16 INTERNRAPPORT
NORSK POLARINSTITUTT, TROMSØ 2004

Bjørn A. Krafft, Christian Lydersen, Magnus Andersen and Kit M. Kovacs

Aerial survey of ringed and bearded seals in Van Mijenfjorden and Van Keulenfjorden, June 2003

Internrapport nr. 16

Bjørn A. Krafft, Christian Lydersen, Magnus Andersen and Kit M. Kovacs

Aerial survey of ringed and bearded seals in Van Mijenfjorden and Van Keulenfjorden, June 2003

Norsk Polarinstitutt er Norges sentrale statsinstitusjon for kartlegging, miljøovervåking og forvaltningsrettet forskning i Arktis og Antarktis.
Instituttet er faglig og strategisk rådgiver i miljøvernsaker i disse områdene og har forvaltningsmyndighet i norsk del av Antarktis.

The Norwegian Polar Institute is Norway's main institution for research, monitoring and topographic mapping in the Norwegian polar regions.
The institute also advises Norwegian authorities on matters concerning polar environmental management.

Norsk Polarinstitutt 2004

Address:
Kit M. Kovacs
Norwegian Polar Institute
PolarEnvironmental Centre
NO-9296 Tromsø, Norway
e-post: kit@npolar.no

www.npolar.no

Forsidefoto: Bjørn Krafft, Kit & Christian
Teknisk redaktør: Gunn Sissel Jaklin
Grafisk design: Audun Igesund
Trykket: Februar 2004
ISBN: 82-7666-206-4

Summary

During June 2002 an aerial survey was conducted in Van Mijenfjorden and Van Keulenfjorden to estimate the number of ringed and bearded seals inhabiting this area during the moulting period. One recommendation from this study was to repeat this aerial survey during the same period in another year to study inter annual variability in numbers of seals. This was the purpose of the present study, where a photographic aerial survey, covering approximately 50% of all land-fast ice in the area, was conducted on the 10^{th} of June 2003. A total of 3,662 digital images were taken during the survey. These images were manually inspected for the occurrence of seals. A total of 315 ringed seals and 13 bearded seals were documented on the images.

A new study on ringed seal haul-out behaviour made it possible to adjust for the proportion of seal that was in the water and not accounted for during the aerial survey. This information, in addition to a newly developed equation for estimating the precision of the estimate based on the proportion of the actual sea ice area covered during the aerial survey, was applied to the ringed seal survey data from both 2002 and 2003 in the current study. This resulted in an estimate for ringed seals in the study area of 1,523 (95% confidence interval (CI): 1,485-1,561) animals in 2003 and 2,094 (CI: 2,014-2,174) animals in 2002.

Ringed seals were unevenly distributed in both years, with the highest numbers occurring in the outer parts of the fjords. The relatively large inter-annual difference of about 500 ringed seals is likely due to variation in ice conditions between the two years. In 2002 the ice cover was much less extensive in all of the fjords of western Spitsbergen; it also formed later and broke up earlier than in 2003. The study area, especially Van Mijenfjorden (due to the its protection from wave-action via Akseløya) kept its ice cover for a long period in both years. During the poorer ice year in 2002 more seals from adjacent regions that were lacking ice in their breeding areas are thought to have moved into the study site(s) to use the remaining ice in this area as a moulting platform. This influx of seals from other areas during moulting is also the likely explanation for the relatively high density of ringed seals in the outer parts of the two fjords. About 30 bearded seals were found on the ice during the aerial surveys both in 2002 and 2003. However, this study was not specifically designed to estimate the bearded seal abundance in the study area. Bearded seals prefer drifting ice floes for hauling out, and therefore it was not expected that very many animals would be found on the land-fast ice within the fjord. In addition there is no published information on haul-out behaviour of bearded seals that would enable us to make a correction factor for animals in the water during a survey.

Based on previous studies and the current research, we conclude that the study area is an important moulting area for ringed seals. Van Mijenfjorden is particularly important moulting habitat because it retains its ice cover late into the spring and early summer due to the presence of Akseløya which covers most of its opening towards the west, protecting the ice on the inside of the blockade from wave action. This ice refuge is likely to be especially important in poor ice years when it attracts ringed seals from surrounding areas during their annual moult.

Acknowledgements

Store Norske Grubekompani A/S, the Norwegian Research Council and the Norwegian Polar Institute provided financial support for this project. We thank Audun Igesund and Odd Harald Hansen for their help with constructing figures and for the layout.

Sammendrag

I år 2002 ble det foretatt en fly-telling for å beregne hvor mange ringsel og storkobber som oppholdt seg i Van Mijenfjorden og Van Keulenfjorden under hårfellingsperioden i juni. En av anbefalingene i etterkant av denne tellingen var å gjøre en tilsvarende undersøkelse til samme tidspunkt et annet år for å få informasjon om hvor mye disse tallene varierte fra år til år. Derfor ble det foretatt en ny telling i juni 2003 hvor omtrent 50 % av is-arealet i dette området ble fotografert fra fly. Totalt ble det tatt 3662 digitale bilder som ble undersøkt manuelt for tilstedeværelse av sel. Det ble funnet 315 ringsel og 13 storkobber på disse bildene.

Siden flytellingen i juni 2002 har det blitt gjort en ny undersøkelse på atferden til ringsel under hårfellingsperioden. Resultater fra denne gjør det mulig å beregne hvor stor del av dyra som er i vannet til enhver tid og som dermed ikke blir registrert på de digitale bildene. Denne informasjonen, samt en nyutviklet likning som forteller hvor nøyaktig en slik undersøkelse blir utfra hvor stort areal som blir fotografert, er brukt på resultatene fra tellingene av ringsel fra både 2002 og 2003. Dermed ble antallet ringsel som var i området i 2003 beregnet til å være 1523 (95% konfidens-intervall (CI): 1485-1561) mens beregnet antall for 2002 ble 2094 (CI: 2014-2174).

Både i 2002 og 2003 var ringselene ujevnt fordelt med høyest antall på isen i de ytre delene av fjordene. Forklaringen på den relativt store forskjellen på rundt 500 ringsel skyldes antakelig forskjellig isforhold mellom de to årene. Isforholdene var mye dårligere i 2002-sesongen i alle fjordene på vestkysten av Spitsbergen. Isen la seg senere, brøt opp tidligere, og det var generelt mindre isdekke sammenliknet med i 2003. I vårt studieområde, og da særlig i Van Mijenfjorden (som er veldig beskyttet mot bølger fra vest på grunn av Akseløya) var isforholdene gode både i 2002 og 2003. I 2002 var det da mange områder som manglet is når hårfellingstiden nærmet seg, og ringsel fra disse områdene trakk inn i studieområdet vårt for å bruke isen her som hvileplattform. Denne tilstrømningen av ringsel fra andre områder som benytter seg av isen i Van Mijen – og Van Keulenfjorden som hårfellingsområde gjenspeiles også i den mye høyere tettheten av sel i de ytre i forhold til de indre fjordområder. Rundt 30 storkobber ble funnet på isen i området både i 2002 og 2003. Denne undersøkelsen er spesielt designet for ringsel og følgelig konsentrert om sel på fastisen. Storkobber fortrekker å ligge oppe mindre isflak, slik at størstedelen av disse selene i studieområdet må antas å finnes vest for fastiskanten, og ble dermed ikke fotografert. Det er heller ikke foretatt studier av atferden til storkobber som gjør oss i stand til å si noe mer om hvor stor andel av dyr som er i vannet til enhver tid.

Informasjon fra dette og tidligere studier får oss til å konkludere med at studieområdet er et viktig hårfellingsområde for ringsel. Særlig vil vi trekke frem Van Mijenfjorden, som på grunn av beskyttelse fra Aksleøya er dekket av is lengre ut over våren enn andre fjorder i området. Spesielt i år med dårlige isforhold vil Van Mijenfjorden kunne tiltrekke seg store mengder ringsel fra nærliggende områder.

