

H. Weimerskirch · O. Chastel · Y. Cherel
J.-A. Henden · T. Tveraa

Nest attendance and foraging movements of northern fulmars rearing chicks at Bjørnøya Barents Sea

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Abstract We studied several aspects of the foraging ecology of fulmars rearing young chicks on Bjørnøya. To determine precisely the duration of foraging trips during the brooding period, we used an automated logging system that recorded the presence of fulmars fitted with transponders. We also tracked, with satellite transmitters, four parent fulmars during the brooding period, and two after the chick had been left alone. When brooding the chick, fulmars appeared to alternate very rapidly on the nest, with foraging trips lasting on average 8 h. This period appeared constraining for the birds since parents lost mass. The growth of chicks was dependent on the ability of the female (and not the male) to do short foraging trips. At this time birds are foraging at an average distance of 60 km from the colony, with birds concentrating on the shelf around Bjørnøya. They did not return from one trip to the next to the same foraging area. As the season progressed and the chicks were left alone on the nest, parents increased the duration and maximum range of foraging trips as well as the distance covered. However, they still perform a succession of relatively short foraging trips to the east of the Bjørnøya shelf but they interspersed these short trips with longer foraging trips. One bird returned twice to the same site along the Norwegian coast 570 km from Bjørnøya, the other foraged at 580 km in the mid-Barents Sea. Average flight speed including time spent on the water was 28 km/h and reached 70 km/h during bouts of more than 1 h when the bird was probably continuously in flight.

H. Weimerskirch (✉) · Y. Cherel · O. Chastel
Centre National de la Recherche Scientifique,
Centre Biologique de Chizé,
79360 Villiers en Bois, France
e-mail: henriw@cebc.cnrs.fr
Fax: +33-549-096526

T. Tveraa · J.-A Henden
Division for Arctic Ecology,
Norwegian Institute for Nature Research (NINA),
The Polar Environmental Centre,
9296 Tromsø, Norway

Introduction

The northern fulmar (*Fulmarus glacialis*) is one of the most common seabirds in the North Atlantic and has spread its range from high arctic sites since the last century (Fisher 1952; Warham 1996). It is an oceanic bird like other members of the order Procellariiformes that are well known to forage at long distances from their breeding grounds, even during the breeding season (review in Weimerskirch 1998). Yet very little information is available on the foraging zones and foraging range of breeding fulmars. During the incubation period when they alternate for periods of 3–5 days (Mougin 1967; Hatch 1990a) they have a potential foraging range of several hundreds of kilometres from their nest. During the chick-rearing period, dye-marked birds have been observed at a maximum range of 120 km from the breeding grounds (Furness and Todd 1984), but one band recovery suggested a potential maximum range for one bird of 466 km (Dunnet and Ollason 1982). It is generally suggested that range may be limited during the chick-rearing period because of the high feeding frequency observed in this species (Furness and Todd 1984; Hamer and Thompson 1997; Hamer et al. 1997). Like several other species of Procellariiformes, fulmars brood their chick for almost 2 weeks (Mougin 1967) before the chick is left alone on the nest and fed by both parents. During the brooding period parents probably alternate very rapidly on the nest (Furness and Todd 1984; Hamer et al. 1997).

The brooding period is a period of high-energy requirement for pelagic seabirds because at this time birds have to fast on the nest to brood and feed the chick that is not thermally emancipated (Ricklefs 1983). At this time brooding parents forage at sea for trips of short duration, suggesting that even the most oceanic species have to reduce their foraging range. These restricted foraging zones around the island are probably not as optimal as distant waters that are favoured during incubation, and, moreover, intraspecific competition may be high. Accordingly, in several species of

Procellariiformes, including fulmars, parents show a rapid decline in mass during that period (Hatch 1990b; Weimerskirch 1990a; Weimerskirch and Lys 2000). Adults are therefore likely to face a trade-off between the needs to brood the chick and feed it at the same time, and the need to spend enough time at sea to restore their body condition (Tveraa et al. 1998).

