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Response behaviour of seals and penguins to helicopter surveys over the pack ice off East Antarctica

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Abstract: Data on the response behaviour of seals (crabeater, leopard and Ross) and penguins (Adélie and emperor) to helicopter surveys over the pack ice off East Antarctica are presented. The surveys involved Sikorsky S76 helicopters flying at altitude 130 m and speed 90 knots along straight-line transects. The relative frequency of alert and movement behaviours by seal and penguin groups decreased with distance out to 800 m from the flight path. Penguin groups were more likely to show a movement response than seals at all distances. The perpendicular distances moved relative to the flight path were small (maximum 20 m, mean ≤ 3 m, for both seal and penguin groups) relative to the width of the area searched (800 m), and there was no evidence that response movement resulted in a spiked detection histogram. Observers were more likely to feel confident in identifying seal and penguin species if the animals responded to the helicopter by changing the body posture or moving. In this application of aerial survey, the response behaviour elicited by the passing helicopter was considered to be beneficial from a technical perspective, and the disturbance caused to the surveyed populations negligible from an ethical perspective.

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Introduction

Aircraft play an important role as survey platforms for the assessment of the status and trends of large air-breathing vertebrate populations, particularly seals and penguins, in Antarctica and the Southern Ocean. Aerial surveys for this purpose have generally employed two broadly differing methods:

1) photographic surveys, where cameras mounted in the aircraft capture images of the target species which are later inspected by an observer, and
2) sighting surveys, where observers in the aircraft undertake direct counts of the target species.

The former method has generally been applied to dense concentrations of animals at localized breeding sites (e.g. Wilson & Taylor 1984, Whitehead & Johnstone 1990), and the latter method to dispersed populations over large expanses of pack ice (e.g. Erickson *et al.* 1974, Gilbert & Erickson 1977). This paper addresses only the latter application.

When planning and undertaking aerial sighting surveys, an important issue to consider is the degree of responsive behaviour exhibited by animals to the aircraft. This issue has technical, ethical, conservation and policy ramifications. This paper primarily addresses technical issues.

At the technical level, aerial sighting surveys have usually employed strip (e.g. Gilbert & Erickson 1977) or more recently line (Bengtson *et al.* 1995) transect methods, both of which make assumptions about response behaviour. Strip transects assume that target animals do not move in or out of the planned survey strip in response to the oncoming aircraft before being counted (Buckland *et al.* 2001). Line transects assume that target animals do not move from their original position before being sighted and distance to them measured (Buckland *et al.* 2001). Violation of these assumptions will cause bias in the resulting abundance estimates, which may be positive or negative depending on the direction and extent of responsive movement.

Another technical consideration, relevant only when multiple species of similar body form are present, is that identification of species may be difficult unless the target animals provide some unambiguous, species-specific characteristic. In this context, eliciting a response or movement by the target animal to the passing aircraft may aid in species identification. Simple movement of the body may provide increased information on body shape and posture to the observer, and movement across the ground may provide information on gait, both of which are often highly species-specific.

Given a particular aircraft type, altitude, through the effect of aircraft noise, is likely to be one of the major determinants of response behaviour. The technical issues outlined above present conflicting requirements with regard to altitude for a researcher planning a multi-species aerial sighting survey: flying too high may compromise species identification because response behaviour is absent, while flying too low may violate the assumptions of the survey

Table I. Survey specifications (altitude and speed) employed in previous aerial sightings surveys of seals and penguins in the pack ice.

Reference	Altitude (m)	Speed (knots)
Siniff & Cline (1968)	90	-
Siniff *et al.* (1970)	90	-
Erickson *et al.* (1973)	152	-
Gilbert & Erickson (1977)	152	-
Erickson *et al.* (1983)	76	-
Erickson (1984)	90	-
Bengtson *et al.* (1995)	152	90
Bengtson *et al.* (1995)	122	90
Bester *et al.* (1995)	61	60
Bester & Odendaal (2000)	91	80
Bester & Odendaal (2000)	61	60
Bester *et al.* (2002)	61	60
This study	130	90

method because response behaviour is too great. Identifying an optimal altitude would be best achieved through an experimental study prior to a survey (e.g. Krausman & Hervert 1983). However, the remoteness and expense of aerial work in Antarctica make prior experimentation very difficult, and researchers planning to undertake aerial sighting surveys usually have to rely on information gleaned from the literature, or make an educated guess as to what an optimal altitude might be.

