AQUATIC MATING STRATEGIES OF MALE BEARDED SEALS.[i]

Sofie M. Van Parijs

Norwegian Polar Institute, N – 9296 Tromsø, Norway. Email:sofie@npolar.no

Little work has previously been carried out on aquatic mating seals, as the logistic difficulty of studying these species hampered research. Recent developments in acoustic techniques have made the study of these species more feasible. The bearded seal, *Erignathus barbatus*, is a high Arctic ice breeding phocid which mates in the water. Female bearded seals give birth on ice floes or the edge of fast ice, a highly unstable substrate. In this study, patterns of male bearded seal vocalisations were studied in Kongsfjorden, Svalbard from April 1999 to June 2000. Males vocalised during a discrete 90-day period from early April to mid July, with a peak in late May. The frequency of vocalisations varied significantly with the diel cycle (increasing in number from 16:00 hrs onward and peaking around 04:00 hrs). This peak coincides with the period when most females are in the water. Female bearded seals were found throughout Kongsfjorden. Their distribution depends on the availability of suitable haul-our sites (ice floes or the ice edge). Males vocalised throughout the study site, however they vocalised in higher densities around the fjord entrances. They may use these 'geographical bottlenecks' to maximise their chances at intercepting passing females. Male distribution appears to reflect the unpredictable nature of female haul-out distribution.

1. INTRODUCTION

All of the Arctic phocids, such as the bearded seal (*Erignathus barbatus*), mate partially or totally in the water. Most studies on phocid reproductive strategies have concentrated on land breeding species [9]. In these species, females are tightly clustered on land and their distribution is highly predictable. Males defend harems [12] or compete for a place within female breeding groups on land [26]. In contrast little information is available on the reproductive strategies of aquatic mating phocids, representing a significant gap in our knowledge of these species. In most aquatic mating species, energetic constraints force females to forage at sea in order to sustain late lactation [1,2, 19,25]. Females come into oestrus directly after weaning, hence they are widely distributed at sea during oestrus. This makes it virtually impossible for males to monopolise females. In the past, the logistics of studying the mating strategies of these species at sea have made research difficult. However, in most aquatic mating pinnipeds, males produce underwater vocalisations during the breeding season [e.g. 6]. Recent studies have developed a variety of acoustic techniques, which use the underwater vocalisations of males to study the reproductive behaviour of these species [14,27,28,29,30,31,32].

The aim of this Marie Curie fellowship is to use male vocalisations as a tool for studying the reproductive strategies of the high Arctic bearded seals. Bearded seals give birth on a highly unstable and unpredictable substrate, drifting ice floes and the edges of fast-ice. Female bearded seals give birth in mid-April to mid-May [3,4,15,20] and pups are not weaned until they are around 24 days old [10,16,19]. Mating takes place towards the end of lactation and males are thought to be in breeding condition from April until July [e.g. 3,4,7]. Males produce loud trilling vocalisations sometime between March and June to advertise their breeding condition [3,4,5,6,7,21,22,23].

2. METHODS

This study was carried out in Kongsfjorden (78°55'N, 12°30'E), Svalbard from 20th of April 1999 to 27th of May 2000 (Fig. 1). Acoustic recordings were made of male bearded seals using an SSQ 906A hydrophone (sensitivity: -170db, frequency response (fr): 5 Hz-15 kHz) and a Sony digital audio tape recorder, TCD-D8 (fr: 5 Hz-22 kHz). Recordings of male vocalisations were used to investigate:

2.1. Seasonal patterns

Seasonal patterns in male vocalisations were investigated by making acoustic recordings from the Ny-Ålesund harbour wall (Fig. 1), between May 1999 and April 2000. 20-min recordings were made between 14:00 hrs and 18:00 hrs around the 20th of each month. The period during which vocalisations were heard was examined in detail. Recordings were made at 12:00 every 3 - 4 days (N = 29) from 20th of April to 17th of June 1999 and from 4th of April to 27th of May 2000. A 10–min sample of vocalisations was extracted from each of these recordings. This sample length was representative of longer recordings and allowed direct comparison with the vocal behaviour of harbour seals [27,29].

2.2. Tidal and diel patterns

Tidal and diel patterns of vocalisations were explored by making 10-minute recordings every hour for 11 24 hour cycles, four during April - June 1999 and seven during April - May 2000. For comparative purposes, each tidal cycle was divided into 10 intervals [see 29]. The number of vocalisations in each sample was counted. The mean number of vocalisations was plotted against the time of day and tidal cycle. A two way ANOVA determined the relationship between the number of vocalisations and the tidal and diel cycles.