The aim of this study is first to examine how parent fulmars balance, during the brooding period, the trade-off between the needs of the chick to be fed regularly and brooded, and that of the adult to spend enough time at sea to restore its body reserves and find food for the chick. The second aim of the paper is to determine the foraging zones of parents during the brooding period and whether they change as the chick gets older. To do so we use a new automatic recording system based on continuous logging of transponders fitted on the parents, and miniature satellite transmitters to track birds at sea. The study was carried out at Bjørnøya, the major breeding grounds for fulmars in the Barents Sea (Mehlum and Gabrielsen 1995).

Materials and methods

The field study was carried out between 25 June and 26 July 1999 at Kapp Heer, (74°22'N, 19°10'E) Bjørnøya (Bear Island), Western Barents Sea. Fifteen thousand pairs of fulmars breed at Bjørnøya (Mehlum and Gabrielsen 1995).

Automatic recording station

To monitor the attendance pattern of fulmars we used a pit tag ID logging system (Francis Scientific Instruments, Cambridge, UK). On 14 nests, between 7 and 15 July, each parent fulmar was fitted with a 14 × 3-mm pit tag (0.35 g), i.e. a miniature radio frequency transponder device. Each pit tag has a unique identity (ID) code and was taped on a plastic leg ring. The adult fulmars were caught on their nest at hatching with a noose at the end of a 5-m-long fishing pole. The birds were at the same time weighed (± 0.5 g) and measured [skull, culmen length and bill depth (all measurements ± 0.05 mm)] to allow determination of sex. We consider the male as the larger member within a pair (Wynne-Edwards 1952; Dunnet and Anderson 1961; van Franeker and Wattel 1982). Thereafter, daily checks of these 14 nests were organised to determine the hatching date and to weigh the chick and the parent attending the nest every 2–5 days. To detect the presence of the pit tag on the nest, each nest was fitted with an annular antenna (30 cm in diameter) that circled the nest. Antennas were installed on nests during the late incubation period and were connected through a cable to a data logger. The data logger searches continuously for the presence of a pit tag and records the ID code along with the time at which the ID is detected. Time and ID data are recorded in binary form. Each logger can store the information from four antennas. The information was downloaded from the loggers through a portable PC. The system was successfully used between 16 and 24 July on 8 nests monitored continuously. On 16 July, chicks from these 8 nests were aged 2–8 days. With this system we therefore obtained the exact succession of the two members of the pair for the 8 nests and determined the duration of foraging trips at sea. To avoid pseudo-replication when examining factors affecting the duration of trips, we used average values for each individual. Growth rates of chicks were measured as the slope of the regression of mass of chick on time.

Satellite tracking

The foraging trips of four adult fulmars rearing chicks were studied using the Argos satellite tracking system. The four transmitters (PTT 100; Microwave Telemetry, Columbia, Md., USA) weighed 20 g ($n = 2$) and 30 g ($n = 2$), which corresponded to 2–4% of the bird body mass (range: 745–985 g). The dimensions of the PTTs were 54–65 mm long, 16 mm wide and 15 mm high, with a 215-mm long aerial. They were attached directly to the back feathers using epoxy resin and a cable tie on four fulmars brooding chicks (different nests from those used with data loggers). The transmission interval was 90 s. The four PTTs were deployed on 16 and 17 July 1999 on three females and one male and allowed the reconstruction of 46 foraging trips. A foraging trip was determined when a location on the colony at the start and at the end of the movement were available. Some very short trips close to the island were probably missed during the first week of tracking. Two PTTs were recovered after 3 and 4 days, i.e. after 4 foraging trips for each bird. The two others were left on the one male and one female because it was no longer possible to recapture the birds when they returned to their nests in the cliffs; the birds temporarily left the nest when approached, yet they continued to attend the chick (see Results). These two PTTs allowed the reconstruction of 16 (female) and 22 (male) successive foraging trips. No transmission failure occurred and because of the high latitude of the study area up to 38 locations per PTT per day were obtained. Data were analysed using ELSA software (CLS Argos, Toulouse, France) and home-made software. All classes of location accuracy provided by the Argos system were used. Only locations that were implausible (flight speed > 90 km/h) were excluded: they represented 31.5% of the locations.