Previous aerial sighting surveys of seals and penguins in the pack ice off Antarctica have been flown at altitudes ranging from 61–152 m above sea level (Table I). None of the publications reporting these surveys provide information on the extent of response behaviour displayed by the target species across this range of altitudes. Bengtson *et al.* (1995) allude to the trialling of two altitudes (122 and 152 m) to compare sighting efficiencies, and Bester & Odendaal (2000) reduced altitude from 91 m to 61 m to improve species identification, but neither paper reports any observations of responsive behaviour.

The Antarctic Pack Ice Seal (APIS) program is a recent, major initiative of the Scientific Committee on Antarctic Research's Group of Specialists on Seals. APIS aims to provide estimates of pack ice seal abundance at regional and circumpolar scales (http://nmml.afsc.noaa.gov/apis/international.htm). As a contribution to the APIS program, the Australian Antarctic Division undertook aerial line transect surveys (Southwell *et al.* 2002) throughout the pack ice off East Antarctica between longitudes 60–150°E. Logistical constraints precluded an experimental study prior to this survey to assess response behaviour and determine an optimal altitude for flying. Given the absence of information in the literature on response behaviour there was no option but to make an educated guess at an appropriate altitude and the resulting response behaviour it would elicit, while also complying with the requirements of relevant legislation and environmental guidelines.

This paper reports the extent of response behaviour by seals and penguins observed in the Australian APIS aerial survey and examines the implications of such behaviour on survey assumptions. In addition, some of the ethical and policy implications of the observed response behaviour are discussed.

Methods

Aerial surveys were undertaken from two twin-engine Sikorsky S76 helicopters flying straight-line transects separated by ≥10 nm over the pack ice. Pilots were requested to maintain an altitude of 130 m and a speed of 90 knots as closely as possible while on transect by visual inspection of aircraft instruments. A digital record of altitude at 10 s intervals indicated that pilots were able to remain within 20 m of the requested altitude for 95% of the search effort.

A total of 12 observers participated in the aerial survey. Prior to survey work, all observers attended a rigorous training program, involving theory and simulation, and undertook training to improve species recognition skills. Theoretical training focussed on line transect sampling issues, with the practical aim of standardizing search patterns between observers and focussing their search effort near the flight path. Simulation involved the use of survey images and data logging equipment to gain proficiency in survey procedures, and to practise appropriate search patterns and strategies for dealing with high-encounter situations. Still images and video footage were used to demonstrate the range of body profiles and behaviours exhibited by each species. All observers participated in shipboard surveys for over a week prior to aerial work, during which time they improved further their species recognition skills.

Observers operated in three four-person teams, rotating between the two helicopters in aerial survey and shipboard survey on a daily basis. During aerial survey, the four observers in a team were seated in front and back positions on each side of the helicopter. Paired observers (termed 'double observers' or 'independent observers' in the survey literature) in front and back seats on each side of a helicopter searched the same area independently (they could not hear or see each other while searching). Each observer searched ahead of the helicopter and up to 800 m outwards from the flight path for groups of seals (crabeater *Lobodon carcinophaga*, leopard *Hydrurga leptonyx* and Ross *Ommatophoca rossii*) hauled out on the ice. The first 100 m from the flight path was obscured due to restricted visibility caused by the window configuration. Data on groups of penguins (Adélie *Pygoscelis adéliae* and emperor *Aptenodytes forsteri*) sighted on the ice were also recorded. To maximize sampling intensity given limited time in the air, the helicopters did not double back to inspect more closely any groups sighted on the first passing. An automatic data logging system was used to record double observer line transect data for abundance estimation

(Southwell *et al.* 2002), in particular the distance of sighted groups from the flight path as they passed abeam of the helicopter. The data logging system allowed additional animal-related covariates, including species, group size and response behaviour, to be recorded without observers compromising their search effort. Observers qualified their identification of seal and penguin species as certain or probable, or if identification to species within animal type was not possible, recorded the sighting as an unknown seal or penguin. Response behaviour was recorded as one of three categories indicating an increasing level of response: still, moved body posture but remained at the same location, and moved both body posture and location. These categories are hereafter referred to as still, alert and moving, respectively. If an animal moved its location in response to the helicopter between the time of initial sighting ahead of the helicopter and the time of passing abeam, observers visually estimated the perpendicular distance moved toward or away from the flight path during that time. If the sighted group contained >1 animal, observers recorded the response category and the distance moved for the most responsive member of the group.