Introduction

Ringed seals are the most abundant mammalian species in Svalbard. They are small seals (adults normally weigh 50-90 kg - Lydersen and Gjertz 1987), which live in close association with sea ice. Ringed seals are able to maintain breathing holes in the ice and can therefore access areas deep into pack- and land-fast ice that are unavailable for other marine mammals. In areas where enough snow accumulates, ringed seals dig lairs over some of their breathing holes (Smith and Stirling 1975). Both juvenile and adult ringed seals of both genders dig such lairs, which are used for general resting and in the case of adult females the lairs are also used as a place to give birth. The lairs protect the animals from harsh environmental conditions (Smith et al. 1991) and also to some degree from predation (Smith and Stirling 1975, Smith 1976, Lydersen and Gjertz 1986, Lydersen and Smith 1989). Each reproducing female ringed seal has several lairs and breathing holes within its territory so it can move the pup between these structures in case a predator attacks the lair containing the pup. The peak birthing period for ringed seals in Svalbard is the first week of April (Lydersen 1995). Following their birth the mothers nurse the pups for about 40 days (Hammill et al. 1991). Toward the end of the nursing period in mid to late May the ringed seal females come into breeding condition and copulate with males that have established territories that include those of several females.

Following the breeding season ringed seals enter the moulting period. All seal species go through this loss and replacement of hair and top layers of skin on an annual basis, and for ringed seals, this period peaks in late spring/early summer (during early June in Svalbard). During this process the animals prefer to stay hauled out on the ice surface. Here, they can perfuse their skin with blood and thus accelerate the growth of new hair with much less energy lost to the environment than if this process took place in the water, where thermal conductivity is so much higher. At the time of the year when the moult occurs the roofs of most ringed seal lairs have melted, so the seals are out on the surface of the ice and hence visible for counting during aerial surveys.

Bearded seals are the second most abundant seal species in Svalbard. They are much larger than ringed seals; adults normally weigh around 250-300 kg (Andersen et al. 1999) and during the lactation period several adult females with body masses of over 400 kg have been recorded (Lydersen and Kovacs 1999). The life history of bearded seals is also closely associated with sea ice. However, in contrast to ringed seals, they do not maintain breathing holes in the fast ice and are therefore restricted to areas that have natural access to open water such as along the edge of the fast ice, or areas containing cracks and leads inside the fast ice, or drifting ice floes outside the fast ice edge.

Similar to ringed seals, bearded seals also utilize sea ice for resting, and in this species adult females give birth to their pups on small free-floating floes (Kovacs et al. 1996). Bearded seals in Svalbard normally give birth during the first week of May (Lydersen et al. 1994). The mothers nurse their pups for about three weeks (Lydersen and Kovacs 1999, Gjertz et al. 2000). During this period mother-pup pairs often move considerable distances; the pairs spend significant amounts of their time swimming and diving (Lydersen et al. 1994; Krafft et al. 2000), but they also move via passive drift with the moving ice (Hammill et al. 1994). The moulting period for bearded seals is more obscure in terms of timing than other northern phocid seal species. It has been suggested that it occurs from April through to August with a peak in May-June (Burns 1981). There is some evidence to suggest that early-mid June is the peak time for moulting in Svalbard's bearded seals (Gjertz et al. 2000). As is the case for the ringed seal, the moulting period is the time of year when most bearded seals are hauled out and visible for counting during aerial surveys.

In connection with the opening and operation of the Store Norske Grubekompani A/S (SNGK) Svea Nord coal mine, SNGK and the Norwegian Polar Institute entered a cooperative agreement dealing with biological investigations and monitoring of the Bellsund, Van Mijenfjorden and Van Keulenfjorden area. Parts of this joint two year programme concerned marine mammals. During 2002, a thorough review of information regarding abundance of marine mammals in this area was performed in addition to some new investigations (Lydersen et al. 2002). One of these new investigations was an aerial survey of ringed and bearded seals. Based on digital images covering about 50 % of the total fast-ice area, this survey concluded that about 1,000 ringed seals and 50-100 bearded seals resided in this area during the moulting period in first half of June 2002 (Lydersen et al. 2002). One recommendation from that study was to repeat the aerial survey during the same period in another year to study inter-annual variability in numbers of seals in the area. This was the purpose of the present study. In addition, new information related to haul-out behaviour in ringed seals during the moulting period has recently become available (Carlens 2004). Based on this new investigation, which studied haul-out behaviour of ringed seals via VHF-telemetry to document individual behaviour patterns, and total count data to explore broader trends, it is possible to perform some adjustments for the proportion of ringed seals that are in the water and hence not accounted for during an aerial survey. This enables us to improve upon the minimal estimate produced by the survey, which simply reflects the number of seals present on the ice, to create estimates that are closer to the total number of animals that actually reside in the area. This new information is incorporated into the 2003 aerial survey and is also used in conjunction with the results from the 2002 aerial survey for comparison between the two study years. Some refinements are still required to deal with all of the complexities that the behavioural study introduced that are relevant when correcting the numbers from the aerial surveys, but the data reported herein can be considered a reasonable preliminary estimate because sampling conditions during the survey and the behaviour study, as well as the seasonal timing of the survey versus the behavioural study were similar in these parallel investigations.

Material and methods

The aerial survey was conducted on the 10th of June 2003. The photographic survey covered the fast ice areas of Fridjofhamna, Van Mijenfjorden and Van Keulenfjorden. The study followed the same survey design and established methodology that is described in Lydersen et al. (2002). Briefly, the aircraft used was a Piper Seneca II (PA 34). Two camera houses (Hasselblad 555 ELD) outfitted with 80 mm lenses and backpacks (H-20 Phase One A/S, 2000 Frederiksberg, Denmark), containing a CCD-chip designed to capture digital images were attached to the floor of the aircraft. The cameras were connected to two laptops with external computer hard disks (Dell Latitude, One pt 120 GB) (Fig. 1). Orientation and positions of the line transects were determined prior to each flight using purpose built software (by Track'Air, Aerial Survey Systems, B.V. Boortorenweg 20, 7550 Hengelo, Netherlands). Parallel transects were flown at 2,400 ft, starting at the innermost parts of each fjord or bay and ending in the drifting ice outside the fast-ice edge. Two images were produced each 5th second, covering an area of 672 m x 336 m of the surface with no image overlap. Purpose built software (Light Phase Image Capture, Phase One A/S, 2000

