Master's thesis

Home range and movements of the Saimaa ringed seal (*Phoca hispida saimensis* Nordq.)

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11.11.2010

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Oksanen Sari, M.:	Home range and movements of the Saimaa ringed seal (*Phoca hispida saimensis* Nordq.)
Master of Science Thesis:	31 p.
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November 2010	

Key Words: habitat selection, migrations, seasonality, site fidelity, VHF radio telemetry

ABSTRACT

The spatial behaviour of the endangered Saimaa ringed seal (*Phoca hispida saimensis* Nordq.) is poorly understood: movements have been studied during open water season but information on the winter is lacking. The Saimaa ringed seal is known to show site fidelity to moulting and breeding areas between years, and also site fidelity throughout the year has been suggested. In this study the home range size, movements and site fidelity of the Saimaa ringed seal were studied throughout the year with VHF radio telemetry. During the tracking periods in 1999-2000 and 2006-2007, altogether 5 individuals were tracked varying periods from tagging in May until detachment of the tag in October-April. The summer and winter home range sizes were estimated using 95 % minimum convex polygon (MCP) and fixed kernel estimators for 3 adults, but one of them also earlier as a juvenile and later as an adult. In addition, only the summer home range size was estimated for one adult and one juvenile. Seasonal movements were studied with the distance between summer and winter home range centroids. Summer home range size estimates of adult seals had more individual variation than wintertime estimates but no significant statistical differences were found (summer, n = 4: 3-15 km^2 (95 % MCP) and 3-27 km^2 (95 % kernel); winter, n = 3: 2-5 km^2 (95 % MCP) and 4-8 km^2 (95 % kernel). Summer home range size estimates for 2 juvenile seals were relatively large (36 and 8 km^2 (95 % MCP); 38 and 15 km^2 (95 % kernel)). The winter home range size of one juvenile was estimated to be 3 to 4 km^2 (MCP and kernel, respectively). All 3 individuals tracked throughout the year were observed to perform seasonal migrations of 8 to 36 km in length from their summer home range to the winter home range. However, one male studied in both tracking periods only made a migration when juvenile. This study gives the first records of the Saimaa ringed seal home range size and further information is needed. The results of this study indicate that some Saimaa ringed seals are not necessarily as sedentary throughout the year as previously suggested but they can do seasonal migrations between summer and winter home ranges. However, the results also indicate site fidelity to moulting and breeding areas, as has been also previously suggested.

JYVÄSKYLÄN YLIOPISTO, Matemaattis-luonnontieteellinen tiedekunta
Bio- ja ympäristötieteiden laitos
Vesistötieteet

Oksanen Sari, M.: Saimaannorpan (*Phoca hispida saimensis* Nordq.) elinpiiri ja liikkuminen
Pro gradu: 31 s.
Työn ohjaajat: FT Mervi Kunnasranta, FM Marja Niemi, lehtori FT Timo J. Marjomäki
Tarkastajat: FT Tapio Keskinen, lehtori FT Timo J. Marjomäki
Marraskuu 2010

Hakusanat: elinympäristönkäyttö, paikkauskollisuus, vaellukset, VHF-radiotelemetria, vuodenaikaisuus

