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NOTE

Short-tailed shearwaters breeding in Australia forage in Antarctic waters

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ABSTRACT: This paper provides the first proof that short-tailed shearwaters *Puffinus tenuirostris* breeding in Australia forage in antarctic waters. The remarkable foraging flights of 3 shearwaters breeding in a colony in eastern Australia were determined from satellite tracking data. The birds were tracked leaving Montague Island, New South Wales, and foraging in the Southern Ocean around Antarctic islands and along the ice-shelf of Antarctica during the chick-rearing period in February to April 1997. The birds flew up to 15 000 km in a single foraging round trip, flying at speeds of up to 88 km h^{-1} They flew further in the day than at night, and were more active on moonlit nights than darker nights.

KEY WORDS: Seabird foraging · Short-tailed shearwater *Puffinus tenuirostris* · Satellite tracking · Southern Ocean flights · Antarctica

The foraging behaviour of most pelagic seabirds is not well documented, so understanding their behaviour at sea remains a major challenge (Croxall et al. 1997). Approximately 20 million short-tailed shearwaters breed on islands around the Australian mainland every year, making it one of the most abundant seabirds in Australasia (Marchant & Higgins 1990). Their population dynamics and breeding ecology have been studied for the past 50 yr (Bradley et al. 1991), yet very little is known about their foraging behaviour at sea.

The first report of short-tailed shearwaters foraging near Antarctica in the 1940s (Routh 1949) was considered erroneous until confirmation in the 1980s (Kerry et al. 1983), although the birds recorded in both these studies were thought to be non-breeders because of the huge distances away from the nearest breeding colonies. In early studies of short-tailed shearwaters breeding in Tasmania, researchers recorded that chicks received fresh food caught by their parents close to the colony, although there was also some evidence of birds foraging at least 800 km from their colony (Serventy et al. 1971). Several studies have found that, although chicks are fed daily for the first 1 to 2 wk following hatching in late January, they can remain unfed for up to 10 to 14 d during the latter half of the fledging period (Naarding 1980, Skira 1986).

More recently, Nicholls et al. (1997) tracked the movements of a non-breeding short-tailed shearwater from a colony in southern Victoria to Antarctica over a 2 wk period. Weimerskirch & Cherel (1998) revealed the presence of Antarctic prey items in the food delivered to short-tailed shearwater chicks by some returning parents. They also documented a dual foraging strategy where breeding adults mixed short foraging trips with long trips of up to 17 d (Weimerskirch & Cherel 1998)—easily enough time for the birds to be foraging in Antarctic waters from Tasmania.

This paper presents the first satellite tracking data documenting flights of breeding short-tailed shearwaters from the Australian mainland to Antarctica. The birds were breeding on Montague Island in New South Wales, near the northern limit of the species' distribution (Marchant & Higgins 1990) and more than 500 km north of the Tasmanian colonies at which most previous studies of these birds have been based (Serventy et al. 1971, Skira 1986, Bradley et al. 1991, Weimerskirch & Cherel 1998).

Methods. We used lightweight satellite transmitters to follow the movements of 3 short-tailed shearwaters (mean body weight of 560 to 614 g and wing-span of 95 to 100 cm) breeding on Montague Island, New South Wales (36.25° S, 150.23° E) during February to April 1997. The 2 males and 1 female had separate breeding partners, were all rearing a single chick of 4 to 6 wk of age at the start of the study, and had all bred successfully in the same burrows with their same partners in the previous year.

The satellite transmitters (Microwave Telemetry PICA PTT) were cased in a low, flat package with rounded corners to minimise drag in the air and underwater. Each transmitter weighed 24 g (deployed), representing 3.8 to 4.1 % of the body weights of the birds. Prior to the deployment of transmitters, 7 birds were

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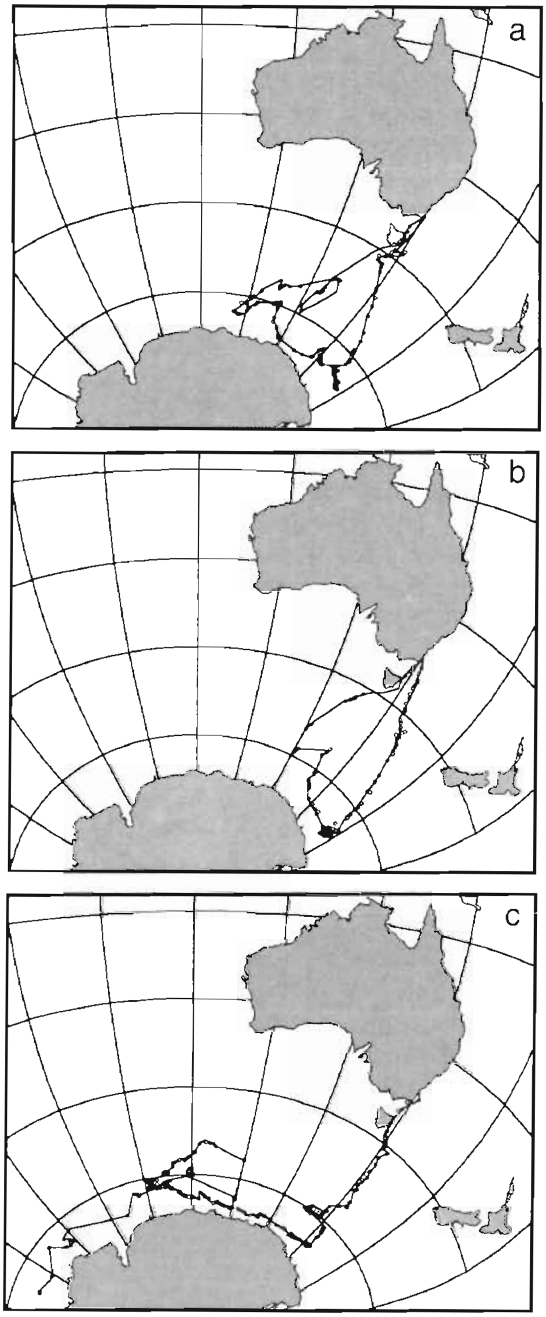