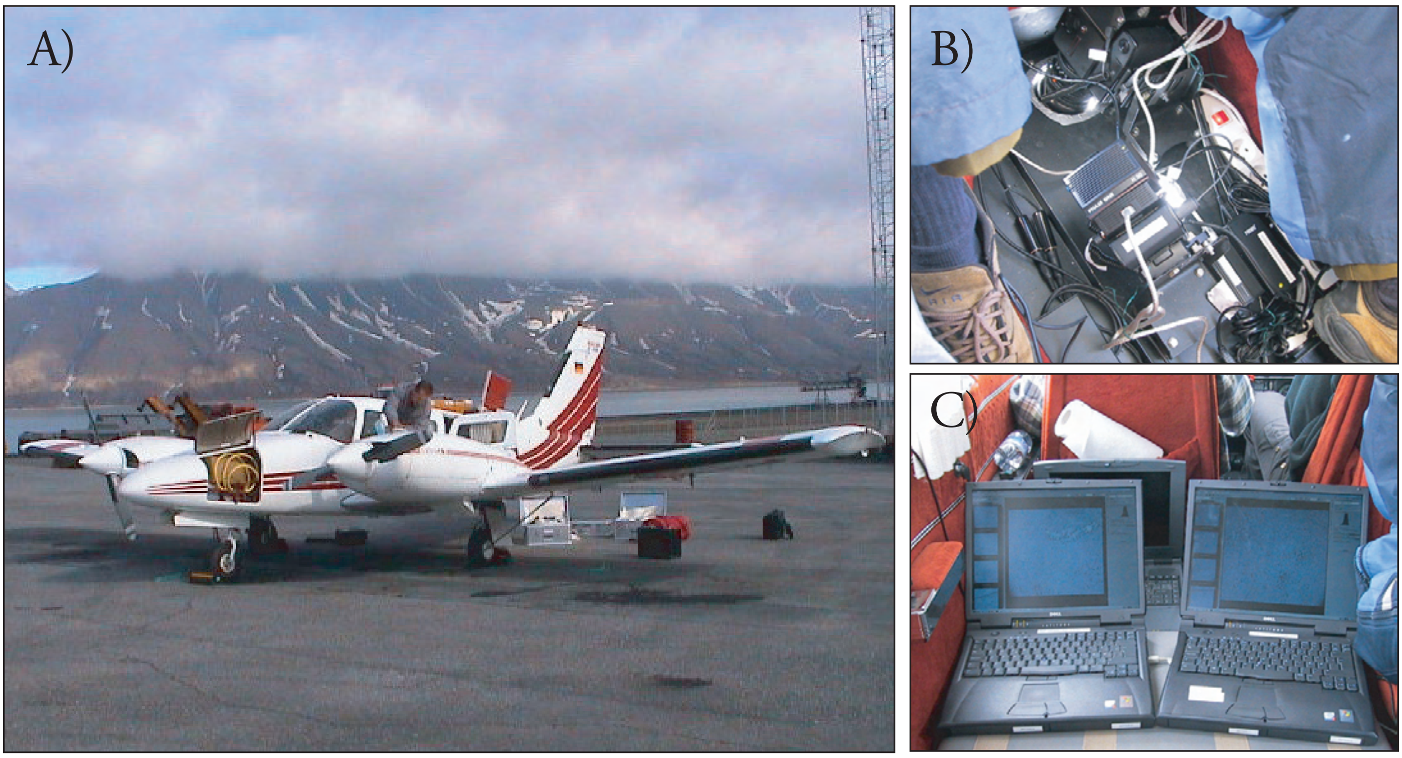


Fig. 1. (A) Survey plane – a twin propeller Piper Seneca II. (B) Two Cameras were attached to the aircraft floor and pictures were taken through a hatchway with 80 mm lenses and a backpack designed to capture digital images. (C) Two external hard disks were attached to the camera backpack, which enabled images to be stored onboard the aircraft.

Frederiksberg, Denmark), was used to manually inspect the digital photographic material. Using this software each image could be enlarged to improve detection of hauled out seals (Fig. 2). Bearded seals were identified separately from ringed seals on the digital pictures based on a combination of the size difference between the two species and haul-out location. A total of 3,662 digital pictures were inspected manually for the presence of seals. The area of fast ice that was photographed was calculated using ArcGIS software (ESRI ArcView, Ver. 8.3, Redlands, CA, USA).

Determinations of the number of seals in the study area were made assuming that the people reading the digital pictures detected all seals that were photographed. Initially two persons inspected a large number of pictures simultaneously, in order to establish a consensus for interpretation of those few cases where doubt was raised whether a seal was in the picture or not. In addition, two independent readers inspected the same 1,000 pictures separately to control for potential reader biases. The variation in the number of ringed seals detected was only 1.6 %, and there was no difference in the number of bearded seals inspected.

Even though the aerial survey was conducted during the peak of the moulting period for ringed seals, thus ensuring a maximal number of the animals being hauled out, there will still always be a fraction of animals that are in the water at any given time and thus not accounted for in a survey of this type. During spring 2003 a study of haul-out behaviour of ringed seals during the moulting period was conducted in Kongsfjorden, Svalbard (Carlens 2004). The numbers of ringed seals hauled out were studied based on visual observations and on behaviour documented using VHF telemetry records of 24 individuals. The results of this study showed significant trends in the numbers of seals hauled out with time of day and season. Additionally, the numbers varied with weather parameters such as wind speed and temperature. Warm temperatures were positively correlated with the number of animals resting on the surface, while increasing winds resulted in decreasing numbers of seals hauled out. From this study an adjustment-factor for the fraction of seals hauled out at the time the survey was flown was created, and applied to the aerial survey counts in order to estimate the total number of seals present (both hauled out on the ice and present in the water) in the study area.

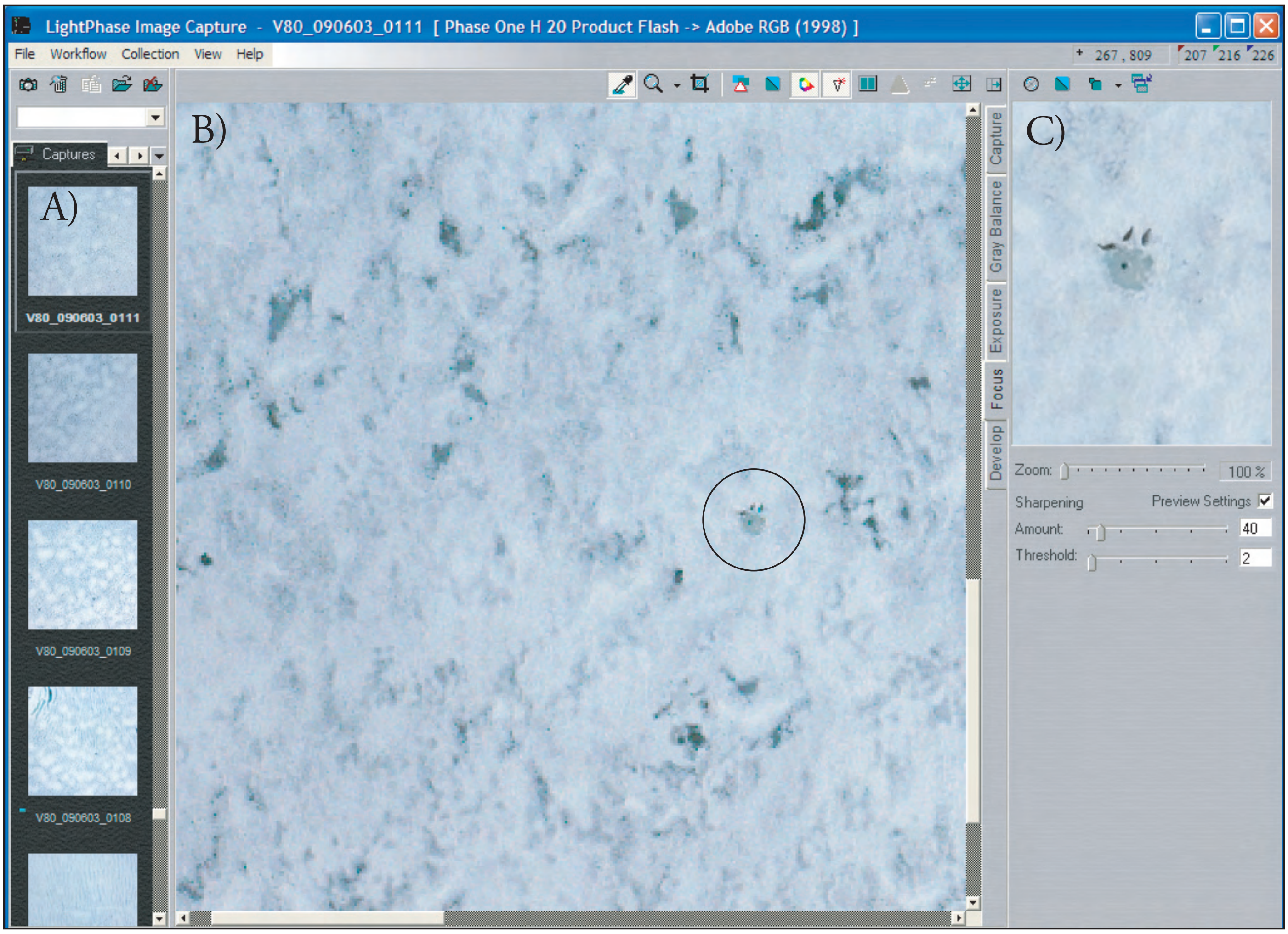


Fig. 2. Digital images were processed using a Light Phase Image Capture Program. (A) Original images (B) were magnified 200% for scanning seals. When seals were detected (C) additional magnification was applied to confirm the sighting.

Generally speaking, when surveying animal populations the precision of the estimate of the number of animals will increase with increasing effort expended on the survey. For aerial survey methodologies, like those used in the present study, this means that the more area you cover with pictures the more precise the estimated number of seals in the area will be. To get an idea about the precision of the present survey we studied the relationship between area covered and the standard error (SE) of the estimated number of seals hauled out based on results from an aerial survey of Kongsfjorden, where the total fast ice area was covered with digital pictures. Covering the entire ice surface allowed us to count all of the seals that were hauled out. We compared this count to the results from estimates that were based on line transects with various degrees of area coverage (Fig. 3). We started with a coverage rate of ~5 % (one transect line) and ran 99 repetitions based on randomly picking the line "flown". Then we increased the coverage by an additional ~5% of the area (two transect lines ~10 %), and again ran 99 new repetitions based on this new coverage and continued until the model covered the whole area. The random choice of the lines was constrained such that a specific transect line could not be chosen twice in one simulation run. This modeling exercise gave us information on how the SE of our estimate for the seal population varied with varying degrees of coverage of the ice surface during the aerial survey. The SE values are used as the basis for the calculations of the 95% confidence intervals in Table 2.