Groups sighted by double observers were classified as having been seen by either one ('single sighting') or both ('duplicate sighting') of the observers according to the level of agreement between observers in the recorded time of sightings, the measured distance of sighted groups from the flight path, the recorded size of sighted groups, and the identification of groups to species (see Southwell *et al.* 2002 for agreement criteria). If, for sightings classified as duplicates, the animal-related covariate data recorded by each of the double observers were not identical, data were merged across observers in the following way:

i) perpendicular distance from the flight path was calculated as the average of each observer's distance measure,

ii) group size was calculated as the average of each observer's group size measure

iii) species identification and its certainty were determined according to the rules outlined in Table II,

iv) response behaviour was taken as the record indicating the greatest response, and

v) distance moved was taken as the estimate indicating the greatest response.

The merged data for duplicate sightings, along with the recorded data for single sightings, formed the dataset of 'sighted groups' on which the analyses described below were performed.

Summary statistics of perpendicular distances moved by groups toward (negative) or away (positive) from the flight path between the time of initial sighting and the time of passing abeam of the helicopter were calculated for 100 m bins away from the flight path. The perpendicular distance of each group from the flight path when initially sighted ahead of the helicopter was calculated by subtracting the estimated perpendicular distance moved between the time of initial sighting and passing abeam from the perpendicular distance measured as the group passed abeam. Sighting histograms of perpendicular distances on initial sighting (before which it was assumed there had been no movement) and on passing abeam (after movement) were constructed using 50 m bins. Chi-squared analyses were used to determine whether

i) the relative frequency of response categories was dependent on distance from the flight path,

ii) sighting histograms differed before and after correction for movement, and

iii) the observers' qualification of species identification for a group of animals as certain, probable or unknown was dependent on the behavioural response attributed to it.

Table II. Rules for assigning species identity and certainty (1 = certain, 0 = probable) to duplicate sightings. The two species IDs A and B are generic, used to indicate whether the observers identified the species as being the same or different. An ID of U (unknown) means that the species could not be determined to better than animal type (seal or penguin). Unknown sightings were always considered as certain. A seal sighting, even if not identified to species, was not be considered as a candidate for a duplicate sighting with a penguin sighting, even if that too was not identified to species. The assigned species IDs and certainty ratings were those assigned to groups of animals that were classified as a duplicate. A group recorded as certainly species A by one observer and certainly species B by the other observer would not have been classified as a duplicate sighting, even if there was close agreement in the other criteria (time, distance and group size).

Species recorded by observer a		Species recorded by observer b		Assigned species	
ID	Certainty	ID	Certainty	ID	Certainty
A	1	A	1	A	1
A	1	A	0	A	1
A	0	A	0	A	0
A	0	U	1	A	0
U	1	U	1	U	1
A	0	B	0	U	1
A	1	U	1	A	0

Results

Sampling intensity and encounter rate

A total of 6300 km of aerial transect was completed in the 1.5 million km^2 survey region, giving a sampling intensity of 0.7%. During the survey effort 3647 seal and 1148 penguin groups were sighted, giving encounter rates of 0.58 groups km^{-1} and 0.18 groups km^{-1} respectively.

