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SHORT COMMUNICATION

Do introduced mammals chronically impact the breeding success of the world's rarest albatross?

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Abstract Introduced mammals may have deleterious effects on avifauna. We investigated whether such species may be affecting the breeding success of the critically endangered Amsterdam Albatrosses *Diomedea amsterdamensis* on its remote breeding island. Twelve camera-traps deployed near albatross nests during the chick brooding period in 2011 captured 25,000 pictures. Two of them showed Black Rats *Rattus rattus*, but without revealing evidence of any direct interaction between the two species. Breeding success in 2011 was similar to that in previous years (60%). Our survey suggests that introduced mammals may not currently represent a primary direct threat to this population, but they might amplify the risks of chick mortality in case of disease outbreaks.

Key words Amsterdam Albatross *Diomedea amsterdamensis*, camera-trapping, conservation, invasive species, seabird

Seabirds are the most threatened group of birds today (Croxall et al. 2012), facing considerable perils to conservation both at sea, from commercial fisheries and pollution, and on land from habitat degradation, human disturbance and alien invasive predators (reviewed in Lewison et al. 2012). Carnivorous alien mammals may impact the dynamics of seabird populations dramatically by consuming the nestlings of species with low fecundity (e.g., Jones et al. 2008; Wanless et al. 2009), as reported earlier for albatrosses (Cuthbert & Hilton 2004; Jones & Ryan 2010).

One of the seabird species giving greatest cause for concern is the Amsterdam Albatross *Diomedea amsterdamensis*. This species is listed as Critically Endangered (IUCN 2012) owing to the extremely small size of the sole population of the species, which breeds only on remote and uninhabited Amsterdam Island in the southern Indian Ocean. Starting from fewer than 10 breeding pairs (when the species was first described 30 years ago; Roux et al. 1983), the Amsterdam Albatross has a larger, but still fragile, population today (Fig. 1). It is estimated that the population had reached 86 breeding adults, and a total of 167 individuals, by 2007 (Rivalan et al. 2010). Given that the population is so small, any additional mortality of only six individuals per year could drive the species to extinction over a relatively short period (Rivalan et al. 2010). Continuous monitoring of the sole Amsterdam Albatross population for the past three decades shows a rather poor average breeding success of 61% (from egg laying to chick fledging; Rivalan et al. 2010) compared to congeneric large albatrosses (e.g. Weimerskirch et al. 1997). On Amsterdam Island, Black Rat *Rattus rattus*, Feral Cat *Felis catus* and House Mouse *Mus musculus* have each been introduced historically in association with human landings and are still present (reviewed in Jouventin 1994). Our aim in the present study, carried out in the context of a National Action Plan for the preservation of the Amsterdam Albatross (ACAP 2013), was to assess whether the introduced predators chronically impact this albatross population. We used a camera-trapping technique as it has been widely used for census and monitoring of cryptic

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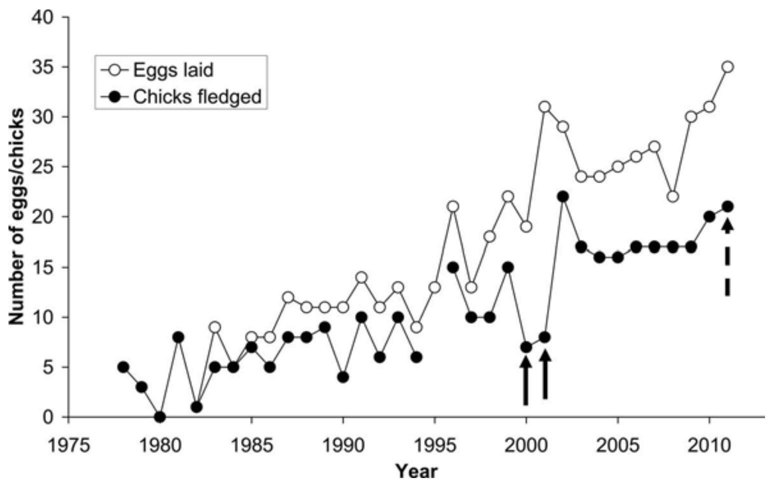

Fig. 1. Annual monitoring of the sole Amsterdam Albatross population since its discovery: number of eggs laid (open symbols) and number of chicks fledged (filled symbols). The two solid arrows show breeding seasons when breeding success was unusually low, and the broken arrow shows the season when we carried out our camera-trapping survey.

species, especially where conventional observation is difficult (e.g. Carbone et al. 2001; Tobler et al. 2008) and has previously been shown to reveal predation of seabirds' nestlings by introduced mammals (Angel & Cooper 2006; Wanless et al. 2012).