Statistical analyses were performed with Systat 8.0 (Wilkinson 1998). For correlation studies, we used Pearson's correlation (r_P) when data were normally distributed, otherwise we used Spearman's rank correlation (r_S).

Results

Nest attendance during brooding

When brooding their chicks, parents alternated on the nest with the chick for periods ranging between 0.2 and 20.3 h (average 8.0 ± 4.5 h, $n = 146$). There was no visible trend in the arrival time on the nest of females, whereas the returns of males peaked in the morning (at 10:00) and in the evening (between 20:00 and 22:00). The average duration of foraging trips did not differ between sexes ($F_{1,14} = 0.002$, $P = 0.962$). There were extensive differences between individuals ($F_{15,133} = 1.83$, $P = 0.037$), with average values for each individual ranging from 5.5 to 13.3 h. There was no significant effect of the age of the chick ($F_{14,134} = 1.59$, $P = 0.089$) nor of the date ($F_{9,139} = 1.14$, $P = 0.342$) on the duration of foraging trips. During the study period, males lost mass at a higher rate than females ($F_{1,13} = 8.0$, $P = 0.014$: -7.8 ± 2.6 g/day versus 2.5 ± 4.3 g/day).

The growth rate of the chick was not influenced by its age, nor by the mass of parents at the start of the study period nor by the rate of mass loss of parents (Pearson or Spearman correlations, $P > 0.1$). It was negatively related to the average duration of foraging trips by the female ($r_P = -0.932$, $P < 0.001$) but not by the male ($r_S = 0.320$, $P > 0.1$; Fig. 1).

We also examined whether the duration of a stay on the nest influenced the duration of the next trip at sea, or

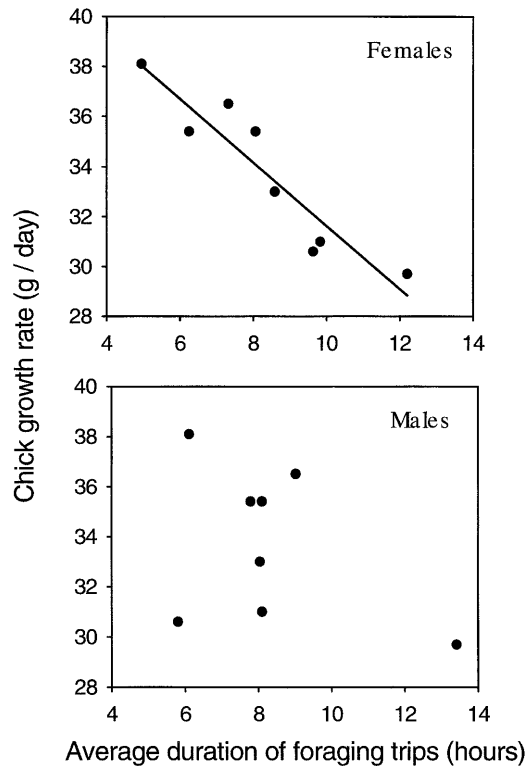


Fig. 1 Relationship between the average duration of foraging trips by female and male parents and the growth rate of the chick

whether the duration of a foraging trip at sea was related to the next trip at sea. Overall there was a tendency for both females and males to spend more time at sea when the previous stay at nest was long ($r_p = 0.226$, $P = 0.075$ and $r_p = 0.303$, $P = 0.016$, respectively). No such tendency was observed when relating the duration of successive foraging trips at sea by the same individual ($P > 0.1$).

Foraging behaviour

The distribution of the locations during the period of brooding, when four birds were tracked, was concentrated in the close proximity of the island (Fig. 2a). At this time the birds perform short foraging trips (Fig. 3a) at an average maximum range of 60.8 ± 48.7 km from the nest during trips lasting 10.2 ± 4.0 h ($n = 164$ trips for four birds). Flying speeds were on average 27.8 ± 8.2 km/h and did not vary between individuals ($F_{3,14} = 1.32$, $P = 0.308$). Nor did the foraging range or the distance covered ($F_{3,14} = 2.33$, $P = 0.119$ and $F_{3,14} = 1.87$, $P = 0.181$, respectively).