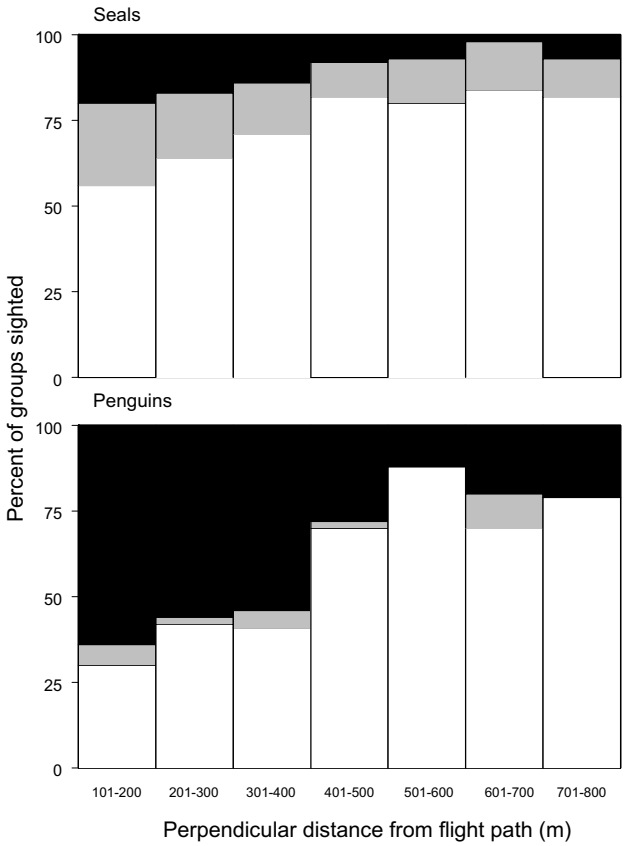

Fig. 1. Frequency of response by seals and penguins in relation to distance from the flight path. Clear = still, grey = alert, black = moved. Animals were not visible within the first 100 m from the flight path due to visual obstruction caused by the window configuration.

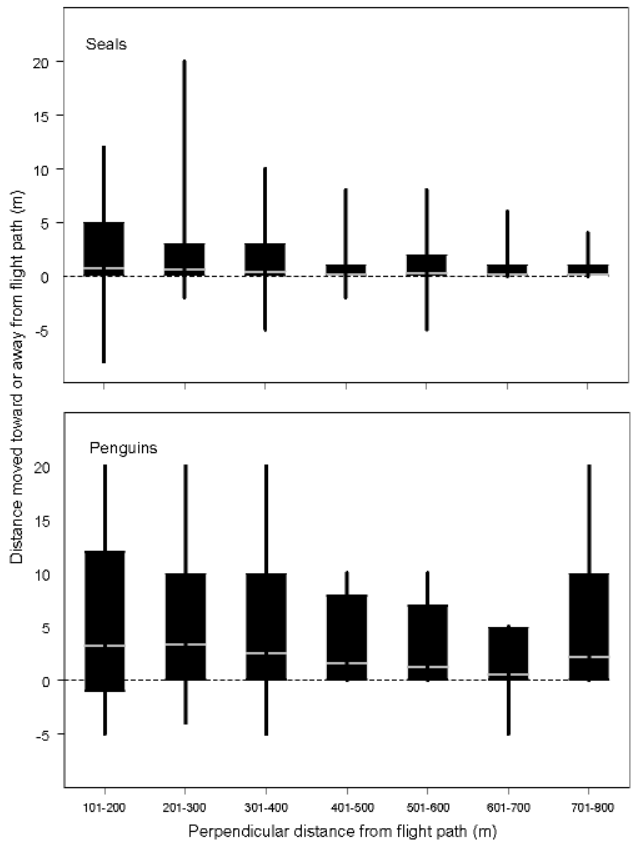

Fig. 2. Summary statistics (complete range: vertical narrow bar; 90 percentile range: vertical wide bar; mean: horizontal grey bar) of perpendicular distances, relative to the helicopter's flight path, moved by seals and penguins located within 100 m increments from the flight path. Positive distances indicate movement away from the flight path, and negative distances movement toward the flight path.

Group size

The great majority of seal groups sighted in the survey comprised single (86%) animals, with pairs comprising another 11%. The largest group of seals had 12 individuals. Penguins were in larger groups than seals, with 41% of groups comprising single penguins, 21% pairs, and 0.8% > 20 individuals.