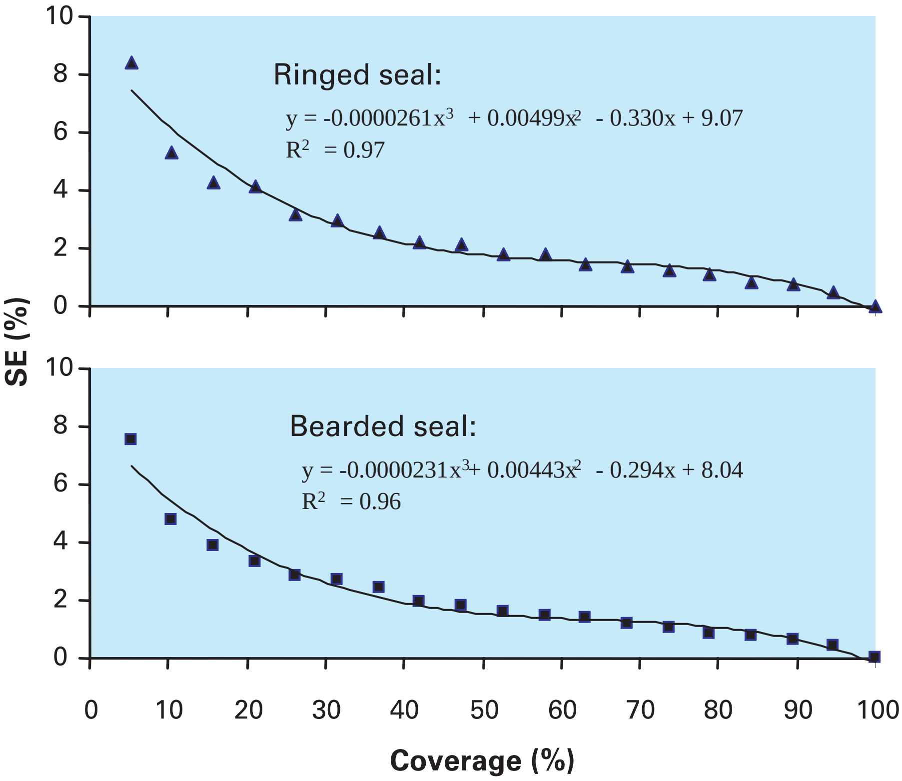


Fig. 3. Relationship between area covered (%) and the standard error (SE) of estimated ringed seals hauled out, based on results from an aerial survey of Kongsfjorden 9th of July 2003.

Results

A total of 315 ringed and 13 bearded seals were counted on the digital images taken 10th of June 2003 (Table 1). The distribution of the animals observed is shown in Figs. 4 and 5. Most of the ringed seals were counted in Van Mijenfjorden (N=193). However, the density of ringed seals was higher in Van Keulenfjorden with 0.6 seals km^{-2} as compared with 0.4 seals km^{-2} in Van Mijenfjorden. The highest densities of seals were found in the outer parts of the fjords (Table 1, Fig. 6). All 13 bearded seals found in the digital images were in Van Mijenfjorden.

Table 1. Area size, surface coverage, number of images, number of ringed seals and number of bearded seals counted on digital images taken during aerial surveys of Fridtjovhamna, Van Mijenfjord and Van Keulenfjord, Svalbard on the 10th of June 2003 and densities of the two species according to area.

Survey area	Area size (km^2)	Coverage (%)	No. of images counted	No. of counted ringed seals	No. of counted bearded seals	Density of counted ringed seals (km^{-2})	Density of counted bearded seals (km^{-2})
Fridtjovhamna	1.7	100	62	5	0	2.9	0
Inner Van Keulenfjorden	82	46	452	36	0	0.4	0
Outer Van Keulenfjorden	103	59	648	81	0	0.8	0
Van Mijenfjorden	465	48	2,500	193	13	0.4	0.03
Total	**651.7**		**3,662**	**315**	**13**		

If we extrapolate the raw data to the whole ice area, and use the adjustment factor for ringed seals present in the water at the specific time of day the survey was flown, the total number of ringed seals present in the study area is estimated to be 1,523. Only time of day is corrected for in this investigation. There is no correction for wind-speed or temperature since these parameters were similar in the study area and in Kongsfjorden where this adjustment-factor was developed. Additionally, no seasonal adjustment was required because the survey's timing was specifically chosen to hit the maximum peak haul-out timing for this area.

Applying the information from the ice-coverage model from Table 2 into the equation in Figure 3, the 95% confidence interval of this estimate ranges from 1,485-1,561 animals.

Bearded seals were only found in Van Mijenfjorden (Table 1), and an extrapolation to the total area of this fjord suggests that 27 animals were present. Since we do not have information that enables us to adjust this estimate for the numbers of bearded seals in the water, this value must be considered a minimum estimate.

Table 2. Total number of ringed seal counted, total area covered, estimated number of hauled out ringed seals and estimated total population numbers for the two survey years in Fridtjofhamna, Van Mijenfjord and Van Keulenfjord, Svalbard during June of 2002 and 2003.

Year	Total no. of ringed seals counted in digital images	Total area covered (%)	Estimated no. of ringed seals hauled out	Fraction hauled out* (%)	Total no. of ringed seals in the area	95 % confidence interval**
2002	399	45.7	873	41.7	2,094	2,014 – 2,174
2003	315	49.6	635	41.7	1,523	1,485 – 1,561

*Based on data from a haul-out study of ringed seals in Kongsfjorden, Svalbard (Carlens 2004). Information from the same date and similar weather conditions compared to the aerial survey was used in the calculation of the correction factor.
** Calculated based on information on area coverage and the Equation for Ringed seals in Fig. 3.

