study was also financially supported by Birds Australia, the School of Geography & Environmental Studies, University of Tasmania and the Cooperative Research Centre for Sustainable Tourism and the Holsworth Wildlife Research Fund.

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