Frequency of response

The frequency of response categories was dependent on distance from the flight path for both seals and penguins (seals: $\chi^2 = 111.3$, df = 12, $P < 0.001$, penguins: $\chi^2 = 70.9$, df = 12, $P < 0.001$). As would be expected, responses to the helicopter (both alert and moving) declined with increasing distance (Fig. 1). Approximately 60% of seal groups close (101–200 m) to the flight path remained still in the time between initial sighting and passing abeam, 20% were alert, and 20% moved, compared with 80% still at distances > 400 m. Penguins were more responsive than seals, with 30% of groups close to the flight path remaining still and 64% moving. Substantially fewer (< 25%) penguin groups moved at distances > 400 m.

Distance moved

As would be expected given their limited mobility out of water, seals moved only short distances over the ice in the time between initial sighting and passing abeam (Fig. 2). The maximum distance moved away from the flight path was estimated to be 20 m by a group located between 201–300 m from the flight path, and the maximum distance moved toward the flight path 8 m by a group located 101–200 m from the flight path. These extremes are small relative to the maximum distances from the flight path at which groups were sighted (> 800 m), and the common response, in this spatial and technical (rather than ethical) context, was so small as to be trivial: for close (101–200 m from the flight path) groups, 90% moved ≤ 5 m, the mean distance moved was < 1 m, and 56% of groups remained stationary. Penguins moved greater distances than seals (Fig. 2), but again in the technical context of the broad

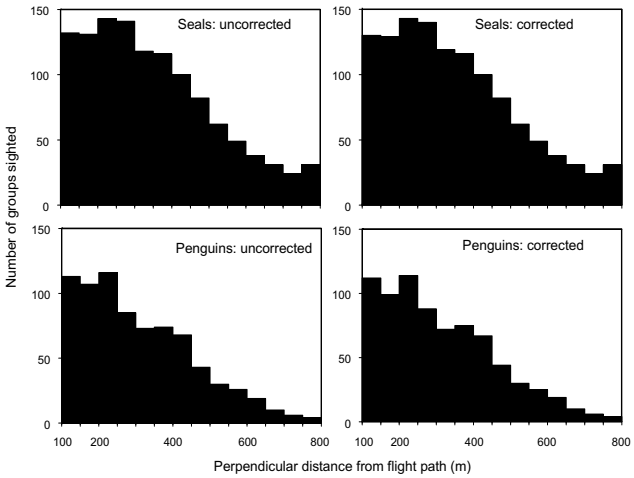

Fig. 3. Sighting histograms for seal and penguin groups (species combined within animal types), before and after correction for responsive movement.

distances over which groups were sighted, the distances moved were considered trivial.

Movement and sighting histograms

Conventional line transect theory assumes that the detection function is constant for some distance away from the transect line before declining monotonically with increasing distance. Since the detection function is estimated from a histogram of sighting frequencies within various distance intervals from the transect line, there is an expectation that the sighting histogram will be non-increasing and/or decline smoothly with increasing distance. This expectation may not be met if

i) movement by the target animal in response to a surveyor or survey platform results in a sighting histogram with a spike in detection frequencies on the transect line (movement toward the surveyor) or some distance away from the transect line (movement away from the surveyor), or

ii) there is some 'noise' in the sighting histogram due to random sampling error.

The former issue can make modelling of detection probability and estimation of abundance problematic if there is no additional information on the extent of movement (Buckland *et al.* 2001). The latter issue occurs in all modelling of real data, especially if sample size is small, and is only a concern with regard to precision (the greater the sampling error the lower the precision in estimates of model parameters). The sighting histogram for seal groups shows a small spike at distances 201–300 m from the flight path, but this cannot be attributed to movement as it appears in histograms both corrected and uncorrected for movement (Fig. 3). Chi-squared tests indicated no differences in the