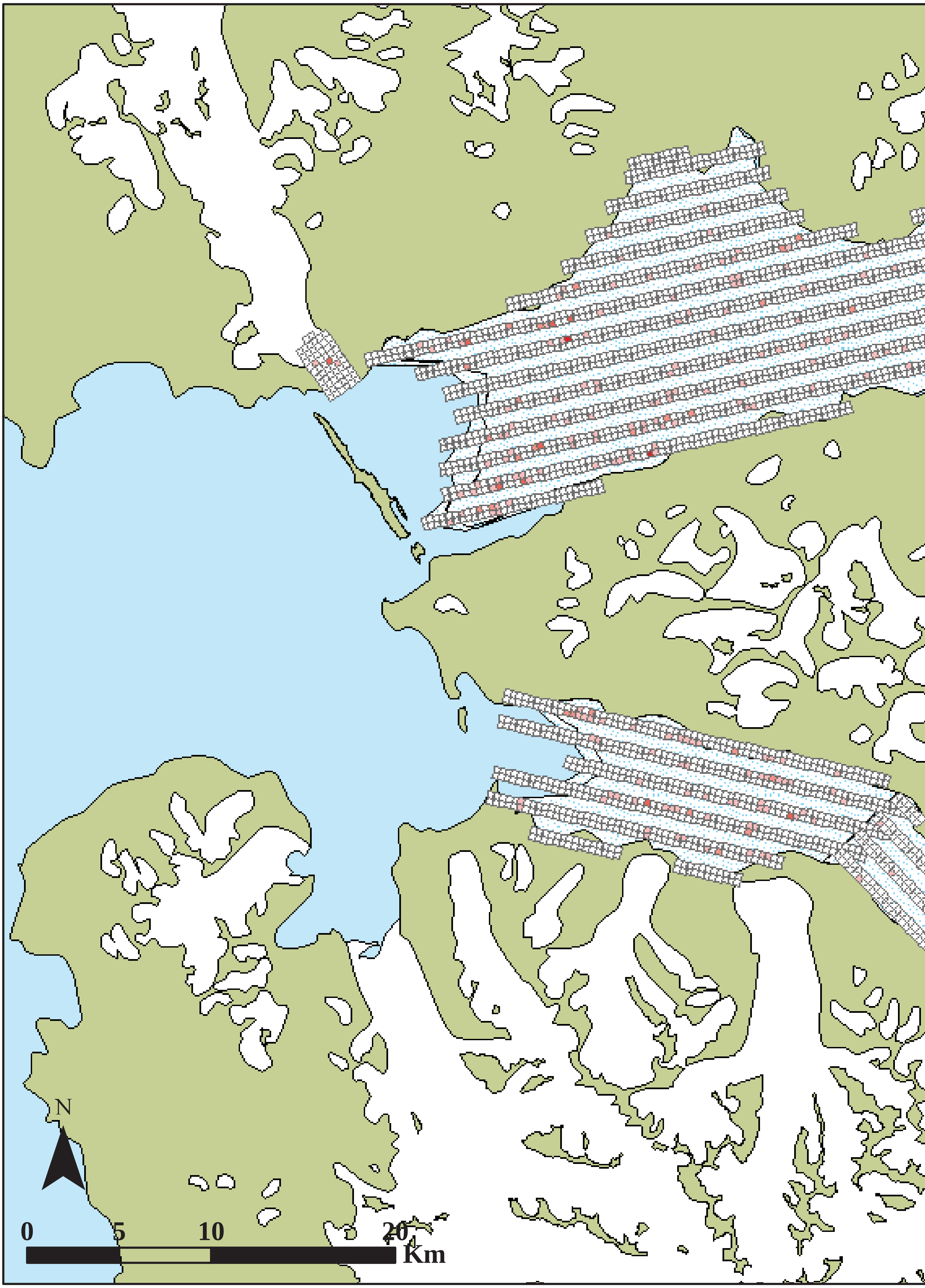
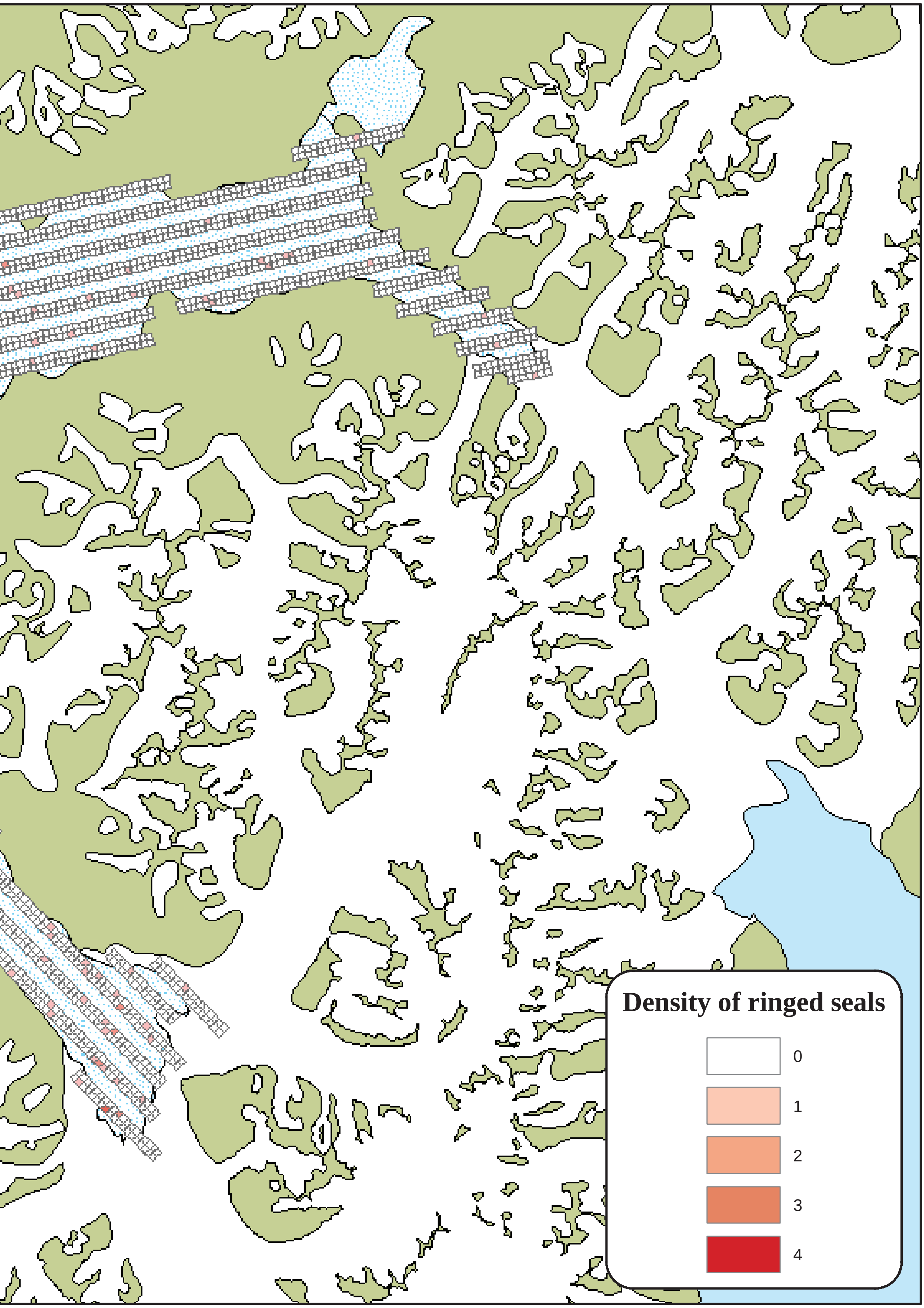


Fig 4. Map showing the study area, extent of ice and transects flown during the aerial survey in June 2003. Each small square on the transect lines corresponds to a digital image covering 336 x 336 m. Ringed seal locations are indicated in red.