TIIVISTELMÄ

Uhanalaisen saimaannorpan (*Phoca hispida saimensis* Nordq.) spatiaalinen käyttäytymisekologia on puutteellisesti tunnettua: liikkumista on tutkittu jonkin verran avovesiajalla, mutta talviajalta vastaavia tutkimuksia ei ole tehty. Saimaannorpan on osoitettu olevan paikkauskollinen karvanvaihto- ja pesintäalueille, ja sen on ehdotettu olevan paikkauskollinen myös läpi vuoden. Tässä tutkimuksessa pyrittiin selvittämään saimaannorpan elinpiirin kokoa, liikkumista ja paikkauskollisuutta läpi vuoden VHF-radiotelemetrian avulla. Seurantajaksoilla 1999-2000 ja 2006-2007 seurattiin yhteensä viittä yksilöä lähetinten kiinnittämisestä toukokuussa niiden tippumiseen saakka (marraskuu-huhtikuu). Kesä- ja talvielinpiirien koot arvioitiin 95 % konveksin peitteen minimointi -menetelmää (minimum convex polygon, MCP) ja ydinestimointimenetelmää (fixed kernel) käyttäen yhteensä kolmelle aikuiselle, joista yhdelle myös nuorena. Lisäksi vain kesäeliinpiirien koot arvoitiin yhdelle aikuiselle ja yhdelle nuorelle. Vuodenaikaisia vaelluksia tutkittiin kesä- ja talvielinpiirien keskipisteiden etäisyyksien avulla. Aikuisten norppien kesäelinpiireissä oli enemmän yksilöllistä vaihtelua kuin talvielinpiireissä, mutta tilastollisesti merkitseviä eroja ei löytynyt (kesä, n = 4: 3-15 km^2 (95 % MCP) ja 3-27 km^2 (95 % kernel); talvi, n = 3: 2-5 km^2 (95 % MCP) ja 4-8 km^2 (95 % kernel). Kahden nuoren yksilön havaittiin liikkuvan kesällä melko suurella alueella (36 ja 8 km^2 (95 % MCP); 38 ja 15 km^2 (95 % kernel)). Talvielinpiirin kooksi yhdelle nuorelle arvioitiin 3 km^2 (MCP) ja 4 km^2 (kernel). Ympärivuodenseuratuista kolmesta yksilöstä kaikkien havaittiin tekevän vaellus (8-36 km) kesäelinpiiriltä talvielinpiirille. Tosin molemmilla seurantajaksoilla tutkittu uros teki vaelluksen vain nuorena. Tässä tutkimuksessa on ensimmäistä kertaa arvioitu saimaannorpan elinpiirin kokoa ympäri vuoden ja lisätietoa tarvitaan. Tulosten perusteella saimaannorppayksilöt eivät välttämättä ole niin paikkauskollisia kuin aiemmin on ehdotettu vaan voivat tehdä vuodenaikaisvaelluksia ja siirtyä eri alueille vuodenaikojen mukaan. Tulokset kuitenkin viittaavat karvanvaihto- ja pesintäajan paikkauskollisuuteen, kuten on aikaisemminkin osoitettu.

Contents

1. INTRODUCTION

The Saimaa ringed seal (*Phoca hispida saimensis* Nordq.) is a subspecies of the ringed seal (*Phoca hispida* Schreber). It has been geographically isolated from the other ringed seal populations since the late glacial period some 8 000 years ago (Müller-Wille 1969, Forstén & Alhonen 1975). The Saimaa ringed seal has adapted to exceptional environment for a marine mammal: a relatively shallow freshwater lake network, which is labyrinthine and dotted with some 14 000 islands (Kuusisto 1999). Isolation has lead to differentiation in morphology, genetic diversity and behaviour from neighbouring subspecies in Lake Ladoga (*P. h. ladogensis*) and in the Baltic Sea (*P. h. botnica*) as well as from the Arctic ringed seal (*P. h. hispida*) (Hyvärinen & Nieminen 1990, Kunnasranta 2001, Amano *et al.* 2002, Palo 2003).

The population of the Saimaa ringed seal is very small, approximately 260 individuals (Sipilä & Kokkonen 2009). The Saimaa ringed seal is classified to a category of species that need strict protection in the Habitats directive of European Union (Annex IV, Anonymous 1992). Breeding sites or resting places of the species in this category should not be deteriorated or destructed and breeding not disturbed. Although the Saimaa ringed seal has been protected since 1955, the population decreased sharply from the beginning of the 20th century until the 1980's, when the estimated population size was less than 200 individuals (Sipilä 2003). Population decline has been mainly due to harmful fishing methods, habitat fragmentation, artificial fluctuations of the water level at breeding season, reproductive failures caused by environmental toxins and human caused disturbance during breeding season (Hyvärinen & Sipilä 1984, Sipilä *et al.* 1990, Hyvärinen *et al.* 1998).

