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ORIGINAL PAPER

Responses of Emperor Penguins (*Aptenodytes forsteri*) to encounters with ecotourists while commuting to and from their breeding colony

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Abstract Emperor penguins (*Aptenodytes forsteri*) were studied at the Snow Hill breeding colony in November 2006 to determine the effect of people on penguins traveling between the colony and the sea to forage. We tested the null hypothesis that the presence and number of people had no effect on the trajectory of movement or the number and duration of pauses. The distances at which penguins noticed people (mean 35.6 m), changed direction (mean 22.8 m), and the number and duration of pauses increased significantly with increases in the number of tourists in their path, which explained more than 50% of the variance. Undisturbed penguins usually tobogganed on their ventral surface over the ice. When penguins noticed people, they usually stood up and often called. In 10 min observation periods, penguins traveling more than 200 m from people paused an average of <1 min vs. 3.8 min for those passing near people, increasing the energetic cost of commuting. After passing people, penguins rarely stopped. Penguins response to people varied by time of day; later in the day they responded less quickly, changed directions when closer to people, stopped for less time, and passed by people closer than they did earlier in the day. We suggest that the effect of ecotourists on traveling penguins can be partly mitigated by having people walk in small, tight-knit groups, by having people stop moving whenever traveling penguins are within about 25 m to allow the penguins to choose the direction of their passage, and by keeping the visitor pathway separate from the penguin paths insofar as possible.

Keywords Human disturbance · Colony management · Antarctica · Response distance · Parental care · Locomotion · Marching · Tobogganing

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Introduction

There is considerable interest worldwide in reducing the adverse effects of people, including bird watchers, photographers, other ecotourists, and scientists, on breeding birds (Sekercioglu 2002; Beale and Monaghan 2004). Seabirds are vulnerable to human disturbance because they frequently nest in dense colonies, making them easy to find (Burger 2002; Boersma et al. 2001). Penguins are particularly vulnerable because they nest in large colonies on the ground, are familiar and fun to watch, and are increasingly accessible to ecotourists. Penguin-watching potentially provides considerable benefit to local economies (Yorio et al. 2001), which therefore have a vested interest in protecting the "resource" (Burger et al. 1995).

Several studies report adverse effects of people on penguins, including African (or Jackass) penguins (*Spheniscus demersus*, Hockey and Hallinan 1981), Adelie penguins (*Pygoscelis adeliae*, Giese 1996), and yellow-eyed penguins (*Megadyptes antipodes*, McClung et al. 2004). However, the presence of people in breeding colonies did not influence breeding success of Gentoo penguins (*Pygoscelis papua*) (Cobley and Shears 1999) and habituation to the presence of people was rapid in Magellanic penguins (*Spheniscus magellanicus*) (Walker et al. 2006), although the relationship between behavioral and hormonal

responses was complex and suggested subtle effects (Walker et al. 2005). Fowler (1999) also reported that hormonal responses of Magellanic penguins differed depending upon the level of human disturbance. Further, Martin et al. (2004) reported that young chinstrap penguins (*Pygoscelis antarctica*) showed an increased fleeing response that varied by the location of people near the breeding colony. These studies demonstrate a range of responses to human visitors, suggesting the need for species and site-specific studies of penguin behavioral responses (Holmes et al. 2006).

In this study, we examined the effect of ecotourists on emperor penguins (*Aptenodytes forsteri*) near the Snow Hill colony near the Antarctic Peninsula, where birds had virtually no prior experience with people. Emperor penguins breed only on Antarctica and represent the ultimate target for penguin watchers. Only about 45 breeding colonies are known; only two of these are on the Antarctic Peninsula, and all but two are located on ice. The global population is estimated at about 200,000 pairs. Some colonies are very large (up to about 30,000 pairs), while others have only a few dozen pairs (Woehler 1993). Emperor penguins are vulnerable to disturbance at and near their colonies (Giese and Riddle 1999; AGAD 2003). Our objective was to examine the behavior of naïve emperor penguins as they encountered people on their "march" across the seasonal ice sheet or "fast ice" between the colony and the sea to forage on fish, squid, and krill (Martinez 1992; Klages 1989). We were interested in whether the presence of people affected their traveling behavior and how the number of people (or penguins) affected behavior. We tested the null hypotheses that (1) the presence of people in their pathway to the sea does not affect penguin behavior or speed of travel, (2) the number of people encountered does not affect penguin behavior or the number and duration of pauses, and (3) the behavior while approaching people does not differ from the behavior when leaving people. We viewed this as a baseline opportunity for examining penguins that have not had the opportunity to habituate to humans.