Density of ringed seals
0
1
2
3
4

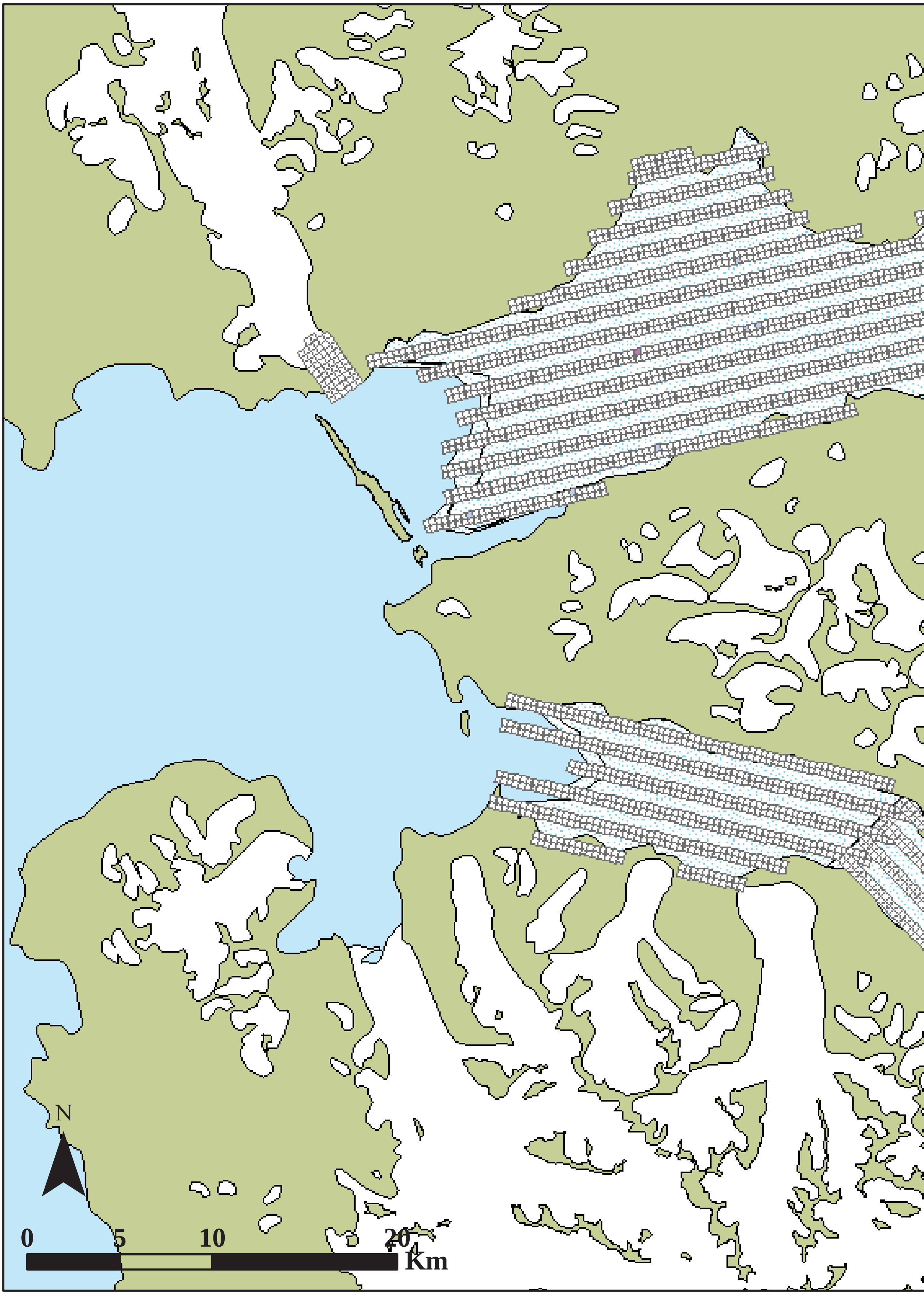
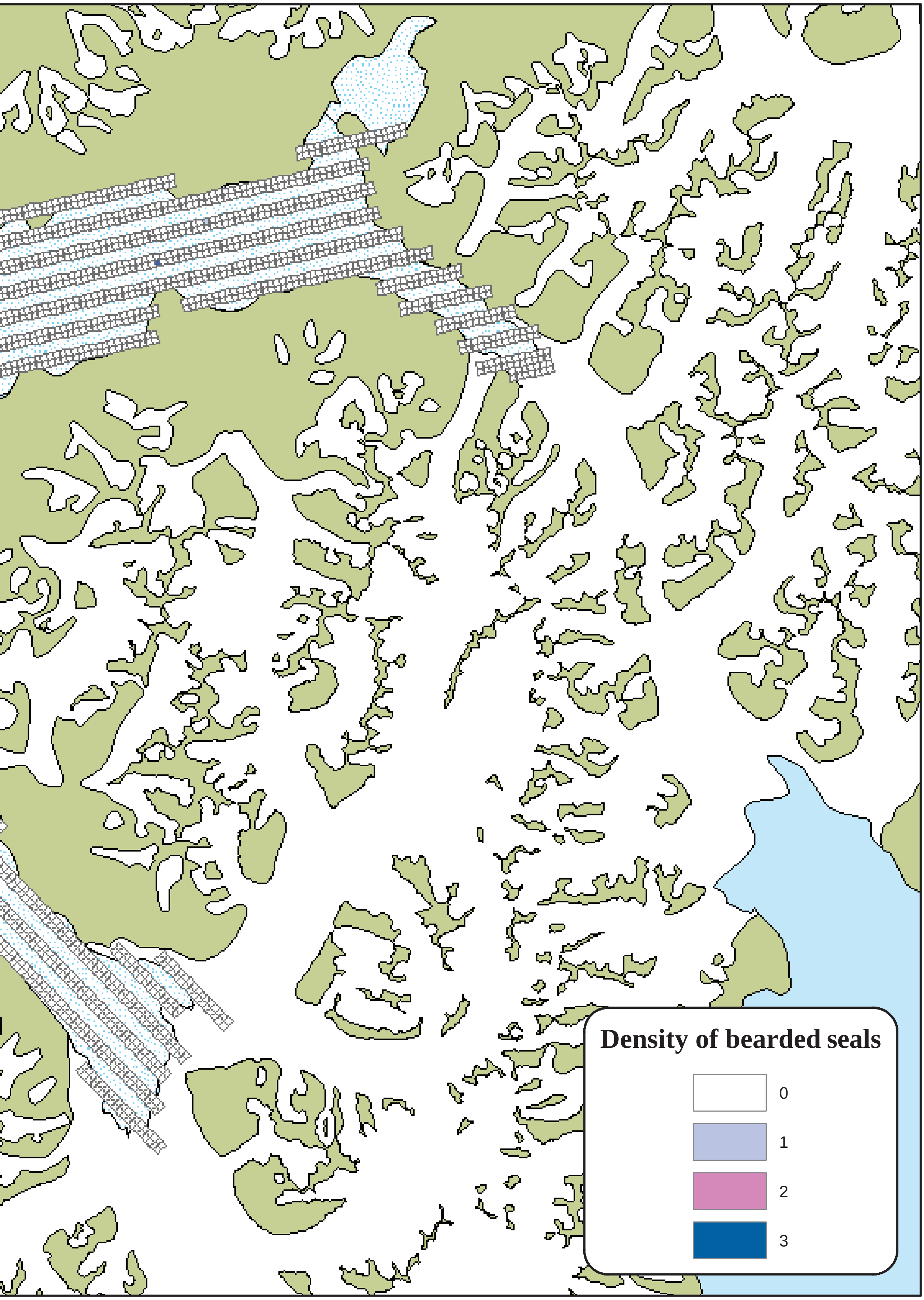


Fig 5. Map showing the study area, extent of ice and transects flown during the aerial survey in June 2003. Each small square on the transect lines corresponds to a digital image covering 336 x 336 m. Bearded seal locations are indicated in blue.


Density of bearded seals
0
1
2
3

Discussion

This study has shown that there are significant inter-annual differences in the number of ringed seals present in the Van Mijenfjorden and Van Keulenfjorden area during the June moulting period. Approximately 500 more ringed seals used this area in June 2002 compared to June 2003 (Table 2). The survey method and design used during these two different seasons were exactly the same, they were conducted by the same people, the surveys were flown on the same dates, and the digital images were analyzed by the same persons. We are therefore convinced that this difference in seal numbers between the two years is not an artifact of sampling. This difference is due to one or more biotic or abiotic factor(s) that differ between the two survey years.

Biotic factors that could influence the number of ringed seals present on the ice during our surveys include age and sex distribution of the seals, prey availability, presence of predators and general disturbance from humans. It is known from many seal species, including ringed seals, that different age and sex groups commence moulting at different times (Daniel et al. 2003, Kirkman et al. 2003, Reder et al. 2003, Carlens 2004). In harbour seals, which are the most closely documented species, sub-adults moult before the adult animals and adult females start the moult before adult males (e.g. Reder et al. 2003). Ringed seals appear to be divided into phenological patterns concerning the timing of their moulting based on age and sex (Carlens 2004). However, it is unlikely that major shifts in the age structure of animals using this area would take place from one year to the next. Since the surveys were conducted at the same time each year, this factor is unlikely to account for the differences in seal numbers observed in our two surveys. Prey availability is a factor that can vary a lot over very short intervals of time. However, during the moulting period most seal species have reduced food intake levels and some do not eat at all. Studies of ringed seals show that they are in negative energy balance during this period (Ryg et al. 1990), meaning that they eat so little that they lose weight during this time. Ryg et al.'s (1990) study of variation in body mass and body composition of ringed seals of different age and sex groups in Svalbard throughout the year, showed that the ringed seals were at their thinnest toward the end of the moulting period in June. Thus, potential variation in prey availability is unlikely to be a contributing factor to the observed difference in seal abundance in the study area between the two years.

Disturbance from predators, which at this time of the year would be only polar bears and humans, is another factor that potentially could affect the number of seals present in the study area. However, polar bears are not present in high numbers in this area at this time of the year and none were seen on the digital pictures. There is no indication of differences between the two seasons related to abundance of this predator. It is unlikely that differences in human disturbance levels between the two years affected the numbers of seals because both aerial surveys were conducted late in the season when the sea ice was unsafe for snowmobile driving, and there is no difference between the two years related to boat traffic. Thus, there does not appear to be any realistic explanation among biotic factors that could account for the difference in number of ringed seals present between the survey in 2002 and the one in 2003.