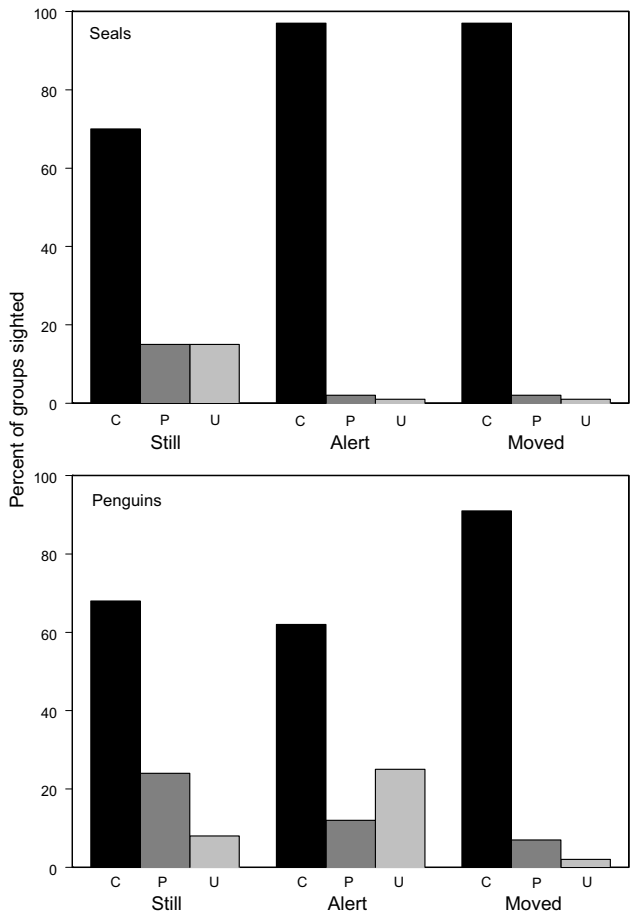

Fig. 4. Observer's perception of their ability to identify seal and penguin species in relation to the level of response behaviour exhibited. Species identification categories: C = certain, P = probable, U = unknown.

frequency of sightings between 50 m distance bins at initial sighting (uncorrected for movement) and on passing abeam (corrected for movement) for either seals or penguins (seals: $\chi^2 = 0.92$, df = 15, $P > 0.999$, penguins: $\chi^2 = 3.11$, df = 15, $P > 0.999$). A chi-squared test of seal sighting frequencies, after correcting for movement, in the four 50 m distance bins from 100–300 m was not significant ($\chi^2 = 0.82$, df = 3, $P = 0.845$), giving no evidence in support of a departure from an expected constant detectability within these distances other than that due to random sampling error.

Movement and species identification

While movement had a negligible effect with respect to sighting histograms, there were significant effects with respect to species identification, especially for seals. Observers were more likely to feel certain in identifying seal species if a member of the group responded (either alert or moving) than if all members remained still, but having responded, the level of response had little effect on observers' confidence (Fig. 4, 70% of still groups identified

with perceived certainty compared with 96% of alert groups and 95% of moving groups, $\chi^2 = 330.1$, df = 3, $P < 0.001$). In contrast, being alert had no positive effect on the observers' perceived confidence in identifying penguin species compared with still groups, but there was greater certainty if penguins moved (Fig. 4, 68% of still groups identified with perceived certainty compared with 62% of alert groups and 91% of moving groups, $\chi^2 = 24.5$, df = 3, $P < 0.001$).

Discussion

From a technical perspective, the response behaviours displayed by seals and penguins to the Sikorsky helicopters flying at 130 m altitude were, on balance, beneficial to the survey effort by improving the observers' confidence in identifying species while causing minimal violation to method assumptions relating to movement. The overall beneficial effect would be manifested in improved confidence in species abundance estimates resulting from the survey. However, it is not possible to conclude whether the survey altitude of 130 m is optimal with respect to these technical issues because no experimental work with differing altitudes was undertaken

From an ethical perspective, observations recorded in the survey indicate that gross behavioural responses were minor. Other studies have observed or suggested gross behavioural responses of penguins to repeated and/or low overflight to include stampede and trampling resulting in mass death (Rounsevell & Binns 1991), panicked fleeing, running or walking from nests or territories (e.g. Sladen & Leresche 1970, Culik *et al.* 1990, Cooper *et al*. 1994, Giese & Riddle 1999) and alert or nervous but stationary behaviour (e.g. Sladen & Leresche 1970, Cooper *et al*. 1994, Giese & Riddle 1999). We are not aware of any published observations of seal responses to overflights. The variety of responses by penguins in these studies suggests that disturbance may be situation-specific, but the consequences can in some cases be catastrophic. In this survey, gross responses generally comprised at most movement over short distances. Although not recorded, there were very few instances where seals or penguins moved across the ice and subsequently dived into the water. Such behaviour could expose the individual to marine predators such as the leopard seal, which with frequent occurrence due to repeated over-flight, could affect the survival of individuals. Repeated disturbance of animals never occurred in this survey because the helicopters did not double back to inspect sighted groups more closely and because of the wide separation (> 10 nm) of transects. As seal and penguin groups were (1) sampled at low intensity, (2) encountered at low rates along transects, (3) generally in small groups when hauled out on the pack ice, and (4) rarely at locations on the ice with obstructions to movement, injury or death caused by collision or stampede in response to the helicopter was extremely unlikely and was not observed in the survey.