Several actions to conserve the Saimaa ringed seal have been done at Lake Saimaa: Gill net fishing and other harmful fishing methods are forbidden at central areas of the Saimaa ringed seal distribution (Anonymous 2004). Increasing number of voluntary gill net fishing restrictions (April 15 – June 30) of local communities supplements these areas substantially. Legislation of water level fluctuations at Lake Saimaa states that no rapid artificial changes in the water level are allowed (Anonymous 1991a). Two national parks and many other conservation areas have been established, where several human activities, such as landing to some small islands and islets, are regulated. Shoreline development has also been regulated in many parts of Lake Saimaa (Anonymous 1991b). Due to these conservation activities, the population size of the Saimaa ringed seal has slowly increased since the 1980's (Sipilä & Kokkonen 2009). However, the population recovery has been slow and after 2005 there has been no population growth. A key factor still contributing to the poor conservational status of the population is high pup mortality. This is mainly due to the high fisheries by-catch mortality and failures in the reproduction caused by mild winters in 2006 and 2007. Therefore, the climate change is an increasingly serious threat to the Saimaa ringed seal population. Human caused disturbance on the breeding season can also be expected to increase as the number of buildings near the shorelines is steadily increasing (Laita 2005). Long term impacts of these threats on the Saimaa seal population are difficult to predict without proper understanding of the ecology of this unique subspecies.

Profound knowledge of the seal ecology is also needed for planning and implementing rational and favourable conservation activities in relation to potential nuisance to the local people. To improve the knowledge of the Saimaa ringed seal, more information concerning basic spatial ecology of the subspecies, such as movements, home range size, habitat utilisation and site fidelity is needed. Previous studies have been mainly conducted during open water season indicating a high degree of site fidelity, probably even throughout the year (Hyvärinen *et al.* 1995, Kunnasranta 2001, Koskela *et al.* 2002). Movements of the Saimaa ringed seal are assumed to be short compared to the ringed seal in the Arctic (Koskela *et al.* 2002). However, there is very little detailed information on the movements of the Saimaa ringed seals. Also, information on the home range size and space use is lacking.

Site fidelity to breeding sites has been suggested on the basis of annual lair counting in the spring (Helle *et al.* 1984, Sipilä 1990). However, wintertime habitat use and movements on an individual level are not known in detail because previous telemetry studies have mainly been limited to open-water season. Winter is crucial for Saimaa ringed seals as they breed on ice. Pups are born in the subnivean snowlairs situated in the shoreline of islands or islets in late February or early March (Sipilä & Hyvärinen 1998). The lactation begins in the shelter of the snow lair but continues also after the collapse of the lair. Also mating is assumed to occur shortly after whelping while females are still nursing pups.

VHF radio telemetry has proved to be a powerful tool in seal studies enabling observation on the behaviour of these most of the time submerged animals on an individual level (Koskela *et al.* 2002, Kelly *et al.* 2010). However, radio telemetry is relatively expensive and laborious method and has many uncertainties concerning functioning of tags and liability of tag attachment (Kenward 2001). Thus, sample sizes tend to be small and between-individual variation may prohibit making firm conclusions. Bearing in mind such limitations of the method and the study design, this kind of detailed information that provides insight into between-individual variation in the spatial behaviour of the Saimaa ringed seal is valuable for improving conservation strategies that are consistent with future challenges.

In this study, movements and home range size were investigated using VHF radio telemetry to observe free ranging Saimaa ringed seals throughout the year. The main aim of this study was to provide detailed information on the spatial behaviour of the Saimaa ringed seal. The subtasks of the study were i) to describe the movements and the home range size of the study seals in detail focusing on general conclusions as well as between-individual variation, ii) to investigate whether home range size or utilisation varies during the year and iii) to investigate the aspects of site fidelity.