2.3. Male and female spatial patterns

A large-scale acoustic survey was undertaken between 14:00 and 22:00 hrs on the 30th of May 1999 throughout Kongsfjorden. Male vocalisations were recorded for 10-minutes at 14 recording stations positioned at 6-km intervals. [5] found that 63% of male vocalisations originated from a 5 km radius, while 15% of male bearded seal vocalisations were heard up to distances of > 20 km. Therefore, by sampling at 6-km intervals overlap between vocalisations from adjacent recording stations was minimised. The survey was conducted in the late afternoon, in order to reduce variation in the number of vocalisations due to diel patterns (see results). The number of vocalisations at each recording station was counted in a 10-minute sample and plotted as densities onto a map. Throughout May and June 1999, GPS locations of all female-pup pairs observed on the ice during daily surveys throughout Kongsfjorden were noted. The relationship between male and female distribution was explored using a two-tailed Spearman's correlation test.

3. RESULTS

3.1. Seasonal patterns

Male bearded seals began to vocalise in early April, through May and June, until mid July (Fig. 2a). No vocalisations were heard during any other month of the year. The number of vocalisations varied widely throughout the mating season, from 2 to 237 vocalisations in a 10-minute sample, with a notable peak around the 22nd of May (Fig. 2b).

3.2. Tidal and diel patterns

Male vocalisations showed a clear diel cycle with vocalisations increasing from 16:00 hrs onwards, with a peak in the number of vocalisations around 04:00 hrs (Fig. 3, Table 1). Vocalisations ranged from a mean of 24 to 82 vocalisations, representing an average change of 2.4 vocalisations/hour. There was no significant relationship between the number of vocalisations and the tidal cycle (Table 1).

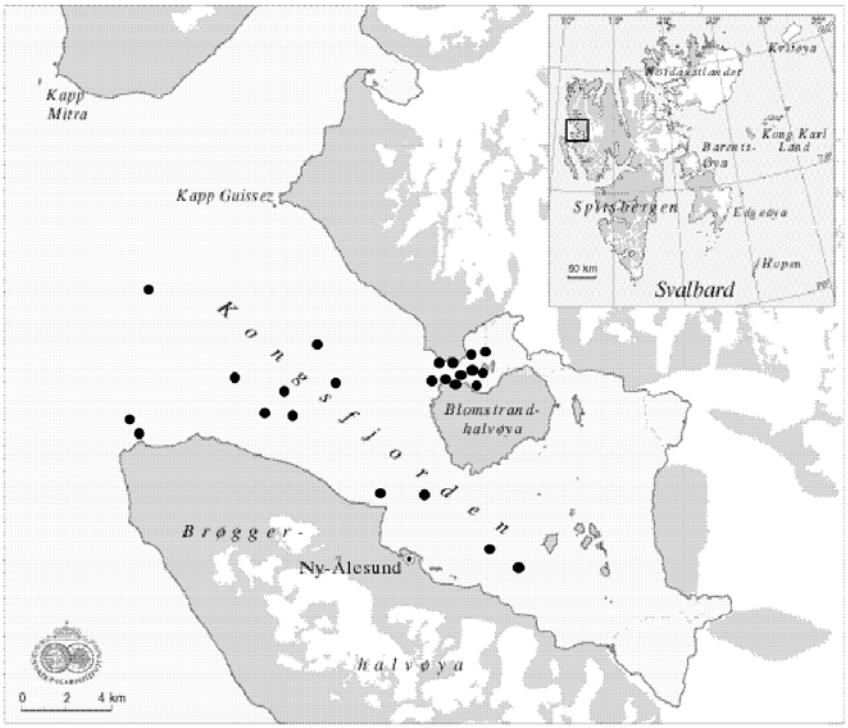
3.3. Male and female spatial patterns

Distribution of females during the pupping season was highly unpredictable and changed daily. Females were frequently found either on floes or along the ice edges (Fig. 1a). Females could be found hauled out throughout all of Kongsfjorden depending on the availability and location of suitable ice floes.

The large-scale survey was carried out over 8 hours, representing a possible mean change of 19.3 vocalisations between recording station 1 and 14. The numbers of vocalisations at each site were corrected using a mean change of 2.4 vocalisations/hour (see section 3.2) with 16:00 representing the base line from which calculations were made.