During the brooding period, birds did not return to the same area from one trip to the next, (Fig. 3a, b). The two birds that were left with a PTT and continued to attend the nest regularly allowed us to study the characteristics of the successive foraging trips. For bird 10896 (male) for which 22 successive foraging trips were obtained, there was a clear overall increase with time in the duration of foraging trips ($r_s = 0.472$,

$P < 0.05$), in the maximum range from the colony ($r_s = 0.666$, $P < 0.01$) and in the distance covered ($r_s = 0.643$, $P < 0.01$; Fig. 4). The bird made two particularly long trips directed to exactly the same site along the Norwegian coast, at 570 km from Bjørnøya (Fig. 5a). For the second bird, 11820 (female, 16 foraging trips), there was also a significant increase with time in the duration of foraging trips ($r_s = 0.706$, $P < 0.001$), range ($r_s = 0.5$, $P < 0.05$) and distance covered ($r_s = 0.585$, $P < 0.05$; Fig. 4), with two longer trips, in the eastern Barents Sea (Fig. 5b). Average flight speeds (including time spent on the water) were consistently high from one trip to the next (Fig. 4). During the commuting part of the long trips, for example the trips to the Norwegian coast (Fig. 5a), flight speeds attained 70 km/h during several bouts of more than 1 h each.