2. MATERIALS AND METHODS

2.1. Study site

The study was conducted in Haukivesi basin of Lake Saimaa in eastern Finland (Figure 1). Lake Saimaa is a large lake complex with an area of 4 400 km^2, making Saimaa the fourth largest lake in Europe by surface area (Kuusisto 1999). It has a long shoreline of 14 900 km with 13 700 islands, which create a lake of labyrinthine nature. Saimaa is a relatively shallow lake (mean depth 12 m and maximum 85 m) with a catchment area of ca. 61 100 km^2. Water quality varies between different areas and basins. Period of ice cover begins normally in December, although exposed large water bodies may remain open until January. Ice melts usually in early May. Haukivesi basin has a maximum length of 80 km and an area of 500 km^2 (Rahkola-Sorsa 2008). Its average and maximum depth is 12 m and 50 m, respectively.

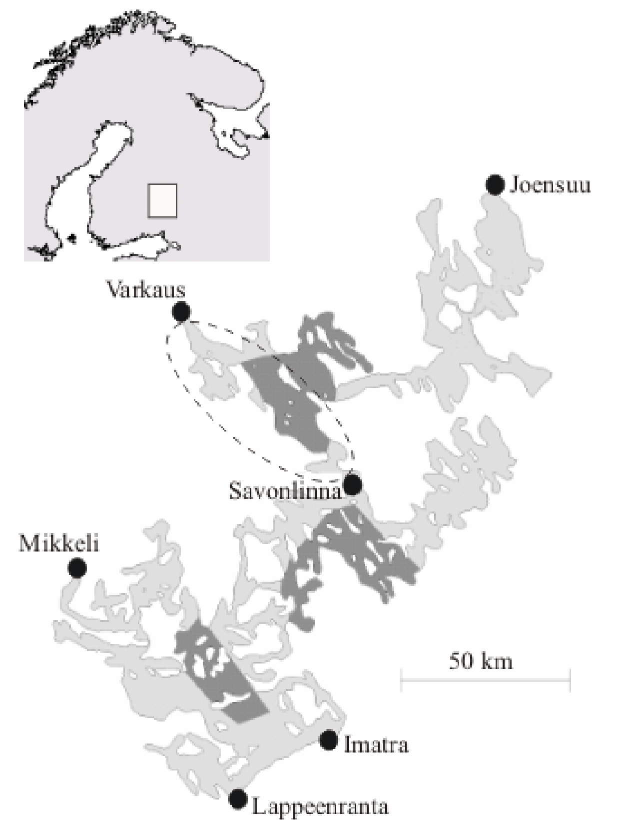

Figure 1. Lake Saimaa, its surrounding larger cities and primary breeding areas of the Saimaa ringed seal (dark grey). Haukivesi is indicated with a dashed line. (Modified from Palo 2003)

2.2. Data collection

Home ranges and movements of 5 free-ranging radio-tagged ringed seals were studied in years 1999-2000 and 2006-2007 (Table 1). In tracking period 1999-2000 2 Saimaa ringed seals (a juvenile male and an adult female) were tagged with VHF radio transmitters and followed until the transmitters dropped off. In tracking period 2006-2007 altogether 5 individuals were tagged, 2 of which were the same individuals as in tracking period 1999-2000. One of the females caught in May 2006 (EL06) was recaptured in May 2007 but the tag dropped off after 7 days due to moult. This data set is included in this study. Tagged individuals were named with 4-digit codes (e. g. EL06) where 2 letters indicate the individual and 2 numbers indicate the year when first captured and marked.

Seals were captured with nets from their haul-out sites in small bays during their annual moulting season in May. At moulting time in spring ringed seals are easier to be approached and caught as they are more unwilling to wet their fur, which would increase the time of the moulting. Long polyethylene gill nets (length 100 m and height 10 m, mesh size from knot to knot 150 mm) were used to enclose the passage from the bay and to catch the seal. After catching, seals were transported to land, weighed, measured and visually examined.