Fig. 1 *Puffinus tenuirostris*. Flight paths of 3 short-tailed shearwaters foraging in Antarctic waters from their breeding colony on Montague Island in New South Wales: (a) male A returned to the colony after 21 d; (b) male B completed two 1 d flights (not shown) before embarking on this 19 d trip; (c) this female appeared to abandon its chick and was still foraging in the Southern Ocean when its transmitter failed 45.5 d after leaving the colony

weighed and examined after carrying dummy transmitters of the same size, shape and weight for 3 to 4 wk during the same breeding season. None of these birds displayed adverse effects from the extra payload or method of attachment. The mean weight change of these birds over this period was 0 g (SD = 50.3 g), after the adults had fed their chicks upon return to the colony. Other non-equipped birds that were monitored as part of another study over the same season (Schultz & Klomp 2000) displayed a similar resultant pattern of colony visits and weight changes. No other birds were equipped with transmitters in this study.

The transmitters were glued (using Loctite 401) to the lower back feathers of the 3 study birds when they returned to feed their chicks at night (see Table 1 for dates of deployment). The birds were then released back into their burrows. Their locations at sea were determined from fixes supplied by 3 satellites of the CLS-ARGOS service, excluding all class Z and other poor quality locations (e.g. Georges et al. 1997). Maximum speeds were calculated between 2 accurate locations (class 3 fixes, ±1 km) over periods of at least 3 h.

Results. The female and male A (Table 1) embarked on a long foraging trip the same night of release. Male B embarked on two 1 d foraging trips, feeding its chick after each day, before commencing its long flight. The 2 males completed a long foraging trip of 21 and 19 d, respectively. The female did not return to the colony, but abandoned its chick and was still foraging in the Southern Ocean when its transmitter failed 45.5 d after leaving the colony.

It can be seen from Fig. 1 that all 3 birds flew directly toward Antarctica. They took only 3 to 4 d to get south of 60° S, then spent differing amounts of time (2 to 8 d) at specific locations in the Southern Ocean, whilst generally travelling west. For example, male B spent a total of 8 d around the northern edge of the Balleny Islands (66° S, 162° E). Upon return male A had increased in body weight by 12.6% and male B by 25.8%. After 18 d foraging, the female flew north-east toward the colony, but then turned back south and continued to forage further and further west, off the coast of Antarctica. Her last known position, after 45.5 d at sea, was 64.3° S, 37.3° E.

The combined data from all 3 birds for those days when there were sufficient fixes to be able to calculate accurately the distances travelled (>8 fixes d^{-1}) revealed several trends. A significant, negative correlation between distance travelled over a 24 h period (from midnight Australian Eastern Standard Time) and latitude ($r = 0.446$, $n = 42$, $p = 0.003$) revealed that the birds tended to travel faster to and from the colony than when they were closer to Antarctica. There was also a significant correlation between the distances travelled in a given day and the distances travelled in the following night ($r = 0.441$, $n = 42$, $p = 0.003$).

The mean distance travelled during daylight hours (411.4 km, SD = 219.6 km) was significantly greater than the mean distance travelled at night (245.6 ±

Table 1 *Puffinus tenuirostris*. Details of the long flights by 3 breeding short-tailed shearwaters from Montague Island, New South Wales, Australia

Bird	Times and duration of flight			Number	Distance covered (km)			Flight speed ($km\ h^{-1}$)	
	Dates (1997)	Days	Hours	of locations	Total flight	% in daylight	Max. from colony	Max.	Mean
Male A	19 Feb–11 Mar	21.0	504	164	15499	73.2	3764	48	30.8
Male B	24 Feb–15 Mar	18.8	452	149	11812	69.8	3468	88	26.1
Female	20 Feb–7 Apr	45.5	1092	252	20124	59.5	7417	63	18.4

138.5 km), even when these distances were corrected for the number of daylight hours each day (t = 3.00, df = 87, p = 0.004), as shown in Fig. 2. The greatest distance travelled in 1 daylight flight (14 h) was 1012 km by male A, then 975 km in 14.6 h of daylight by male B. The greatest distance travelled at night was 697 km in 10.5 h of darkness by the female. The distances flown at night were greater when there was 25% or more of the moon illuminated (mean = 261.9 ± 150.6 km, n = 35) than when there was little or no moon (188.7 ± 59.0 km, n = 10) (t = 2.32, p = 0.026).