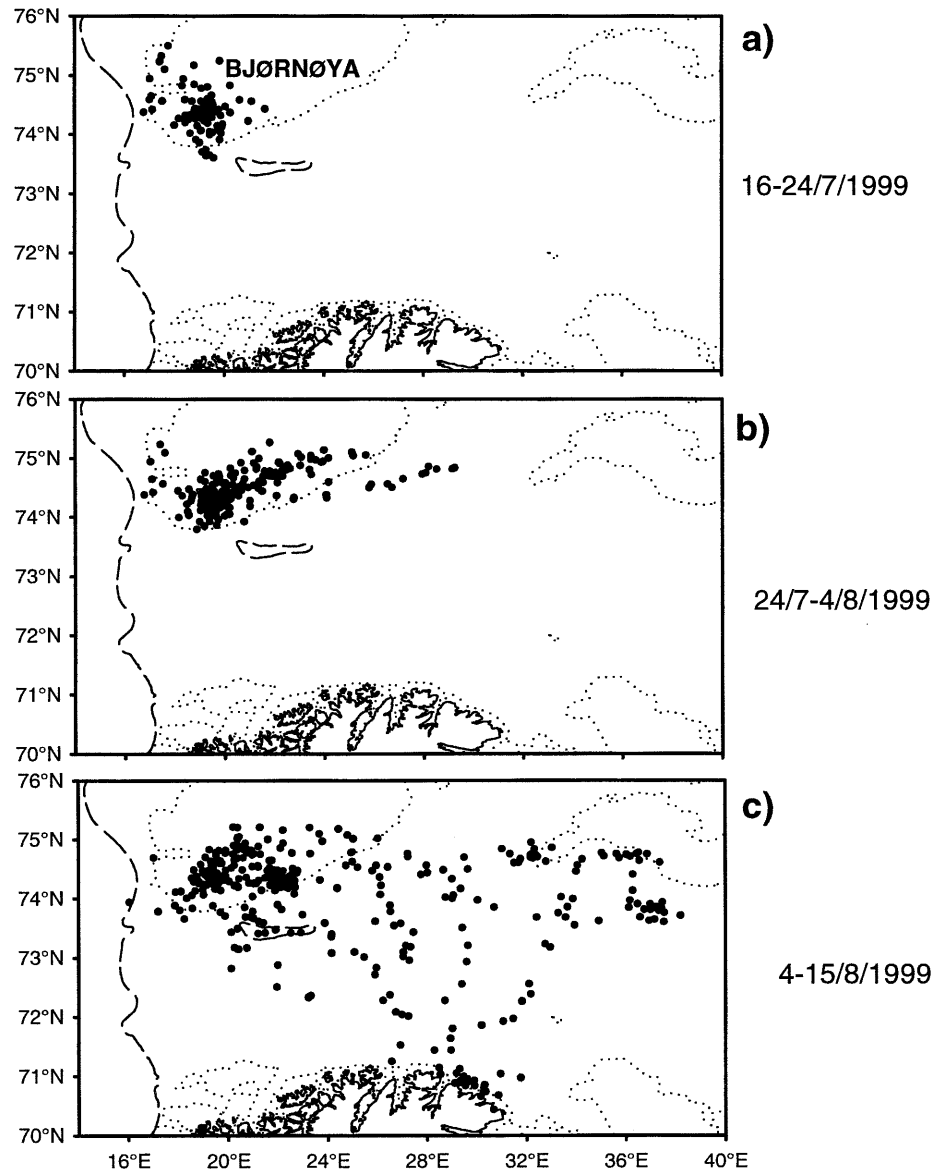
Discussion

Although our sample sizes were small, this study provides two new findings on the foraging ecology of northern fulmars. First the use of an automatic recording station using pit tags has allowed us to precisely measure the duration of foraging trips during the brooding period. This technique presents the advantage to avoid continuous observation of the nest. Moreover, to fit the bird with a minuscule tag, fixed to the leg band, cannot harm the behaviour of the bird. Second, to our knowledge the foraging zones of fulmars rearing chicks was not known, and even compared to studies of other larger Procellariiformes, such as albatrosses, it is one of the few where so many successive foraging trips have been studied successfully, but only for two birds. Falk and Møller (1995) tracked breeding fulmars from Greenland, but the birds deserted their nest. The reasons for the failure may be related to the larger size of the satellite transmitters deployed at this time, but also to the use of harness instead of simple taping or gluing of the equipment. Our experience on Procellariiformes shows that harnesses are often difficult to adjust even for a short-term deployment.

Nest attendance and the constraints of the brooding period

Like all Procellariiformes brooding young chicks, fulmars are performing short trips, the average duration being only 8 h, but values are extremely variable both among and within individuals. There was a tendency for birds to stay longer at sea when they had fasted for a long period, but there was no tendency for birds to stay for a similar period at sea from one trip to the next. Similar results were obtained for fulmars during the incubation period (Hatch 1990a). This suggests that the major factor influencing the duration of a stay at sea is the necessity for the bird to restore its body reserves.

Fig. 2 Distribution of locations of fulmars fitted with satellite transmitters during three successive periods, **a** during the early brooding period, **b** during the late brooding period and **c** after the chick is left alone on the nest



The brooding period is theoretically energetically constraining for pelagic seabirds (Ricklefs 1983) and data have supported this for several species of Procellariiformes (Weimerskirch 1990a; Weimerskirch and Lys 2000). During this period adult fulmars were losing mass, males to a larger extent than females, suggesting a stressful period for the birds. The extent of mass loss by adults or the mass of adults at the start of the study period had no influence on the growth of chick although this has been shown in several other studies (see, for example, Weimerskirch et al. 1997; Tveraa et al. 1998). However, our sample size is small. An important result of this study was that the growth rate of chick, the parameter that parents are likely to maximise to optimise fitness, is related to the ability of females to do short foraging trips, but not of males. Differences between individuals may be related to the age and experience of the individuals (Weimerskirch 1990b). Females could be more constrained during this period because of their

smaller size, and therefore have a reduced ability to buffer poor foraging success by losing mass compared to males. A poorer foraging efficiency by the females would directly affect the duration of foraging trips and therefore the growth of chicks, whereas males could still buffer a poor foraging efficiency by losing mass. Males tended to return preferentially to the nest in the morning and in the evening, but not females, suggesting again that males could be more able to have fixed schedules compared to females. In other sites it has also been a tendency for returns (sex not known) to peak in the morning and in the evening (Furness and Todd 1984; Hamer et al. 1997).