The most important abiotic factors that have been shown to influence the number of ringed seals hauled out during the spring at any given point in time are time of day, date, wind-speed and air temperature (Carlens 2004). Potential effects of time of day and date can be excluded from this comparison since we conducted the surveys at the same date and time in these two seasons. The average air temperature was 6 °C warmer (2°C vs. -4°C) and the wind speed was 4 ms^{-1} higher (6 ms^{-1} vs. 2 ms^{-1}) in the 2002 versus the 2003 survey. These parameters are not different enough to cause any significant change in number of ringed seals hauled out. In addition, since warmer temperatures increase and higher wind speeds decrease the numbers of ringed seals hauled out, the small potential effects of these two parameters between the two survey periods would likely counterbalance each other in any case.

Another abiotic factor that varies between the two surveys is ice cover. During the 2002 survey a total of 465 km^2 of ice was present in the study area, while the corresponding figure for the 2003 survey was 652 km^2. Ringed seals are thought to be territorial during the breeding season (Reeves 1998), when adult animals of both sexes defend underwater territories with associated breeding holes and lairs. The most attractive breeding habitats for ringed seals are areas deep into the land-fast ice, far from the ice edge, at the specific sites where snow accumulates to sufficient depths for the construction of lairs to be possible. Adult females prefer this habitat where the ice is most stable, so they can complete the six week long lactation period of this species (Hammill et al.1991; Lydersen an Hammill 1993; Lydersen and Kovacs 1999). In the more unstable outer areas of fjords, the ice is more likely to break up early resulting in increased risks of separation of the mothers and pups, and thereby reducing the chances for pup survival. This territorial behaviour results in a segregation of different sex and age groups in the breeding habitat of this seal species. Typically, adult individuals are found deep into the fjords while sub-adult individuals are more commonly found in the outer parts and along the fast ice edges. Based on this discussion one would assume that the number of ringed seals found in the study area in 2002 would likely be lower than in 2003, since the latter season had almost 50 % more ice. However, subsequent to the breeding season territoriality ceases in this species and it is common to see many seals around the same breathing hole and hence the total ice

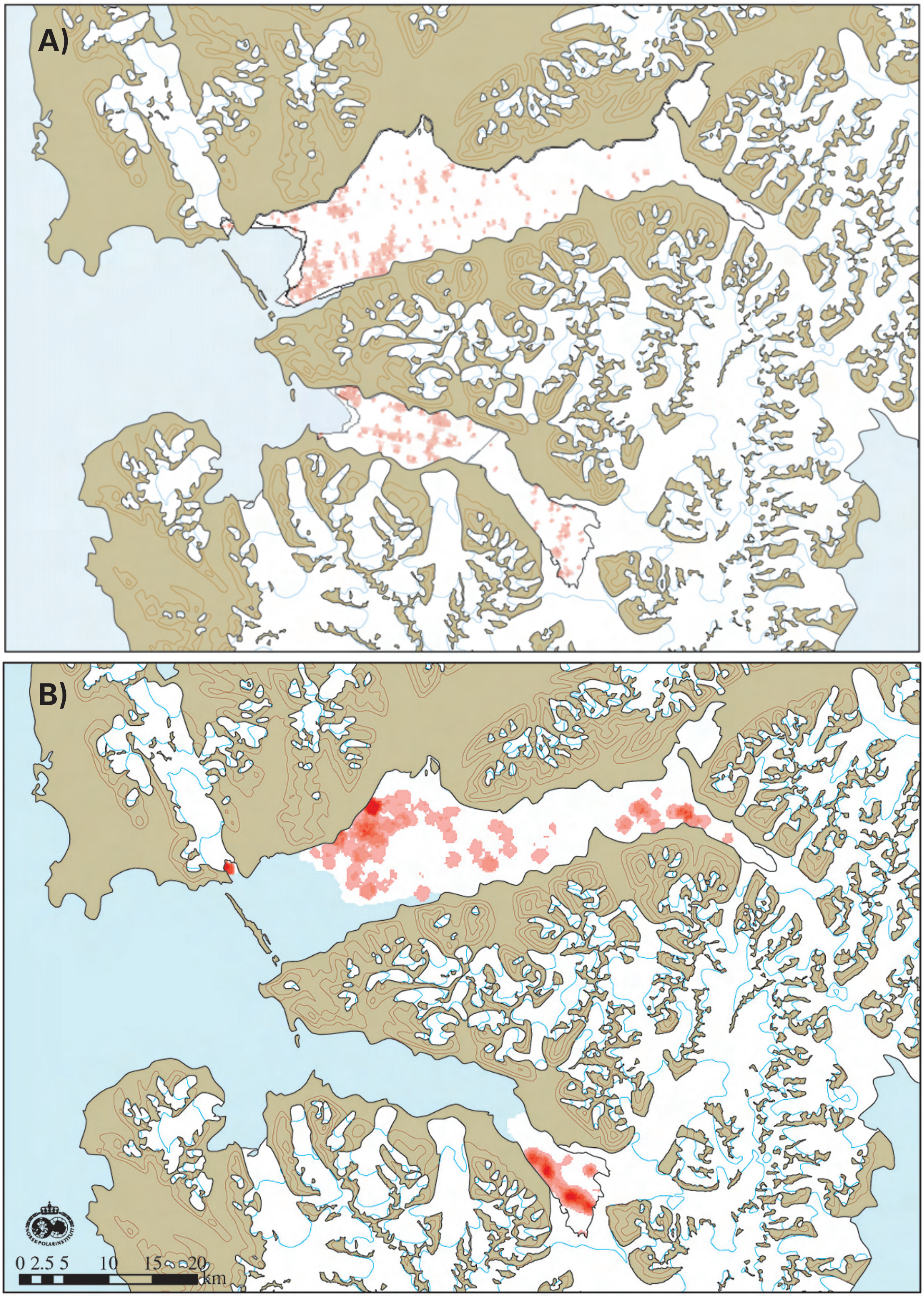


Fig. 6. Map showing the interpolation of the densities of ringed seals from aerial surveys (A) in June 2003 and (B) June 2002 applied to the whole of Van Mijenfjorden and Van Keulenfjorden area. Higher color intensity (red) corresponds to a higher ringed seal density.

area does not directly affect total numbers of animals able to use it. However, the general conditions of the sea ice are in fact likely to have had an influence on our counts in the two years. Ice maps from the Norwegian Meteorological Institute reveal that the 2002 season was a very poor ice year compared with 2003. In 2002, the ice cover was generally less in all of the fjords in western Spitsbergen compared with the 2003 season. The ice formed later, broke up earlier and was generally less abundant in 2003. When ringed seals start to moult in late May/early June they seek out an ice platform where they can go through this process. Moulting involves replacing all the old hair and the outer layers of the skin. A rich blood supply to the periphery of the body is essential to accomplish this process effectively. Moulting while resting on the surface of the ice in the relatively warm spring air drastically reduces the energetics costs of this physiological process compared to if it has to take place in water, where thermal conductivity is so much higher. Since it is so energetically favourable to moult in air (i.e. on the ice), ringed seals will move over large areas to seek out an ice platform if one is no longer available in the area where they spent the winter and early spring. The ringed seals that spend the winter and spring in the study area almost certainly remain in this area for moulting. Van Mijenfjorden is one of the fjords in Svalbard that keeps its sea ice cover for the longest period. Akseløya serves as a natural break for incoming waves that serve to break-up the ice platform in other fjords. Hence, the poor ice conditions in 2002 likely resulted in ringed seals from a large area around the study area being drawn to this fjord system in order to use the sea ice for moulting. Since the sea ice conditions in June 2003 were better than in 2002, fewer ringed seals from adjacent areas would have been forced to seek ice on which to moult. They could remain in their own breeding areas. This factor is almost certainly the major cause for the difference in the number of ringed seals between the two seasons.

The distribution pattern of the ringed seals on the ice in Van Mijenfjorden and Van Keulenfjorden during the surveys (Fig. 6) shows that the highest densities are found in the outer parts of the fjords. This pattern supports the discussion above concerning distribution of different age and sex groups and the likely migration phenomenon of seals from adjacent areas. During moult, the resident adult seals probably stayed where they were during the breeding period, deep into the fjord. The outer areas will tend to contain the younger seals that spent the winter and spring in this area, and the influx of animals arriving from other areas. There is no point for these travelers to penetrate deep into the fjord ice, when all they need is an ice-platform for accomplishing the moult. Thus, they congregate in the outer parts of Van Mijenfjorden and Van Keulenfjorden.