Our observations in the colony itself showed that most chicks were not attended by an adult, indicating that both parents were making foraging trips to the sea. At this stage, foraging period intervals are 1-19 days, which may be the interval of chick feedings, depending on the colony and ice conditions (median 7 days; Zimmer et al. 2006). Since our observation period was limited to 4 days, we avoided observing the same penguins more than once. Penguins moved to and from the colony in groups ranging in size from two (rarely one) to several hundred. They traveled from the colony to the sea in several directions, and showed a slight tendency to follow a few paths, one of which intersected the path that tourists took from a base camp to visit the colony. Despite the remoteness of their breeding sites, emperor penguins have been studied at their breeding colony and at sea (Robertson et al. 1994; Wienecke and Robertson 1997; Burns and Kooyman 2001). This paper fills a unique niche because we address emperor penguins in a previously unvisited colony, and on traveling behavior rather than on behavior at the colony.

Many studies use approach distance as a measure of the effect of people. Approach distance refers to the distance a bird will allow a human to approach without either moving away or demonstrating behavioral effects at nesting colonies (Gutzwiller et al. 1998; Burger and Gochfeld 1993, 1999; Holmes et al. 2005; Gonzalez et al. 2006) or foraging groups of birds (Burger and Gochfeld 1991, 1998, 2001). Approach distances can then be used to establish minimum approach distances to reduce adverse effects on birds (Rodgers Jr and Smith 2005). Recommended minimum approach distances have varied markedly, from 5 m for some species of breeding penguins (Holmes et al. 2005) to 100 m for some petrels (Villiers et al. 2006). The International Association of Antarctic Tour Operators recommends that people remain 5–10 m from nesting seabirds (25 m from displaying albatross, IAATO 2006a). Our studies also used approach distance, but it was a penguin-mediated approach distance, rather than a tourist-mediated one. That is, we observed how close the penguins would approach us before changing their behavior, rather than the other way around.

Study site and colony history

We studied the behavior of emperor penguins at Snow Hill (64°28′S, 57°15′W), an island on the eastern side of the Antarctic Peninsula during the period November 5–8, 2006. The Snow Hill colony is estimated at 4,000 pairs (Todd et al. 2004). The emperor penguin is the only bird that initiates breeding in the middle of winter. After egg-laying the females depart for the sea, and the male incubates in June–July for a period of 62–67 days. The fledging period is 147–190 days long (Schreiber and Burger, Appendix 2, 2001). During our visit in early November the chicks were about half grown; they would have hatched in August and would depart the colony by late December.

The presence of a colony near Snow Hill was detected in 1997, but the location was only identified in 2004 when a tour group visited it for a day (Todd et al. 2004). There were no tour visits in 2005. Two tours spent a total of 7 days at or near Snow Hill in October 2006; ours was the third tour in 2006, or the 9th–12th days on which Snow Hill penguins could have encountered people. It is unlikely that the Snow Hill colony will be visited by many tourist ships early in the season when chicks are most vulnerable because an ice-breaker is required to reach it, and tours usually do not begin

until October. However, by mid-summer it may be more accessible when the fast ice is mainly broken up.

During our visit the icebreaker *Kapitan Klebnikov* wedged itself into a position in the fast ice at a distance of about 12 km from the colony. Groups of visitors were ferried by helicopter to a base camp behind a stranded iceberg about 2.5 km from the colony, a distance considered adequate to avoid disturbance at the colony. From the base camp, tour leaders used red flags to denote a safe pathway to the emperor penguin colony, and tourists were supposed to follow this path. The path meandered over the ice, avoiding open leads and places where thin ice overlaid recent melt pools.

Methods

We made most observations from the marked path between the base camp and the colony, and some from the deck of the ship when there were no people on the ice. We recorded the behavior of penguins when confronted with people. The penguins did not use one main pathway to the sea, but moved in several directions toward the open water. The number of people along the path ranged from 2 (the researchers) to 60. In some cases, we were part of the group, in others we were at least 50 m from the people and penguins being observed. People walked to the colony at varying speeds, and groups were amorphous. Most people were anxious to reach the colony and did not tarry, but some stopped to photograph approaching penguins.

We defined two types of penguin movements: (1) those moving toward people on their way to or from the sea, and (2) those that moved on a trajectory that would keep them at least 200 m from the tourist pathway (and were not going to intersect this pathway). This meant that we determined whether penguins were traveling on a path tangential to the tourist path, or on an intersecting trajectory (approaching tourists). We observed that undisturbed penguins followed a more or less straight line, only avoiding obstructions. Since the terrain was generally flat, with some icebergs trapped in the fast ice, we could see penguins that were hundreds of meters away, and we could record data on several distant penguin groups at once.