Foraging zones

When brooding chicks and foraging on average for only 8 h, it is obvious that the bird cannot forage very far from the nest. Satellite tracking shows that birds forage

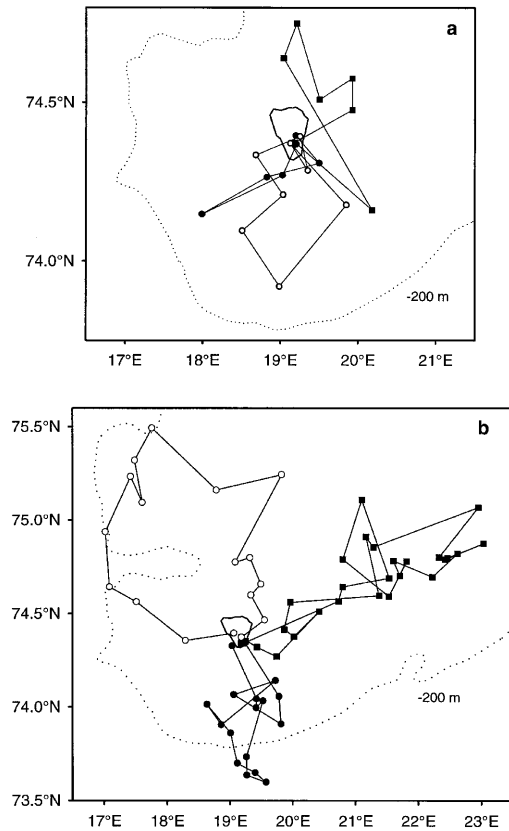


Fig. 3 Successive foraging trips of two fulmars, **a** during the early brooding period (PTT 10896, male) and **b** during the late brooding period (PTT 11820, female)

on average at 60 km from their nest and concentrate on the shelf around Bjørnøya. Interestingly, birds do not return to the same area from one short trip to the next, a situation that is very different from other petrels foraging during short trips (Weimerskirch et al. 1993, 1997; Catard et al. 2000). This probably explains the results from the data logger system that indicates no relationship between the duration of two successive trips by the same individual. At this time fulmars from Bjørnøya were feeding almost exclusively on capelin *Mallotus villosus* (author's unpublished data) and since no fishing unit was operating in the vicinity of the island, this indicates that the food of breeding fulmars was available naturally just off the island in large numbers.

When the chicks become older, fulmars appear to increase significantly the duration, range and distance covered during their foraging trips. Yet their main effort was still concentrated in the vicinity of Bjørnøya, mainly to the east of the island on the shelf area, in an area that is free of ice. They never move to the west of Bjørnøya in the deeper yet closer waters, suggesting that they favour shelf area rather than deep waters. When the season progresses and chicks become older, fulmars appear to intersperse their short trips with much longer trips of 2–3 days where they reach distant zones at more than 500 km. Based on band recoveries, Dunnet and Ollason (1982) also suggested that fulmars