The observations in this study were made from a helicopter flying at 130 m altitude and 90 knots speed, so only obvious changes in posture would have been observed and recorded. Subtle behaviour such as minor changes in posture, or changes in physiological state as might be indicated by measurement of heart rate or body temperature would have been missed. Physiologically, Regel & Pütz (1997) recorded increased body temperatures of moulting emperor penguin chicks during helicopter operations which they calculated would require a 2–3 times increase in the moulting metabolic rate to achieve. Giese & Riddle (1999) argue that energy expenditure by repeated helicopter disturbance could have significant implications for emperor penguin chick survival, and also suggest that, at least for Adélie penguins, the adult moult phase is another period of heightened energy-sensitivity to repeated helicopter operations. These more subtle behavioural or physiological responses are most likely to be detrimental, in a conservation sense, if flights are repeated, causing the response to be frequent or prolonged, and if undertaken at energy-sensitive stages of the life history, such as breeding or moulting. Whilst no quantitative information on physiological effects was recorded in this survey, the lack of repeated flights over the same individuals, and the lack of proximity of flights to energy-sensitive individuals (the survey was undertaken within the Adélie penguin breeding season but transects were never closer than 20 km to a breeding site), make it likely that any physiological responses would have been minor and transitory.

As signatories to agreements such as the Antarctic Treaty, the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR), and the Convention for the Conservation of Antarctic Seals, nations have an international obligation to protect and manage the Antarctic and Southern Ocean environments. Effective management policies for these environments require sound scientific data; CCAMLR for example, requires data on the status and trends in krill and predators of krill (including seals and penguins) to manage the Southern Ocean krill fishery in a sustainable manner (the APIS surveys were designed to contribute to management of the krill fishery). Fulfilling the obligations of the Antarctic Treaty requires that any activity, including collection of data for management, is undertaken in a manner that is not detrimental to the environment, including fauna. In the context of aerial surveys of seals and penguins, Australia has enacted legislation requiring that aircraft are not to be used 'in such a manner as to disturb a concentration of birds' (Antarctic Treaty (Environment Protection) Act 1980) and 'in such a manner that disturbs a concentration of seals' (Antarctic Seals Conservation Regulations 1986), with the regulations of the 1980 Act defining a concentration as a group of >20 animals. More specific guidelines are provided in the Australian Antarctic

Division's 'Flight Paths for Aircraft Operating in Australian Antarctic Territory' (Anon 2005), which requires that twin-engine fixed wing aircraft and single-engine helicopters maintain a distance of 750 m from wildlife concentrations, and twin-engine helicopters a distance of 1500 m. Several other countries have guidelines that are similar in spirit, but different in detail (United Kingdom 2001). The important issue of what comprises 'significant' disturbance has not been defined in any of these guidelines. It must also be acknowledged that regulations and guidelines are currently based on little scientific information on the circumstances, nature and extent of disturbance caused by aerial operations (United Kingdom 2001).

In a strict sense the conditions of this survey were largely outside the scope of the Australian regulations because seals were never, and penguins very rarely, encountered in numbers sufficient to comprise 'concentrations' as defined by the regulations. Nonetheless, the intent of the regulations (protection) should be reasonably considered on a case by case basis, which is one purpose of this paper. A second purpose is to provide quantitative observations, which along with experimental studies (e.g. Giese & Riddle 1999), will in time provide a better scientific basis for the development and improvement of policy that allows the twin responsibilities of management and protection to be best met.

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