For each group of moving penguins we recorded date, time of day, type (with or without people), number of people in the encounter, direction of penguin movement (to or away from the sea), number of penguins, and penguin response. Penguins usually walked in a single line, occasionally forming a phalanx if the lead penguin paused near an obstacle or person. Only the behavior of the lead penguin was recorded, since the behavior of other penguins in a group would not be independent. Penguin behavior included distance they first appeared to notice people, distance they changed directions (response distance), number of pauses before they reached people, total time of these pauses, distance at which they passed people (tolerance distance), number of pauses after they passed people, and total time of these pauses. We used a rangefinder to determine distances for distances <10 m; for shorter distances, we measured the distances once the people and penguins had passed. With people present, we truncated observations to include only penguin groups that paused 10 min or less before reaching the crossing point (where penguin and human paths crossed). Penguins lingering for more than 10 min prior to passing people were counted, but were not considered further because their behavior was so influenced by the presence of people.

About 10% of the penguin groups halted for over 10 min when faced with people. Photographers usually waited, hoping for the birds to approach more closely. Penguin groups that stopped for more than 10 min were either those that seemed afraid to pass or those that seemed curious, as indicated by their relatively close approach and close observation of people and their photographic equipment. The penguins that halted for long periods may have been nonbreeders or failed breeders, without the constraints of chick feeding.

MANOVA procedures were used to determine if disturbance type (people, or no people), movement type (to or from sea), time of day, number of people, and number of penguins affected the responses of traveling penguins (SAS 1995). The procedure allows for interactions variables (e.g., time of day × number of people). We also used the nonparametric Kruskal–Wallis ANOVA to examine differences between disturbance groups (Siegal 1956).

Results

Penguins moved to and from the sea either by tobogganing (sliding on their ventral surface) or walking upright. Undisturbed penguins, observed far in the distance (>200 m), normally tobogganed over the ice unless it was very rough or they arrived at a lead. Tobogganing was the preferred means of travel over the snow-covered ice, and birds we timed averaged about 1 m/s tobogganing versus about 0.5 m/s when walking. Tobogganing over smooth ice could be even quicker; a penguin panicked by a nearby commotion, tobogganed rapidly over smooth ice for a distance of several meters much faster than its usual speed.

As penguins approached the tour group path, photographers moved toward and congregated at the anticipated crossing point to secure close photographs. If there were no visitors within about 30 m of the crossing point, penguins usually continued their uninterrupted travel. Other penguins either altered course to avoid people or waited for people to

move away. Although penguins sometimes crossed within 2 m of visitors, the modal crossing or tolerance distance was 5–6 m (46 of 167 crossings, Fig. 1) and the median was 8 m. When people were within 5 m of the anticipated crossing, penguins always paused.

Observations were made on 361 groups of moving penguins. Of these, 66% were moving toward people, and the rest moved tangentially to people (i.e., on paths that did not intersect the tour route) or were more than 200 m away. Of those moving toward people, about 10% ($n = 37$) lingered for over 10 min before passing by people; some of these remained for up to 47 min before continuing on their journey to the sea (these departed only when the tourists moved on). Over 60% of the penguins observed were moving toward the sea from the colony (Table 1). Penguin group size was significantly less for groups that passed people, compared to those traveling parallel to people, suggesting that penguins may have been influenced by the presence of people much earlier than we observed or that the tour route fortuitously was away from the main penguin path (Table 1). Of those penguins coming toward people, 91% shifted directions to avoid people. All of the penguins that passed within 5 m of people stood up some of the time to watch, while only 2% of those traveling more than 200 m from people stopped and stood up during the 10-min observation periods.

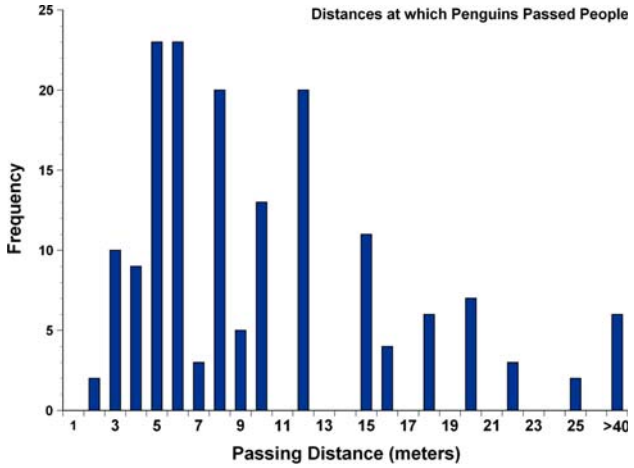

Fig. 1 Tangential distances from nearest person at, which adult penguins crossed the path between the base camp and the Snow Hill breeding colony

Penguins that passed by people stopped significantly more often, and paused for significantly more time, than those without people (Table 2). Penguins passing people paused for an average of over 4 min, mainly before passing people (Tables 1, 2). Penguins appeared to first notice people when they were an average of 36 m away and changed directions when they were an average of 23 m away (Table 1), although some approached to about 5 m before stopping. Noticing people usually meant stopping their tobogganing, standing up and peering at people, and often braying to companions behind them. Most birds did not appear overtly alarmed, although some altered their path quickly and retreated. However, their behavior in proximity to people was clearly altered. After the penguins passed people, they normally flopped down to toboggan and moved silently and rapidly away from the people (Table 2).