The 2 returning males averaged overall flight speeds of 26 to 31 $km\ h^{-1}$. All birds could sustain high average speeds over long periods, with the maximum of 88 $km\ h^{-1}$ over 3 h calculated from accurate locations of male B.

Discussion. Short-tailed shearwaters are regularly recorded in Antarctic waters between January and March (Woehler et al. 1990), foraging extensively on krill *Euphausia superba* (Kerry et al. 1983), although it has not been clear whether the birds sighted were breeders or non-breeders. Weimerskirch & Cherel (1998) provided strong evidence to suggest that short-tailed shearwaters breeding in Tasmania foraged in Antarctic waters, but this had not been documented directly until now. Further, the birds in the present study were breeding in New South Wales, 500 km north of the Tasmanian colony studied by Weimerskirch & Cherel (1998).

The birds in this study spent most of their time south of 60° S at latitudes where krill are in great abundance (Pauly et al. 1998). Although providing only 1 feed to the chick upon return, these long foraging trips of breeding short-tailed shearwaters are important in maintaining the body condition of the adults whilst raising young (Weimerskirch & Cherel 1998); the 2 adults that returned from long foraging trips in this study had increased their body weight by 12 and 26%. Yet, by alternating these long foraging trips with 1 to 3 short trips, the adults can maintain an average chick-feeding frequency of 1 feed every 4 to 6 d (e.g. Weimerskirch 1998, Weimerskirch & Cherel 1998). The importance of accessing prey at high latitudes in the Southern Ocean is reflected in the flight patterns revealed in this study, with the birds travelling faster to and from the colony than when closer to Antarctica, and appearing to forage over greater areas during the day and on moonlit nights.

The wings of short-tailed shearwaters have evolved for gliding flight that uses the force of the wind to soar, dive and glide over the ocean surface; they rarely flap their wings in windy conditions, so can travel great distances expending minimal energy (Kuroda 1991). The mean overall flight speeds of the returning adults in

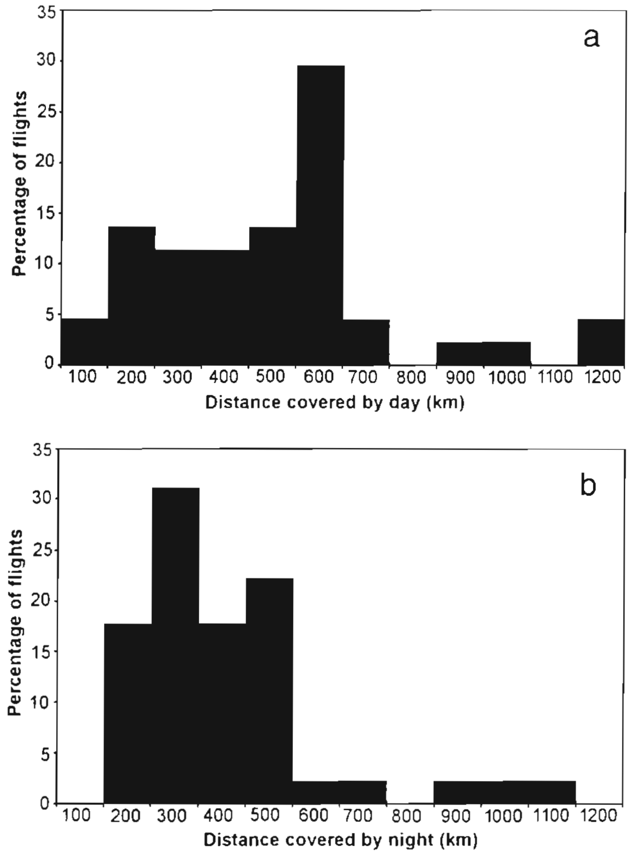

Fig. 2. *Puffinus tenuirostris*. Short-tailed shearwaters travelled significantly further by day (a; n = 44) than by night (b; n = 45), even when these distances were corrected for the number of daylight hours (based on the time of year and locations of the birds in the Southern Ocean, these birds spent 54 to 55% of their time in daylight)

this study (26 to 31 km h^{-1}) and the sustained maximum speed recorded of 88 km h^{-1} were undoubtedly influenced by speed and direction of the prevailing winds, which are consistently strong at these latitudes. Similar flight speeds were recorded for wandering albatrosses foraging close to Antarctica (Jouventin & Weimerskirch 1990), although these albatrosses have wing-spans that are 3 times larger and 20 times heavier than short-tailed shearwaters. Despite this species being able to utilise the reliable energy source of krill in Antarctic waters to breed in eastern Australia, there is likely to be a limit to the foraging distances it can travel to provision chicks. Indeed, the results of this study may help elucidate the apparent limit to the northern distribution of short-tailed shearwaters around southern New South Wales. The foraging locations reported here probably reflect the historical breeding distribution of short-tailed shearwaters in the Southern Ocean (Harper 1987).

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