MATERIALS AND METHODS

Our survey was carried out during the 2011 breeding season in the sole breeding colony of the Amsterdam Albatross, on the 'Plateau des Tourbières', a high plateau situated at an altitude of 600–700 m on Amsterdam Island. This plateau is characterized by wet peat with Sphagnum mosses, liverworts, ferns, grasses and sedges. Currently, about 30 Amsterdam Albatross pairs nest there each year (Fig. 1). We used 12 Scout Guard camera-traps (model SG550V, dimensions: 13×8×4.8 cm), which are capable of taking and storing digital photographs when movement is detected within their 40° cone of detection. The triggering time given by the manufacturer is of less than one second. These waterproof motion detectors operate silently during both day and night and do not emit light. During the day, still pictures or videos can be recorded in natural colors, while during the night, or in low ambient light levels, 22 infra-red diodes take monochromatic pictures. The maximum distance of detection is up to 60 m in the visible spectrum, but under infrared light it is only 6 m (when hot) or 20 m (when cold). We surveyed either isolated or aggregated nests, with each camera being used for a different nest. Other known nests in the colony were not photographed but used as controls of breeding success, with less than one visit per month to minimize risks of introducing lethal pathogens (Weimerskirch 2004). One batch of seven cameras was deployed 5 to 6 m from nests in the open. Each camera was mounted with adhesive tape on an 80 cm-high tripod. Another batch of five cameras was deployed within 2 m of nests situated in more closed or uneven areas. In this latter case, two 30 cm-long plastic rods were mounted with adhesive tape on each side of the cameras, and the rods were firmly stuck in the ground, with the camera being barely above the vegetation cover. We deployed the first cameras at the colony on 27 March and retrieved the last ones nearly 100 days later on 3 July (Table 1). The functioning period of each device systematically spanned the end of the chick brooding period in early June (Jouventin et al. 1989), when the adults begin to leave their chicks alone on the nest and when the chicks are possibly at the greatest risk of predation. All the cameras were directed towards the south to avoid sun glare as much as possible during the day. We programmed the camera-traps as follows: photo mode (still pictures), 3 mega pixels resolution, date/time stamps on the images, one image captured as soon as motion is detected, no minimum interval between two successive pictures, and no program of hourly activation. With this set-up we intended

Table 1. Summary of the dates and duration of the camera-trapping survey of Amsterdam Albatross nests, and number of pictures taken by each camera. Asterisks indicate which cameras were deployed barely above ground (as opposed to others mounted on tripods).

Camera no.	Deployment date	Retrieval date	Effective survey duration (h)	Number of pictures
1	27 March	3 July	2184	213
2*	27 March	3 July	1421	1584
3	27 March	29 June	1512	18305
4	23 April	3 July	1560	15
5	1 May	3 July	1560	8
6	1 May	3 July	1560	16
7	1 May	3 July	1560	7
8	5 May	3 July	1464	22
9*	12 May	3 July	1272	3171
10*	12 May	29 June	1128	666
11*	12 May	29 June	1176	207
12*	12 May	8 June	648	347
	Mean (± SD)		1420.4 ± 361.2	2046.8 ± 5205.1
	Total		17,208	24,398

to maximise both the ability to capture movement events and battery life duration. We used 2-Gb SD memory cards and 2,500 mAH AA batteries. Every five days on average, we checked battery strength using the communicating module provided with the cameras. Taking the opportunity of such unusually frequent visits to the colony, we also collected any biological samples (such as scats or carcasses) that may attest to the presence of alien mammals in the colony and complement insights gained from the cameras. We finally compared the breeding success of the population at the end of the 2011 breeding season with the 30 previous years of monitoring, in order to control whether our survey depicted a typical situation.

RESULTS

Each camera-trap operated for 1,420 hours (range 648–2,184 hrs, Table 1) and took more than 2,000 pictures (range: 7–18,305) on average. In total, the number of pictures taken amounted to nearly 25,000, with about 1.4 pictures per hour per camera. The batch of cameras set at low levels did not show a significantly higher triggering rate than those set at higher levels (Wilcoxon rank sum test, $W_{11}=6$, $P=0.07$). In most cases, only the chick, adult and/or vegetation neighbouring the nest appeared in the photographs (Fig. 2 ab). However, careful analysis revealed that a rat was visible in two photographs of different Amsterdam Albatross nests both of which were monitored from ground-level cameras (Fig. 2 cd). The time stamps on the images indicated that the rats passed close to these nests during the nights of 12 and 28 May, respectively. On these dates, both nests contained a chick and a brooding adult.