The best models explaining variation in distance to notice, distance to change direction (response distance), number of pauses, and total time paused included whether people were present, and the number of people present, but not the number of penguins or other variables (Table 3). For these data, we combined behavioral observations before and after penguins passed people (up to 10 min before and after crossing). For penguins without people we watched for 10 min. The greatest variation in the behavioral endpoints was explained by the number of people in groups; as group size increased, penguins noticed people

Table 1 Behavior of penguins when faced with people compared to having no people within 100 m (analyzed by Kruskal–Wallis non-parametric one-way ANOVA)

	Type		$\chi^2(P)$
	No people	People	
	Mean ± SE	Mean ± SE	
Sample size	138	186	
Time of day	13:03 ± 0:20	12:32 ± 0:12	2.3 (NS)
% Going away from colony toward sea	65%	63%	0.1 (NS)
Number of penguins in group	16.9 ± 2.4	7.0 ± 1.2	27.9 (<0.0001)
Number of people in group		9.5 ± 0.8	
Distance first noticed		35.6 ± 1.1 [35]	
Distance changed direction		22.8 ± 1.0 [20]	
Total duration of pauses pre-passing (minutes)	0.21 ± 0.05	3.83 ± 0.22 [2.5]	170.8 (<0.0001)
Total number of pauses in 10 min	0.20 ± 0.04	1.96 ± 0.08 [2]	153.2 (<0.0001)
Passing distance		12.1 ± 1.3 [9]	

This does not include 37 penguins that paused for more than 10 min prior to crossing. Values are mean ± SE; median values are provided in [square brackets] for the response variables

Table 2 Duration and number of pauses in 10 min while approaching people and in 10 min after passing people

	Before reaching people	After passing people	χ^2 (*P*)
Duration of pauses (minutes)	3.8 ± 0.2	0.3 ± 0.05	239.7 (<0.0001)
Number of pauses	2.0 ± 0.08	0.3 ± 0.04	203.7 (<0.0001)

Compared by Kruskal–Wallis non-parametric one-way ANOVA (n = 185 observations)

sooner, changed directions sooner, paused more often, and paused for longer periods of time (Fig. 2). The behaviors of the penguins were significantly correlated (Table 4).

Time of day entered the model for distance to first notice people. Later in the day, penguins took longer to notice people in their path than they did earlier in the day. To further understand the effect of time of day, we examined only those observations that involved penguins and people. When only these observations are considered, time of day influenced nearly all of the behavioral endpoints. Later in the day, penguins took longer to notice people (i.e., had shorter approach distances), came closer before they changed directions, stopped less often for less time, and passed by people closer (i.e., had shorter tolerance distances). This is consistent with penguins trying to reach either the sea or the colony before dark.

Overall, these data indicate that penguin behavior while traveling between the sea and their breeding colony is affected by the presence of people in proximity to their path, particularly when people position themselves to intercept the approaching penguins. The response is directly related to the number of people present, and penguin response is greater before they reach people than after passing them. Thus, all three null hypotheses were rejected.

Discussion

Effects of people on traveling penguins

In this paper, we examined the effects of people on penguins traveling to and from their breeding colony at Snow Hill. The effects of ecotourists at the breeding colony during our work appeared to be minimal, although we did not examine physiological endpoints. We base this conclusion on the fact that although ecotourists were required to remain 5–10 m from any penguin, the penguins did not maintain this distance, but instead both adults and chicks readily approached people. Both adults and young also followed people as they moved away, and both appeared curious about the people. Also there was a lack of any competing behaviors chicks needed to conduct while waiting for their parents to return with food, a wait that could be several days. Parents likewise were resting with their chicks. On the other hand, parents that were traveling had a job to do: they either had to go to the sea to search for food for themselves and their chicks, or they had to return to the colony with food for their chicks. In either case, they had a mission with time and energy constraints, although some adults at the colony had undoubtedly lost their eggs or chicks, and were not under the same time constraints as parents.

Penguins traveling to the colony or to the sea have many km to travel, depending upon the stage of the fast ice. During our visit, they traveled between 8 and 12 km from the colony to the edge of the open water. Groups of penguins did not travel non-stop, but stopped periodically to rest, to look around, and to decide how to cross-open leads. In our long-distance (>200 m) observations, we saw groups of penguins that had stopped and were resting or looking around. After a pause, however, they usually returned to the toboggan position and continued along their path. We only recorded data on penguins that were moving at the start of the observation period. Traveling penguins altered their behavior when faced with people. They stopped, stood upright, changed directions, brayed loudly to their companions, walked the remaining distance to and by people, and paused before passing people. Walking (also called waddling) has considerable energy costs for penguins as compared to tobogganing (Pinshow et al. 1977), and their waddling requires twice as much energy as does the walking of other birds (Griffin and Kram 2000).