Vocalisations were heard throughout the whole of Kongsfjorden, ranging from 38 to 107 vocalisations/10-minute sample (Fig. 1b). Analyses of the call rate of individual males showed that males vocalised on average every 56.3 ± 10.3SE seconds around the 30th of May. The total number of individuals vocalising around each recording station was calculated based on the total number of calls recorded/average call rate. The number of individual males was not significantly correlated with female distribution (Spearman's correlation = 0.41, $p = 0.084$, $N = 14$).

a)



b)

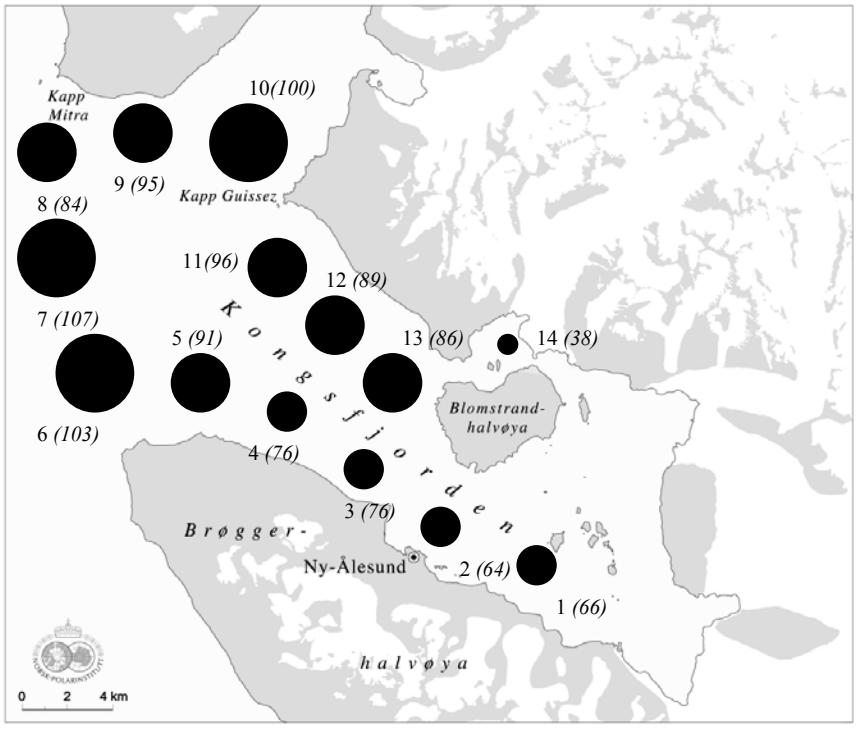


Figure 1: A map of Svalbard (inset) and the study area Kongsfjorden located on the island of Spitsbergen. a) Locations of female/pup pairs on ice floes or the ice edge(●) on the ice during daily boat surveys of Kongsfjorden in May and June 1999, b) The station number and the number of male vocalisations (in italics) counted during 10-minute recording periods at 14 sampling stations throughout Kongsfjorden, Svalbard on the 30th of May 1999 (Key: ● = 0 – 30, ● > 30 – 60, ● > 60 – 90, ● > 90 – 120 vocalisations/ 10 minute sample).