Two types of back mounted VHF radio transmitters were used (in 1999-2000: AML-465, Fintracker, 230 MHz and in 2006-2007: Backmount MM230, Advanced Telemetry Systems, Inc., 138 MHz). The transmitter was clued to dorsal fur with epoxy adhesive and placed at the middorsal line behind the widest part of the body. Seals were manually restrained during the operation. Dorsal transmitters were planned to last until the next annual moult and were active directly onwards from the time of the attachment. Four of five captured seals were tagged with dorsal transmitters in May 2006. Tagging was not possible for one female (MI99) that had no new fur at the time of capture. In spring 2006, additional radio transmitter (Temple tag MM430, Advanced Telemetry Systems, Inc., 138 MHz) was attached to the hind flipper of all five seals by making a small hole to the flipper and attaching a plastic holder through it. Seals were released after the operation. A duty cycle (2 days on/ 298 days off/ on forever) was programmed to the flipper transmitters to enable tracking in spring after the dorsal transmitters have dropped off. However, all flipper transmitters dropped off before the onset in spring 2007.

During the tracking periods, tagged individuals were located with three-element hand-held Yagi antenna and hand-held receivers (in 1999-2000: AOR 8000; in 2006-2007: ICOM IC-R20) at the minimum of 2 times/week. Time of the locating varied but was mainly conducted during the light hours of the day (Figure 2). Locationings were more concentrated near the hours of midday in the winter than in the summer. Position, time, behaviour and weather were recorded at the moment of locating an individual. Behaviour was divided into three categories: i) diving, ii) hauling out on rocks or iii) in the snow lair. Locationings were carried out from a small boat in summer, whereas in winter a snow mobile was used to move on the ice. However, locationings were carried out by walking and shorelines were not approached to avoid disturbance during winter. At periods of weak ice cover locating of the seals as frequently was not always possible and locationings were carried out from land. A visual sighting of the seal was targeted whenever conditions allowed, otherwise locationing was determined from the signal.

Table1. Periods of data collection from the capture to the date of the last locationing (Last signal) and the obtained sample sizes as number of locationings (Loc. No.) for the studied ringed seals (UR99, MI99, EL06, AL06, ON06) and selected data collection periods (Duration) and sample sizes as number of locationings (Loc. Nr.) for summer and winter home range analyses.

					Summer period		Winter period	
Tracking period	ID	Capture	Last signal	Loc. No.	Duration	Loc. No.	Duration	Loc. No.
1999-2000								
	UR99 ♂	26.5.1999	28.3.2000	54	26.5.-24.9.	34	10.11-28.3.	20
	MI99 ♀	25.5.1999	14.4.2000	70	25.5.-17.10	35	28.11.-14.4.	35
2006-2007								
	UR99	30.5.2006	29.4.2007	123	5.6.-29.9.	35	8.1.-30.3.	35
	MI99	27.5.2006	no tag	1	-	-	-	-
	EL06 ♀	21.5.2006	12.3.2007	113	5.6-29.9.	35	7.1.-20.3.	33
	AL06 ♀	27.5.2006	24.11.2006	53	6.6.-23.9.	35	-	-
	ON06 ♂	23.5.2006	8.11.2006	67	5.6.-29.9.	35	-	-
2007								
	EL06	19.5.2007	26.5.2007	7	-	-	-	-