Murphy (1936) noted that emperor penguins resort to standing up when frightened. Murphy also reported that tobogganing penguins can travel at 14–16 km/h. Although penguins may occasionally move very fast, this is not sustainable. Their average speed (1 m/s according to our measurements) would impose a maximum of 3.6 km/h, if they did not pause to rest. We estimated that it required at least 6 h to go from the Snow Hill colony to sea at this stage. After passing people, penguins returned to tobogganing. These observations indicate that the behavior of the penguins approaching the tourist path was influenced by the presence of people at the crossing point. Further, delaying their reaching either the sea or the breeding colony site could have additional energy costs for penguins (Pinshow et al. 1976). For some penguins that stopped for half hour or more, human disturbance may be significant (adding about 8% to their trip durations), but for others that stopped for only a few min in response to people and then crossed close by, the effect may be insignificant.

The behavior of the emperor penguins followed a dose-response; the more people, the more severe the response of the penguins. The increased response was steepest at the

Table 3 Regression models explaining variation in duration and number of pauses and in distance to notice, change direction, and pass people

	Entire sample with and without people		Observations only when people were present					Passing distance
	Duration of pauses	Number of pauses	Duration of pauses (pre)	Number of pauses (pre)	Number of pauses (post)	Distance to notice people	Distance to change direction	
Model								
F	82.5	84.1	32.3	29.9	1.15	20.45	55.1	4.53
df	8,211	8,213	7,127	7,127	7,127	5,132	6,128	7,119
P	<0.0001	<0.0001	<0.0001	<0.0001	NS	<0.0001	<0.0001	0.0002
r^2	0.75	0.76	0.64	0.62	0.06	0.31	0.72	0.21
Factors entering								
F (*P*)								
Type (people versus no people)	11.1 (0.001)	15.3 (<0.0001)	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
Number of people	337 (<0.0001)	231 (<0.0001)	107 (<0.0001)	61.8 (<0.0001)	0.38 (NS)	51.03 (<0.0001)	37.9 (<0.0001)	9.84 (0.022)
Number of penguins	0.26 (NS)	0.64 (NS)	1.34 (NS)	1.89 (NS)	0.16 (NS)	0.48 (NS)	6.73 (0.01)	0.11 (NS)
Time of day (hour)	8.08 (0.005)	3.76 (0.05)	5.59 (0.02)	1.40 (NS)	0.02 (NS)	1.11 (NS)	7.24 (0.008)	0.36 (NS)
Distance to notice	–[a]	–[a]	0.76 (NS)	0.03 (NS)	0.11 (NS)	–[c]	110 (<0.0001)	9.52 (0.002)
Distance to change	–[a]	–[a]	0.03 (NS)	5.69 (0.02)	0.12 (NS)	–[c]	–[a]	1.44 (NS)
Direction (to or from) colony	1.01 (NS)	0.10 (NS)	1.81 (NS)	0.17 (NS)	0.58 (NS)	0.77 (NS)	1.94 (NS)	0.15 (NS)
Hour × type	4.06 (0.05)	3.21(0.07)	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]
Hour × direction	0.96 (NS)	0.46 (NS)	1.75 (NS)	0.01 (NS)	1.24 (NS)	0.86 (NS)	1.82 (NS)	0.27 (NS)
Type × hour × direction	0.10 (NS)	2.01 (NS)	–[b]	–[b]	–[b]	–[b]	–[b]	–[b]

Degrees of freedom are given for the model and error terms. General linear models with type III estimates (SAS 1995)

NS not significant ($P > 0.10$)

[a] This variable not obtainable in the absence of people

[b] This variable only obtainable in the presence of people, hence "type" cannot be included in model