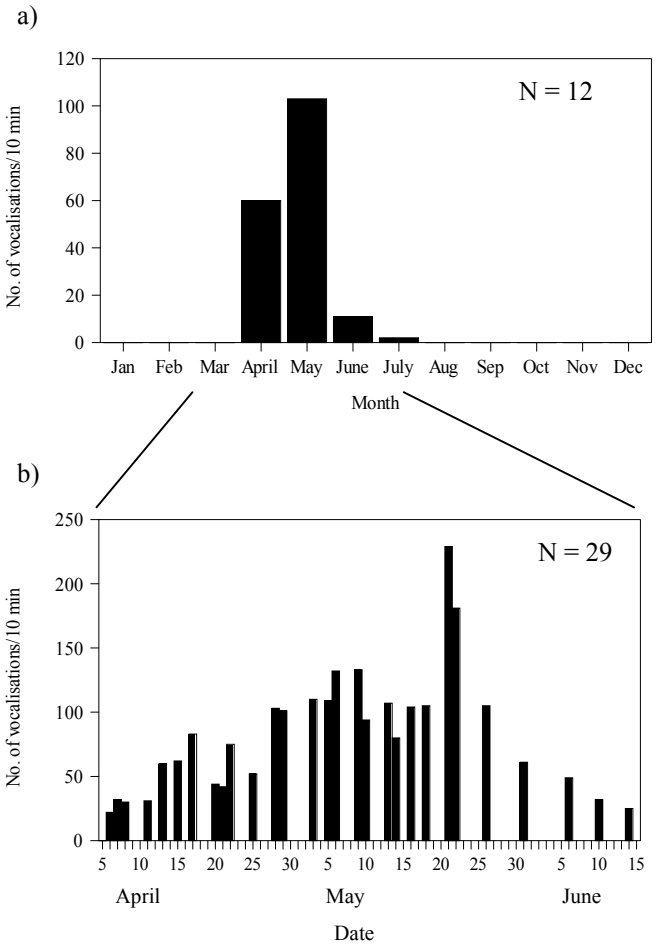


Figure 2: Seasonal variation in the total number of male bearded seal vocalisations a) per 10-minute monthly recording sample April 1999 until April 2000 (N = 12) and b) during more intense sampling during April, May and June 1999 and 2000 (N = 29).

Interval	Sum of squares	*df*	F-ratio	*P*
Time of day	17315.0	23	37.8	< 0.0001
Tidal stage	970.7	9	1.1	0.25
Tide x Time	5022.2	206	1.0	0.54

Table 1: A two-way ANOVA comparing the relationship between the number of male vocalizations, tidal stage and time of day for bearded seals in Kongsfjorden, Svalbard.

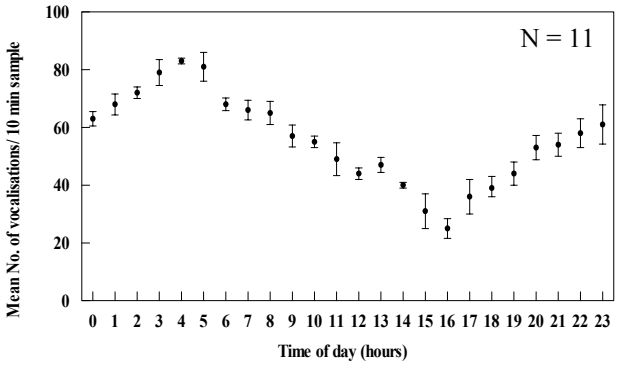


Figure 3: The diel pattern in the mean number of male bearded seal vocalisations for all 10 minute sampling periods across 11 tidal cycles from April, May and June 1999 and 2000.

4. DISCUSSION

Bearded seals in Svalbard vocalise from early April until mid July, a period of around 90 days. No vocalisations were heard during any other month of the year. In previous studies, bearded seals have been reported to vocalise from late March to late June [3,4,6,7,21,22]. Male vocalisations exhibited a clear temporal pattern in relation to the diel cycle. In Canada, male vocalisations also followed a 24-hour cycle pattern, with a similar increase in male vocalisations in the night/ early morning hours [5]. Similarly, in Weddell, leopard, *Hydrurga leptonyx*, and crabeater seals, *Lobodon carcinophagus*, underwater vocalisations exhibit a night-time pattern during the breeding season [11,24]. In Svalbard, female bearded seals spend the greatest proportion of their time in the water between 21:00 hrs and 09:00 hrs and exhibit little variation in activity patterns according to the tide [18].

Therefore, the increase in male vocalisations coincides with the period when most females are in the water. These results are similar to those for harbour seals, where male vocalisation patterns also reflect variations in female movement patterns [29].

Female bearded seals were sparsely distributed and their distribution was highly variable throughout the mating season. Female distribution was strongly related to the availability of suitable habitat for nursing their pups. Male distribution was greatest around fjord entrances and was not correlated with the location of females within the fjord. This increased concentration of males around the fjord entrances suggests that males may target 'geographical bottlenecks' in order to intercept passing females. In harbour seals, male densities reflect the variation observed in female distribution, with the highest densities of males' occurring in areas where female density is greatest [27,29]. Female harbour seals exhibit strong site fidelity and travel along predictable routes from their haul out sites to forage at sea [25,27]. Thus, the distribution of vocalising bearded seal males throughout Kongsfjorden may be a consequence of the unpredictable nature of female distribution. The reproductive strategy of male bearded seals appears to have adapted to the constraints imposed on females by an unstable ice habitat.

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