Only about 30 bearded seals were found on the ice during the aerial surveys both in 2002 and 2003. However, this study was not specifically designed to estimate the bearded seal abundance in the study area. Bearded seals prefer drifting ice floes for hauling out, and therefore it was not expected that very many animals would be found on the land-fast ice within the fjord. Some bearded seals can be found along the fast-ice edge, and also in cracks and leads inside the ice. Late in the season they are also often observed using ringed seal holes that have melted to a sufficient size to accommodate bearded seal haul out. But, the survey would have had to extend further beyond the ice-edge to include prime bearded seal habitat. Most of the bearded seals in the general area would be found to the west of the areas that were photographed. In addition there is no published information on haul-out behaviour of bearded seals that would enable us to make a correction factor for animals in the water during a survey.

Earlier studies have shown that most of the study area, i.e. Van Mijenfjorden, is a relatively poor breeding habitat for ringed seals (Lydersen et al. 1990) compared with other fjords on Spitsbergen such as Kongsfjorden (Lydersen and Gjertz 1986) or Sassenfjorden, and Tempelfjorden (Lydersen and Ryg 1991). This was thought to be largely due to the fact that the ice in the fjord contained very few structures such as ridges or glacier calves captured in the sea ice. These sorts of structures cause snow to accumulate to depths that allow ringed seals to dig out lairs. However, the two aerial surveys conducted in 2002 (Lydersen et al. 2002) and 2003 (this study), in addition to an earlier aerial survey (Jensen and Knutsen 1987), show that the study area is an important moulting area for ringed seals. Van Mijenfjorden is particularly important moulting habitat because it retains its ice cover late into the spring and early summer due to the presence of Akseløya which covers most of its opening towards west, protecting the ice on the inside of the blockade from wave action. This ice refuge is likely to be especially important in poor ice years when it attracts ringed seals from surrounding areas during their annual moult.

References

Andersen, M., Hjelset, A. M., Gjertz, I., Lydersen, C. & Gulliksen, B. 1999. Growth, age at sexual maturity and condition in bearded seals (*Erignathus barbatus*) from Svalbard, Norway. Polar Biol. 21: 179-185.

Burns, J. J. 1981. Bearded seal Erignathus barbatus Erxleben, 1777. Pp. 145-170 *In* Ridgeway, S. H. &. Harrison, R. J. (eds.) Handbook of marine mammals. Vol 2. Seals. Acad. Press, London.

Carlens, H. 2004. Spring hauled out behaviour of ringed seals (Phoca hispida) in Kongsfjorden, Svalbard. MSci. Thesis. Stockholm University. 25 pp.

Daniel, R. G., Jemison, L. A., Pendleton, G W. & Crowley, S. M. 2003. Molting phenology of harbor seals on Tugidak Island, Alaska. Mar. Mammal Sci. 19: 128-140.

Gjertz, I., Kovacs, K. M., Lydersen, C. & Wiig, Ø. 2000. Movements and diving of bearded seal (*Erignathus barbatus*) mothers and pups during lactation and postweaning. Polar Biol. 23: 559-566.

Hammill, M. O., Kovacs, K. M. & Lydersen, C. 1994. Local movements by nursing bearded seal (*Erignathus barbatus*) pups in Kongsfjorden, Svalbard. Polar Biol. 14: 569-570.

Hammill, M. O., Lydersen, C., Ryg, M. & Smith, T. G. 1991. Lactation in the ringed seal (*Phoca hispida*). Can. J. Fish. Aquat. Sci. 48: 2471-2476.

Jensen, P. M. & Knutsen, L. Ø. 1987. Distribution and abundance of ringed seals (*Phoca hispida*) in the Van Mijen and Van Keulen fiords, Svalbard, June-July 1986. Pp. 113-148 *In* Prestrud, P. & Øritsland, N. A. (eds.) Miljøundersøkelser i tilknytning til seismisk virksomhet på Svalbard 1986. Norsk Polarinst. Rapp. Ser. 34.

Kirkman, S. P., Bester, M. N., Pistorius, P. A., Hofmeyr, G. J. G., Jonker, F. C., Owen, R. & Strydom, N. 2003. Variation in the timing of moult in southern elephant seals at Marion Island. S. Afr. J. Wildl. Res. 33: 79-84.

Kovacs, K. M., Lydersen, C. & Gjertz, I. 1996. Birth-site characteristics and prenatal moulting in bearded seals (*Erignatus barbatus*). J. Mamm. 77: 1085-1091.

Krafft, B. A., Lydersen, C., Kovacs, K. M., Gjertz, I. & Haug, T. 2000. Diving behaviour of lactating bearded seals (*Erignathus barbatus*) in the Svalbard area. Can. J. Zool. 78: 1408-1418.

Lydersen, C. 1995. Energetics of pregnancy, lactation and neonatal development in ringed seals (*Phoca hispida*). Pp. 319-327 *In* Blix, A. S., Walløe, L. & Ulltang, Ø. (eds.) Whales, seals, fish and man. Elsevier Science B. V. Amsterdam.

Lydersen, C. & Gjertz, I. 1986. Studies of the ringed seal (*Phoca hispida* Schreber 1775) in its breeding habitat in Kongsfjorden, Svalbard. Polar. Res. 4: 57-63.

Lydersen, C. & Gjertz, I. 1987. Population parameters of ringed seals (*Phoca hispida* Schreber, 1775) in the Svalbard area. Can. J. Zool. 65: 1021-1027.

Lydersen, C. & Hammill, M. O. 1993. Diving in ringed seal (*Phoca hispida*) pups during the nursing period. Can. J. Zool. 71: 991-996.

Lydersen, C., Hammill, M. O. & Kovacs, K. M. 1994. Diving activity in nursing bearded seal (*Erignathus barbatus*) pups. Can. J. Zool. 72:96-103.

Lydersen, C., Jensen, P. M. & Lydersen, E. 1990. A survey of the Van Mijen fiord, Svalbard, as habitat for ringed seals, *Phoca hispida*. Holarct. Ecol. 13: 130-133.

Lydersen, C. & Kovacs, K. M. 1999. Behaviour and energetics of ice breeding North Atlantic phocid seals during the lactation period. Mar. Ecol. Progr. Ser. 187: 266-281.

Lydersen, C., Krafft, B. A., Andersen, M. & Kovacs, K. M. 2002. Marine mammals in the Bellsund – Van Mijenfjorden – Van Keulenfjorden area. New investigations and status of knowledge. Norw. Polar Inst. Rep. Ser. 121. 38 pp.

Lydersen, C. & Ryg, M. 1991. Evaluating breeding habitat and populations of ringed seals *Phoca hispida* in Svalbards fjords. Polar Rec. 27: 223-228.

Lydersen, C. & Smith, T. G. 1989. Avian predation on ringed seal *Phoca hispida* pups. Polar. Biol. 9: 489-490.

Reder, S., Lydersen, C., Arnold, W. & Kovacs, K. M. 2003. Haulout behaviour of high Artcic harbour seals (*Phoca vitulina vitulina*) in Svalbard, Norway. Polar Biol. 27: 6-16.

Reeves, R. R. 1998. Distribution, abundance and biology of ringed seals (*Phoca hispida*): an overview. Pp. 9-45 *In* Heide-Jørgensen, M. P. & Lydersen, C. (eds.) Ringed seals in the North Atlantic. NAMMCO Sci. Publ. 1.

Ryg, M., Smith, T. G. & Øritsland, N. A. 1990. Seasonal changes in body mass and body composition of ringed seals (*Phoca hispida*) on Svalbard. Can. J. Zool. 68: 470-475.

Smith, T. G. 1976. Predation of ringed seal pups (*Phoca hispida*) by Arctic fox (*Alopex lagopus*). Can. J. Zool. 54: 1610-1616.

Smith, T. G., Hammill, M. O. & Taugbol, G. 1991. A review of the developmental, behavioural and physiological adaptations of the ringed seal, *Phoca hispida*, to life in the Arctic winter. Arctic 44: 124-131.

Smith, T. G. & Stirling, I. 1975. The breeding habitat of the ringed seal (*Phoca hispida*). The birth lair and associated structures. Can. J. Zool. 53: 1297-1305.