[c] These variable are dependent variables in this model

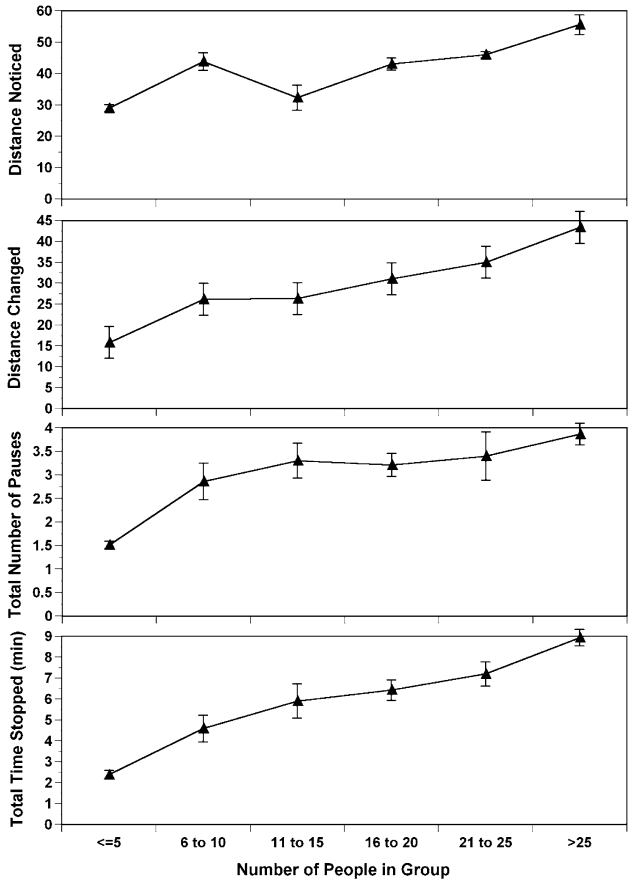

Fig. 2 Response of adult emperor penguins to ecotourists during their march between the sea and the Snow Hill breeding colony

lower part of the curve (refer to Fig. 2). We did not, however, record the compactness of the people, but this factor appeared to affect the penguins. When people were in a tight group, the penguins only had to shift their trajectory slightly to avoid people; when people were spaced out, penguins had to deviate farther away to avoid walking toward the people. The same group of people may look more imposing (broader front) if people are spaced out, rather than in a tight group. This aspect requires further study, and has conservation and management implications.

Our non-systematic observations on the photographers was that photographers would approach the crossing point, wait for the penguins, and would then spread out sufficiently along the path to obtain a clear "shot" at the approaching birds. Thus, photographers could cause a greater disturbance than people merely wanting to see the penguins. This is consistent with our observations of photographers at migrant shorebird stopover sites on Delaware Bay, NJ (Burger et al. 1995).

Other researchers have suggested that breeding penguins at a colony can habituate to the presence of ecotourists, and will even decrease the allowable approach distance (Yorio and Boersma 1992; Fowler 1999). However, these studies were conducted at colonies where penguins can maintain their territory, while we studied penguins moving to the sea that had to pass by tourists to reach the sea, or shift their trajectory (which most emperor penguins did). Even so, studies with other penguins suggest that visitation should be limited to a small area of colonies (Fowler 1999), and that species-specific management is required (Ellenberg et al. 2006). We suggest that for any species, location-specific and time-specific management is also necessary (see below).

We also made observations for several hours in the colony itself. At this stage the colony had separated into about six subcolonies about 100–500 m apart, with about 400–800 chicks each. Visitors were encouraged to separate and visit different subcolonies. All persons were told not to approach penguins closer than 5 m. However, if a person sat and waited, both adults and especially chicks were likely to approach them, and the birds would often sit for many minutes close to a person (within 1–2 m), although sudden movements caused birds to retreat a short distance. Although predation is a major threat for most seabird species (Burger and Gochfeld 1994), there were no predators on the half-grown emperor penguin chicks or adults while they are in the colony, although we did observed Antarctic skuas (*Catharacta antarctica*) interrupt feedings. Skuas are predators on eggs and newly hatched chicks. We noted an average of two feedings per hour for a group of about 400

Table 4 Correlation of penguin behavior with number of people and number of penguins

	Number of people	Number of penguins	Distance first noticed	Distance changed direction	Passing distance	Number of pauses	Duration of pauses
Number of people	*********	−0.16	0.48	0.54	0.15	0.61	0.63
Number of penguins	0.0001	*********	−0.01	0.06	0.07	0.03	0.06
Distance first noticed	<0.0001	NS	*********	0.59	0.27	0.46	0.41
Distance changed direction	<0.0001	NS	<0.0001	*********	0.31	0.47	0.43
Passing distance	0.011	NS	<0.0001	<0.0001	*********	0.1	0.06
Number of pauses (in 10 min)	<0.0001	NS	<0.0001	<0.0001	0.09	*********	0.67
Duration of pauses	<0.0001	NS	<0.0001	<0.0001	NS	<0.0001	*********

Kendall tau correlation coefficients are above the diagonal with *P*-values below. Based on 186 encounters when people were present

penguin chicks. This is consistent with an average frequency of one feeding every 8 days. Overall observations and photography at this colony at this stage appeared to have little adverse impact on the birds, although subclinical effects on heart rate, metabolism, or energetics were not assessed. We expect that at earlier stages, when adults are on eggs or small chicks, human presence could be very disruptive.