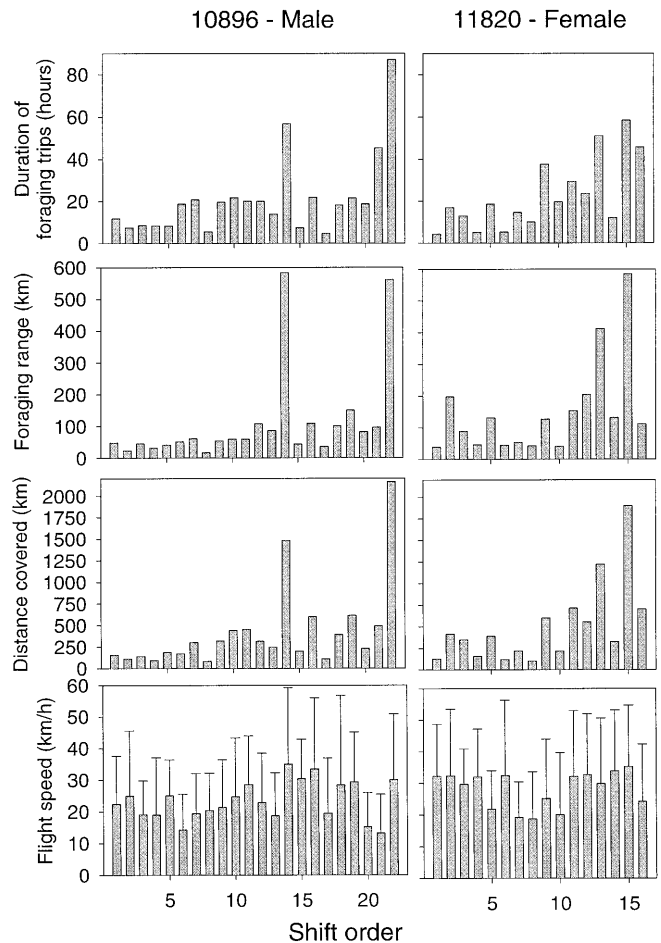


Fig. 4 Changes over time in the characteristics of foraging trips of two fulmars

from the Orkneys may forage as far as 466 km during the chick-rearing period. These longer trips appear to be made after a succession of several short trips in the vicinity of Bjørnøya. Thus, similarly to other Procellariiformes (Weimerskirch et al. 1994; Weimerskirch 1998), fulmars could be using a dual strategy of using short and longer foraging trips. This strategy may have been overlooked until now because it can only be detected when the exact duration of individual foraging trips is measured (see, for example, Granadeiro et al. 1999), and because in this species long trips appear to be rare compared to short trips of less than 24 h. These long trips could be used by the adult to reach productive waters where they can rapidly refill their body reserves but these results have to be confirmed by a larger sample size.

When foraging, we found that fulmars were moving at speeds that were fairly consistently high from one trip to the next. Indeed 27 km/h is high because this value includes the time spent resting or feeding on the water, therefore the actual flight speed when in flight is much higher, regularly attaining 70 km/h during long bouts. This high speed is made possible by the use of wind by fulmars, a parameter that is probably vital for this

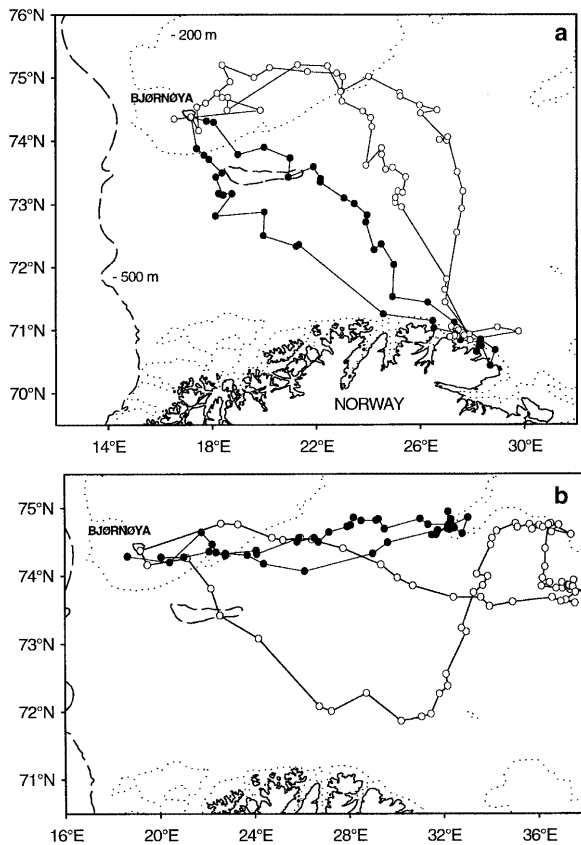


Fig. 5 Long foraging trips of two fulmars during the chick rearing period, **a** PTT 10896 twice visiting the same specific sector off the Norwegian coast and **b** PTT 11820 foraging twice in the eastern Barents Sea

species since the costs of foraging are reduced with high-speed winds (Furness and Bryant 1996).

This study has demonstrated the potential of automated logging systems using transponders on seabirds like fulmars, which are shy and often difficult to study. It especially allows the long-term monitoring of individual attendance patterns. The technique should be tested on birds attending emancipated chicks, i.e. at a time when parental attendance is even more difficult to monitor by conventional techniques, because they irregularly visit their chick for very short periods.

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