Diurnal activity patterns suggest nocturnal foraging in Northern Fulmar (*Fulmarus glacialis*)

Dagligt virksemi hjá havhesti (Fulmarus glacialis) bendir á, at hann leitar sær føði um náttina

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Úrtak

Eygleiðingar við myndatólum av í alt 12 havhestareiðrum í Føroyum árini 2006 (sjey reiður) og 2007 (fimm reiður) vístu, at greiður samanhangur var millum, nær havhesturin kom til og fór av reiðrinum, og daglongd, sólarris og sólsetur. Við tveimum undantøkum vórðu øll skiftini á reiðrinum gjørd millum kl. 7 um morgunin og kl. 19 um kvøldið. Ungarnir vórðu sum oftast mataðir millum kl. 9 um morgunin og kl. 18 um kvøldið. Hesar eygleiðingar saman við úrslitunum frá eini føðikanning, ið vísti týdningin av prikkafiski sum føði, geva góða ábending um, at havhesturin leitar sær føði um náttina.

Abstract

The continued camera observations of nest-site attendance at a total of 12 nests in 2006 (7 nests) and 2007 (5 nests) showed a strong correlation between nest-site attendance and sunrise, day length and sunset in a Faroese Northern Fulmar (*Fulmarus glacialis*) colony. Incubation shifts were all between 7 in the morning and 19 in the evening, except on two occasions, while feeding of the chicks mainly occurred between 9 in the morning and 18 in the evening. The timing of these attendance and activity patterns at the colony, combined with the importance of the nocturnally vertically migrating Glacier lantern fish in the diet of the Fulmars, as shown in a previous study, indicates a nocturnal feeding strategy adopted by the birds.

Introduction

Several studies have demonstrated high nest-site attendance by the Northern Fulmar throughout the year (e.g. Fisher, 1952; MacDonald, 1980; Hatch, 1989). However, studies of nest-site attendance are usually only done during the light hours of the day, ignoring nocturnal attendance patterns. Optical devices for night observations have been available for a long time but have rarely been used to study nest-site attendance by this species.

I studied the daily nest-site attendance, chick feeding schedule and incubation rhythm of the Northern Fulmar at a small colony on the Faroe Islands throughout night and day for two years using surveillance cameras with infrared LEDs. The attendance patterns were analysed to see if they correlated to sunrise, sunset and day length and analysed in relation to time of day for incubation shifts, and feeding of the chicks. Since a previous study showed that the diurnally migrating Glacier lantern fish (*Benthosema glaciale*) was an important part of the diet of the Northern Fulmars on the Faroe Islands (Danielsen *et al.,* 2010), I postulate that the birds would be away from the colony at night, in order to forage out at sea.

Furthermore underlining the importance of doing observations during both day and night is the fact that although birds might show signs of breeding by staying faithfully at the nest and apparently incubate during day-time, this is not necessarily true when also adding observations during the night. This can easily lead to biased estimates regarding how many of the birds in the colony are actually producing eggs. This information is important for e.g. estimating breeding colony size (Mallory and Forbes, 2007).

Material and methods

Observations

The study was carried out at the same colony and using the same method (i.e. surveillance cameras) as by Danielsen and Bengtson (2009). Although ten potential nest-sites were studied each year, only a total of 12 nests produced usable data for the daily attendance patterns studied here,