Three of the 12 monitored nests failed before hatching, with no evidence for the reason of failure visible in the photographs. The proportion of failed breeding pairs was not greater in the monitored (3/12=25%) than in the non-monitored (11/23=48%) nests during the 2011 breeding season (effect of the monitoring: Fisher's exact test, $P=0.193$). The average breeding success of the 35 pairs censused during the 2011 breeding season was 60%. No albatross (chick or adult) was found dead in the colony during the duration of the camera-trapping survey.

In addition to camera-trapping, we collected 12 fresh samples of rat scats between 27 March and 28 May, as well as one rat carcass on 27 March, and four samples of cat scats between 27 March and 2 June. These samples were generally found near the paths we used to commute between nests. Analysis of these samples is yet to be carried out. In addition, a mouse was observed on the colony on 8 April, and cat footprints were seen in a muddy area on 15 April.

Fig. 2. Pictures taken by the camera traps deployed near Amsterdam Albatross nests showing two cases of 'false-alarm' (a: adult leaving its nest after switching with its partner; b: adult brooding its newly-hatched chick on its nest) and two cases when a rat passed close to a nest (c: the brooding albatross is visible in the background; d: zoomed detail of the camera-trapped rat; in both cases the rat is indicated with a broken arrow).

DISCUSSION

We confirmed that feral rats, mice and cats are present within the sole breeding colony of the Critically Endangered Amsterdam Albatross. We also revealed that rats occasionally occur in close vicinity of albatross nests at night, during the chick-brooding stage. Given the duration of our survey, two detections of introduced mammals is within the same order of magnitude as the seven mouse attacks recorded on other Procellariiforms during a survey spanning more than 800 days (Wanless et al. 2012). However, we obtained no data indicating predation events by mammals on albatrosses during the chick brooding stage. Importantly, our results are compelling in that they represent a 'normal' breeding season for the colony, i.e. breeding success was not unusually low (61% over 30 years; Rivalan et al. 2010; Fig. 1). Previous studies have shown that the presence of introduced predators alone cannot be used to indicate systematic predation (e.g., Ruffino et al. 2008).

Among the camera records reported here, many of them were likely to have been triggered by movements made by the birds themselves on the nest (Fig.

2ab), or by movements of the vegetation within the frame caused by the wind. The latter may especially apply to camera number three, which was monitoring a nest surrounded by tussock grass and took the majority of pictures (Table 1). However, we cannot rule out that some of these apparently 'false-alarm' photographs might have been caused by mammals (especially mice) passing near the cameras, but too quickly to appear in the images. Reduced triggering time is a key aspect to be developed for camera trapping (Meek & Pittet 2012). Nevertheless, we are confident that we did not miss predation of adults, chicks or eggs, because these events would take longer for the predator to achieve (due to prey handling time) than a simple passage (Angel & Cooper 2006). Hence, any predation event would likely have been captured by the cameras.

In comparison with other large albatross species, breeding success appears relatively low in this population (Fig. 1, Weimerskirch et al. 1997), and we could not relate this rate of success to nest predation during the chick brooding period in 2011. Other causes of breeding failure may be intrinsic, and may include infertility, mis-synchronization of partners and adult desertion, all of which are more likely to occur in either younger or older breeding pairs (Pardo et al. 2013). The current demographic structure of the Amsterdam Albatross population may be abnormal, as it is recovering from an extreme bottleneck (Weimerskirch et al. 1997). The population is comprised of an unusually high proportion of young birds, as supported by estimates for the immatures (40% for Amsterdam versus 25% for Wandering *D. exulans* Albatrosses; Rivalan et al. 2010; Rolland et al. 2010). Hence, although our results cannot exclude the possibility of nestling predation, we suggest that alien mammals are not the main cause chronically affecting the breeding success of the Amsterdam Albatross population, at least during chick brooding in a 'normal' year. In contrast, previous crashes in breeding success (Fig. 1) involving heavy mortality of young chicks suggests that disease outbreaks may be another serious threat of sudden death, that could quickly drive the population to extinction (Weimerskirch 2004; Rivalan et al. 2010). Introduced mammals might be the vectors of at least one of the lethal pathogens identified so far in albatrosses on Amsterdam Island (*Erysipelothrix rhusiopathidae*, the bacterium responsible for the disease Erysipelas; Weimerskirch 2004; Jaeger et al. 2013). Our study supports that introduced mammalian species on Amsterdam Island may facilitate disease outbreaks in this unique colony by commuting between nests, in the close vicinity of breeding birds. Further epizootic outbreak risk assessments are currently being carried out (Jaeger et al. 2013). We therefore stress the importance of considering potential interplay between the identified threats to refine the conservation strategy for this Critically Endangered albatross species.

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