Conservation implications

Commercial tourism activity in Antarctica is over 50 years old (Moser 2002), but the annual number of tourist visits to Antarctica has increased by a factor of four since 1992, and the number of available ships has increased from 12 to 47 (IAATO 2004, 2006b). The Antarctic will receive increasing tourism pressure as trips become easier to arrange, as more seabird colonies are available for visitation, and as interest grows in polar habitats, animals and scenery. Television and other mass media have made the images of birds, mammals, and scenery available to an interested public. With increased ecotourism pressure, scientists, and managers must consider ways to minimize possible disturbance to birds while maximizing the viewing (and photographing) needs of people. For well over a decade it has been recognized that accommodating ecotourism is essential in multiple use planning for coastal and marine protected areas (Agardy 1993; Miller 1993; Yorio et al. 2001).

Penguins pose a unique problem for managers and conservationists. Unlike other colonial seabirds, they cannot simply fly away from their colonies. Penguins must travel from their breeding colonies to the water to forage for foods, and they must do this by traveling over land or ice. For penguins, the shortest distance from their colony to the sea is often direct, but ecotourists may be standing in the way. At Snow Hill, both penguins and people moved between the edge of the fast ice and the colony. Penguins thus have two disadvantages over other seabirds: they travel only on the ground, and they must travel over the same distances as ecotourists.

Our observations suggest that when penguins and people cross-paths, both alter behavior when an encounter is imminent. There were two main effects of the alteration in penguin behavior: (1) penguins require more time to cover the same distance, and (2) penguins use more energy because instead of tobogganing, they stand up and walk some of the way, returning to tobogganing only when they are away from the people. Penguins that encountered people regularly stop for about 5 min before proceeding on. However, a small percentage of the penguins stopped and remained with people until the people left. Thus, their march was interrupted. Second, the energy demands of tobogganing are less (about a third) than those of a penguin walking upright (Akos Hivekovics, personal communication), which is consistent with the twofold difference in velocity. Thus, people encountering marching penguins exact a cost in terms of time and energy. While penguins do take rest stops during their travels to the sea, they do so when they want, rather than when forced to do so by the presence of people.

Moreover, ecotourists often believe that they are not affecting the penguins because birds do not "look upset." However, Regel and Putz (2004) reported an increase in body temperature in the presence of people, and energetic costs for maintaining a high-body temperature in emperor penguins are high (Pinshow et al. 1976). Martin et al. (2004) even suggested that human disturbance has a similar effect as predation risk for chinstrap penguins, and that escape behavior needs to be factored into ecotourist regulations. The fact that some penguins walk toward people in breeding colonies does not negate the negative effect on other individuals. Similarly, the fact that some penguins walk toward people while on their way to the sea does not mean they are not affected or at least delayed by the presence of people. For example, Otley (2005) reported that <20% of the gentoo (*P. papua*), king (*Aptenodytes patagonicus*), and Magellanic penguins commuting between the beach and colony did so when people were present. This suggests birds were avoiding people, another aspect requiring exploration with a number of penguin species.

There are several methods of reducing the effects of people on penguins traveling to and from their breeding colonies, including temporal and spatial restrictions, as well as more complicated control of people. Temporal restrictions can include restricting the stage in the breeding cycle when people can visit (e.g., no visits during the chick hatching stage), or restricting daily or weekly visits (e.g., so many hours a day, or on so many days a week). For the emperor penguins we studied, such restrictions might be useful early in the hatching and chick stage because the distance (and thus the time) required to travel over the fast ice to open water to forage is the greatest. As the ice melts back in the spring the travel distance is lessened, just as the chicks are getting older and their food requirements are increasing. It is important to note that travel to and from the sea (measured in hours) is only part, and maybe a small part, of the entire feeding trip duration (measured in days), and that the main proximate limitation on the penguin breeding success is probably declining food availability, particularly from the increasing commercial exploitation of krill (*Euphausa superba*) which began only in the 1970s (Croxall et al. 1984).

Further, penguins altered their behavior later in the day in response to people; penguins took longer to notice people, shifted directions less quickly, stopped for shorter periods of time, and passed closer to tourists than they did

earlier in the day. These observations suggest that they are responding not only to people, but to time constraints to hurry to the colony or to the sea, presumably to reach their destination before dark. This suggests that ecotourists should be off the ice in the late afternoon so that penguins are not unduly disturbed during this period. Additionally, ecotourists could be encouraged not to stop to watch or photograph penguins during this time, but instead to continue along the path without tarrying.