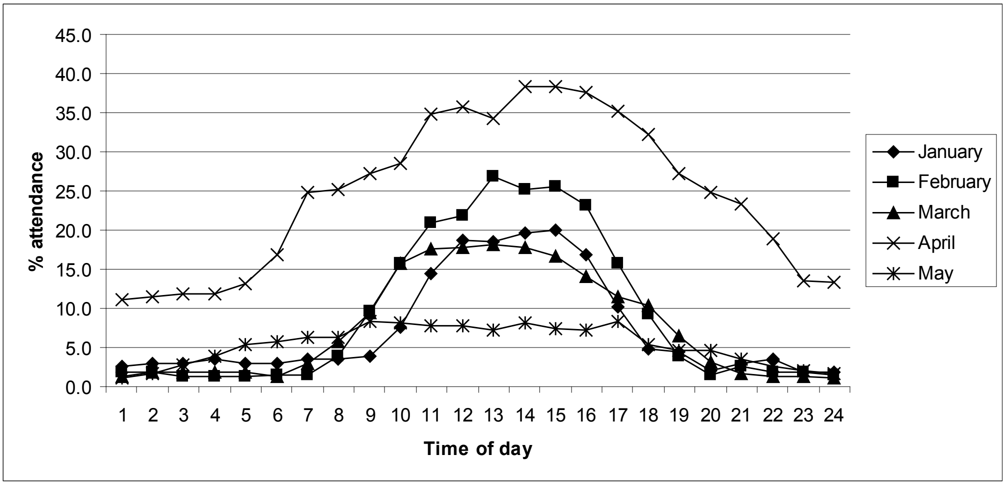


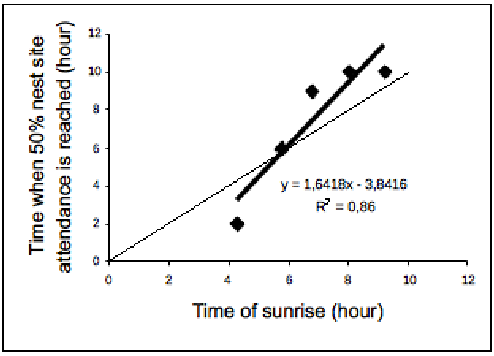
Figure 1. Percentage (%) nest-site attendance throughout the day, from January to May on 12 nest-sites from 2006 (7 nests) and 2007 (5 nests).

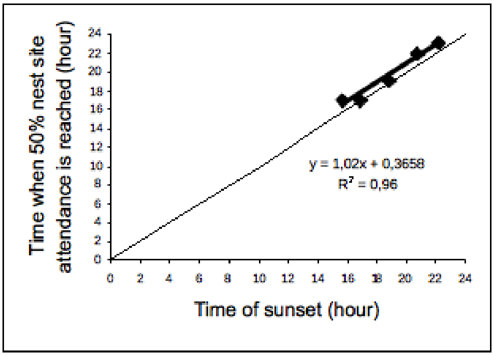
7 in 2006 and 5 in 2007. Monthly day lengths were calculated as the mean length of days number 5, 10, 15, 20, 25 and 30 each respective month, except in February.

Since the cameras were fitted with infrared LEDs, recording during the night was as easy as during the day. This means that any failure to observe birds during the night was not caused by difficulty for the observer, which is usually the case, but was in fact caused by the absence of birds from the colony at night.

Although the individual birds could not be positively identified (few were ringed and it was rarely possible to observe the ring number), I feel confident that the labour division between the sexes during the incubation period was correctly recorded since it was possible to see when the eggs were laid and then follow the shifts from the time of laying (female takes first incubation stint). Furthermore, I rely on what is known about this species regarding nest-site and mate fidelity (Ollason and Dunnet 1983) assuming that a ringed bird returning to the nest is the same one that left it, even if it was not always possible to read the number on the ring.

To see if attendance patterns over the various months were correlated to sunrise, sunset and daylight, a 50 % attendance limit was used. This limit was defined as 50 % of maximum attendance in a given month. Maximum attendance in a given month was calculated as the mean of the 3 highest attendance values in that month. The mean time in each month when 50 % attendance was reached was plotted against the mean





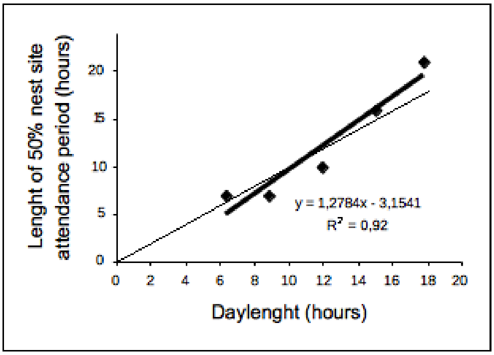


Figure 2. Correlation between sunrise and arrival (upper left), sunset and departure (upper right) and day length (time from sunrise to sunset) and 50 % attendance length. Although a logarithmic trend-line had a better fit (R^2 = 0.92) for sunrise and arrival, a linear trend-line was chosen since the attendance in May probably was affected by the pre-laying exodus.

time for sunrise during that month. The time when attendance came down to 50 % again in the evening was plotted against sunset. The length of the period from when 50 % attendance was reached in the morning until it was down to 50 % again in the evening, termed the 50 % attendance length, was plotted against day lengths in the various months. To clarify lets look at the attendance in April as an example. The 3 highest attendance values in April were 38%, 38%, and 37.6% (Fig. 1). The mean value of these 3 values is approx. 38% which then is set as maximum attendance in April. The 50% limit will then be at 19% attendance which was at 6 AM and was plotted against time for sunrise, and then again at 22 PM which was plotted against time for sunset (Fig. 1). The length of the 50% attendance period was from 6 AM to 22 PM i.e. 16 hours which was plotted against day length (Fig. 2).

Analyses

Recorded observations were stored and treated the same way as by Danielsen and Bengtson (2009). The analysis of the data and the presentation of the results are split into three periods of the year. The first period covers the daily rhythm during the pre-breeding period in 2006 and 2007: from January when the Fulmars begin to attend the colony on a more regular basis until May when egg-laying normally commences. The second period covers the incubation period from end of May to mid July 2006 and 2007. The third period covers the feeding period: from 8 August 2005, when the chicks were about 1 month old (pers. obs.), until the chicks died or fledged. The 2005 data was collected by binoculars and not cameras.

Results and discussion

Overall nest-site attendance, measured as % of total time, during the pre-breeding period was low in the morning, then increased during the day until it reached a maximum and decreased again during the evening (Fig. 1). As the breeding season approached, the frequency of over-night attendance increased and reached a maximum in April where it never dropped below 11.2 % at night. Throughout the period January-May, mean daily attendance varied between 1.2 % in March and May and 38.3 % in April (Fig. 1).

The birds arrival at and departure from the nest-sites were strongly correlated with sunrise and sunset, respectively, and the 50 % attendance length and length of day were also correlated (Fig. 2). Since the attendance pattern in May probably was affected by the pre-laying exodus (Hatch, 1990), a linear trend-line was used even if a logarithmic trend-line gave a better fit.

Cullen (1954) noted a diurnal rhythm of colony attendance for Fulmars at 71°N with partial evacuation of the breeding cliffs around midnight. According to Moss (1965) Fulmars would be expected to change their daily activities as day lengths shortened towards winter. Furthermore, he also noted that most birds left the cliffs at night and suggested that the lengthening period of darkness forced the birds to remain out at sea, explaining their absence from the colony at night. However he did not give any further explanation for why a lengthening period of darkness would have this effect on the birds. Alternatively, the birds might simply be more at home at sea than on land which is why they stay out at sea, as suggested for Cory´s Shearwaters (*Calonectris diomedea borealis*) (Jouanin *et al.*, 2001).

During the day when the birds attended the colony they usually sat on the nest for a short time, then flew off only to return a short time later (except in April when they spent more time at the nest-site than in any other month). This was repeated throughout the day and most likely prevented the birds from engaging in any effective foraging activity. This is further supported by the very few observations of birds actually foraging in the sound where the colony was situated (Danielsen, unpublished).

Instead it seems as if the Fulmars foraged during the night. This has previously been suggested for Fulmars foraging on large cod shoals in Allen Bay in late August (Furness and Tod 1984) and around St Kilda (Hobson and Welch 1992).

However, the opposite attendance pattern has also been observed, with maximum attendance at breeding sites usually occurring in the evening after a gradual increase in numbers during the day (Hatch 1989). In contrast, Falk and Møller (1997) found no clear diurnal variation at a colony situated at the northeast water polynya in north-eastern Greenland (80°N).

All but two incubation shifts were between approximately 7 in the morning and 19 in the evening, i.e. during the day. The two exceptions were at 1:39 and 4:19 in the morning, in 2006 and 2007, respectively, and in both cases at nest-site 3. This demonstrated that the birds actually could arrive during the night (Table 1).

The mean duration of the first incubation stints undertaken by females and males in our study, was similar (5.9 and 5.1 days, respectively (Table 1)). Unlike the mean incubation time, which was longer in our study, this was only half the time of the first incubation stint for males in successful pairs (10.3 days) in the Canadian High Arctic (Mallory, 2009). Marine productivity in the Arctic is still seasonably low during incubation time, and the reason for the males' long incubation stints in the Canadian High Arctic is thought to be in order for the females to have enough time to recoup energetic reserves after egg-laying (Mallory, 2009). Although some studies have shown that the females leave right after egg-laying, leaving the first long incubation stint to the males, this was not the case in our study. In 5 cases the female undertook the first incubation stint, which lasted longer than 1 day, while for males the number was 3 (Table 1).

Most feedings were between 9 in the morning and 18 in the evening, although feeding of the chicks occurred as late as 23 in the evening. The maximum number of feedings was at 9 in the morning, where feeding activity was recorded on 9 occasions. Chicks were never fed earlier then 5 in the morning. The total number of feedings was 91 for all 4 chicks (Fig. 3).