A second method of management is spatial restriction; people can be limited to only a small section of the breeding colony (Yorio and Boersma 1992; Cooper et al. 2000; Yorio et al. 2001) or as in the case of our visit, a single path. Spatial restriction would aid the emperor penguins at Snow Hill by limiting human disturbance to only a small part of the perimeter of the colony or to some of the subcolonies, and likewise it can restrict encounters outside the colony to a single pathway. During our research, tourists were limited to one pathway, but their behavior on this path was not limited either spatially or temporally. Further, people could walk in tight groups, or in sparse groups, which clearly influenced the behavior of the penguins. At some colonies penguins can reach open water only in one direction. The Taylor Rookery Management Plan recognizes the importance of having visitors avoid the penguin travel route as much as possible (AGDA 2003).

Another method of managing ecotourists near breeding penguins is to set minimum approach distances; tourists cannot approach penguins closer than a set distance (Holmes et al. 2005). Minimum approach distance requires considerable study to determine, and should be determined for each species (Ellenberg et al. 2006). Holmes et al. (2005) found that royal penguins (*Eudyptes schlegeli*), a Macquarie Island endemic, showed increased heart rate even when people maintained a minimum approach distance of 5 m, the current recommended approach distance for penguins, and the distance tourists were asked to maintain for the emperor penguins at Snow Hill. Holmes's research suggests that the 5 m minimum approach distance should be reevaluated for breeding penguins. At Macquarie the 5 m distance was imposed by confining visitors to a boardwalk and platform, thus limiting the negative impact only to perimeter birds. Most of these birds were in the center of the subcolony and were largely undisturbed. Our observations indicate that maintaining a distance of 5 m from a breeding emperor penguin is not sufficient for penguins traveling to the sea that must pass people to reach the sea (or shift directions or wait). Coming to within 5 m of a traveling penguin causes it to shift directions, increase speed, or walk rather than toboggan. Holmes et al. (2005) noted that minimum approach distance guidelines should be based on the separation distance necessary to allow animals to undertake normal activities, and we concur. For emperor penguins, this distance is at least 25 m (the mean distance penguins shifted directions to avoid people), and if there is only one path penguins can follow, a 25 m setback from this path should be required. However, where the penguins have alternative paths, as at Snow Hill, this is less critical.

Penguins and other seabirds are capable of distinguishing a direct versus a tangential approach (Burger and Gochfeld 1981; Martin et al. 2004). The penguins we observed appeared to be able to distinguish whether people were standing at or within 5 m of their anticipated crossing point. We were admonished in advance to stand back at least 5 m from a crossing point, and most people adhered to this most of the time. This suggests that there are three ways humans could reduce their effect on emperor penguins traveling to the sea: (1) people could move forward or backward so that they are not in the direct path of the penguins moving toward them, (2) they could remain absolutely still, in a tight group, and allow the penguins to either shift their trajectory or move by quickly, or (3) people could move rapidly away from the penguins. Our data showed that the penguins became aware of people at an average of 36 m, which suggests that people should try to remove themselves from the anticipated crossing point when the penguins are still at this distance. At the least, once penguins have shifted directions to avoid coming directly toward people, they should remain immobile to allow the penguins to choose their own pathway by the people.

Our data on penguins traveling to and from the sea to forage showed a clear dose-response in behavior; as the number of people increased, the penguins responded at greater distances, shifted directions sooner, stopped more often, and paused for more time. This suggests that larger tourists groups cause a greater disturbance than smaller groups. This effect could be minimized by controlling for group size (not having a group of 15 or more people traveling together), by having some time in between exposure to tourist groups, by limiting the time tourists could linger near groups of penguins traveling to the sea, and by carefully instructing tourists on how to avoid such interactions by moving forward or backward to avoid the crossing point in the direct path of traveling penguins. To a large extent this was accomplished during our pre-encounter briefings, and by the visitation schedule itself in which helicopters brought groups of eight visitors at 15 min intervals.

Resource protection in Antarctica relies on both governmental guidance (e.g., AGAD 2003, Harris 2006) and industry guidelines (IAATO 2006a). There has been substantial emphasis on ships, aircraft, and noise. By having our ship ice-locked about 12 km from the colony and landing the helicopters about 2.5 km from the colony and behind a stranded iceberg, the impact of transportation was minimized. Transportation noise can be locally important in

Antarctica, and emperor penguins close to scientific bases may experience such disturbance. Helicopters are expected to stay a least 1,000 m above a colony, but at this altitude most emperor penguin chicks responded to overflights by moving quickly, leading Giese and Riddle (1999) to propose at least 1,500 m height restriction.

Finally, self-policing by an industry is often problematic, but the power of the tourist industry can be harnessed for conservation, and Antarctica appears to be a working laboratory. Management guidelines must be species and colony specific, and while our observations at Snow Hill clarify management issues, the results are not necessarily applicable to all emperor penguin colonies, nor to all stages of the breeding cycle. The impacts of ecotourism and other direct human activities should be considered in the context of other human-related threats such as pollution, over-fishing, and climate change (Croxall et al. 2002).

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