Although the results in this study show that the Fulmars are absent from the colony during the night, and colony attendance and activities mainly occur during daytime, it is not clear why this is so. As mentioned earlier, a recent diet study demonstrated

Nest No	Egglaying date	Incubation change	Time of day (change)	Female incubation length (days or hours)	Male incubation length (days or hours)
2	21-5-2006				
		29-5-2006	07:09	8	
		5-6-2006	13:31		7
		22-6-2006	16:48	17	
2	24-5-2007	5-6-2007	19:04	12	
3	20-5-2006*				
		20-5-2006	–	less then 1 day	
		27-5-2006	14:06		7
		28-5-2006	01:39	1	
		28-5-2006	14:42		13h
		26-6-2006**	17:45	29	
		8-7-2006	–		12
3	28-5-2007				
		29-5-2007	04:19	1	
		29-5-2007	15:46		11.5h
		29-5-2007	17:47	2h	
		9-6-2007	18:55***		11
6	21-5-2006*				
		30-5-2006	08:39	9	
		2-6-2006	09:10		3
		2-6-2006	14:58	6h	
		3-6-2006	17:22		1
11	24-5-2006	8-6-2006		15	
11	20-5-2007				
		21-5-2007	08:21	1	
		21-5-2007	09:10		1h
		26-5-2007	14:16	5	
		8-6-2007	10:50		13
15	22-05-2006				
		23-5-2006	13:29	1	
		5-6-2006	10:48		13

Table 1. Incubation schedule at 5 nest-sites for male and female Northern Fulmars during 2006 and 2007. Although the exact time of day for egg laying was uncertain for nest No 2 in both 2006 and 2007, it was possible to pinpoint the day it happened.

*exact laying date not certain
**data missing from 8-6-2006 to 16-6-2006. But a female was incubating on 8-6-2006 and again/still on 16-6-2006. The male may have come and gone during these 8 days, but minimum incubation time for the female was from 28-5-2006 to 8-6-2006 and then again from 16-6-2006 to 26-6-2006 i.e. 11+10=21 days
***incubating male chased off by 2 crows and egg predated

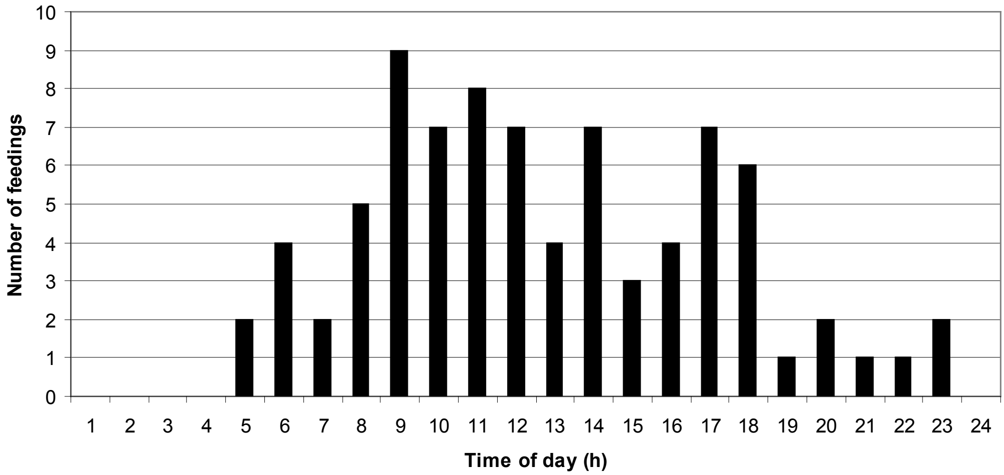


Figure 3. Number of feedings (n=91) throughout the day during the chick rearing period on 4 nests from 8 August to 4 September, 2005.

the importance of the energy-rich (van de Putte *et al.*, 2006), nocturnally vertically migrating Glacier lantern fish (Danielsen *et al.*, 2010). Thus, the availability of food resources around the Faroes and/or the food choice of the Fulmars present us with two different scenarios that might help explain the observed patterns of nocturnal absence from the colony: 1) although the Fulmar can feed on many different prey types, e.g. fish, squid, zooplankton (Danielsen *et al.*, 2010) it *chooses* to forage for the energy-rich Glacier lantern fish, which is only available to the birds at night, or 2) because the Glacier lantern fish is the only prey that occures on a regular enough basis and is abundant enough thoroughout the year, the birds are *forced* to feed at night.

There also might be a third possibility: predator avoidance. Rats were observed in the colony on several occasions, almost exclusively during the night, and a rat was recorded attacking and killing a more then half-grown chick. But rats were never seen close to nests occupied by adult birds so predation of adults seems an unlikely explanation.

Conclusion

The combination of absence from the colony during the night and the correlations between time of arrival in the morning and sunrise, the length of time spent at the colony and length of day, and evening departure and sunset, combined with incubation rhythms and chick feeding schedules, as well as results from a diet study on the Faroes and other studies, suggests that the Fulmars on the Faroe Islands were mainly foraging during the night. And that the energy rich Glacier lantern fish probably was the main reason for this nocturnal foraging behaviour.

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