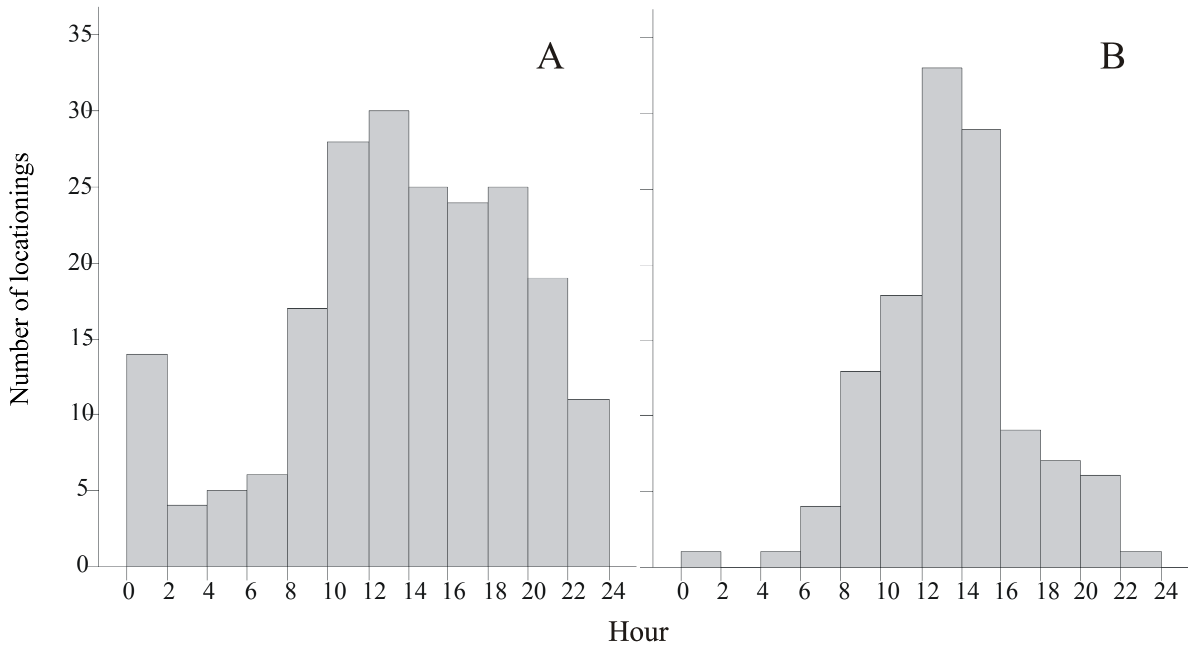

Figure 2. The frequency distribution of all collected locationings in study periods 1999-2000 and 2006-2005 (all studied seals combined) over day (24 hours) in the summer (A) and in the winter (B).

2.3. Home range size analyses

Home range can be defined simply as 'an area repeatedly traversed by an animal' in certain time period, thus including excursions which are from the area and back but enabling migrations and other unidirectional movement to be separated (Kenward 2001).

Two frequently used estimators, minimum convex polygon (MCP) and fixed kernel, were used in this study. Home ranges were analysed using Ranges 6 software (Anatarck Ltd.). MCP minimises the sum of link distances between edge locations (Kenward 2001). In this study, 95% of locations were included in the home range, thus 5% of observations were subjectively defined as outliers. To exclude this 5 %, a harmonic mean centre to peel furthest locations was selected. The harmonic mean centre is the location where the inverse reciprocal mean distance to all the other fixes is a minimum (Spencer and Barrett 1984).

Fixed kernel estimator is one of the estimators that base on densities of locations creating a utilisation distribution (UD), which describes the relative frequency distribution for the locationing data over a specific time period (Worton 1989). Thus, kernel method assesses an animal's probability of occurrence at each point in space (Kernohan *et al.* 2001). One advantage of UD methods is that a home range boundary is calculated by using the complete distribution of location data set rather than characterising the outermost set of points which for example MCP does. However, the method has also disadvantages such as poor comparability to other estimators as well as to other kernel estimates conducted with different settings (Kenward 2001). MCP on the contrary is more comparable to other studies (Harris *et al.* 1990). Due to these reasons both MCP and kernel estimators were used in this study. Boundaries for 95% and 50% utilisation distribution estimated with fixed kernel estimator were considered total home range and core area, respectively.

The bivariate kernel estimator works as follows (Worton 1989): a probability density function, kernel, is placed over each data point. The estimator is then constructed by summing up the kernel components. Thus, where there is a concentration of points, the kernel estimate has a higher density than where there are fewer points. The resulting estimate is a probability density function which can be presented as utilisation distribution (UD). The smoothing parameter (h) defines the bandwidth of the kernel in the kernel estimator (Seaman & Powell 1996). The reference smoothing parameter calculated by Ranges 6 is the standard deviation of rescaled x and y coordinates divided by the sixth root of the number of locations and in fixed kernel estimator the bandwidth is constant over the location data (Kenward 2001). First choice of the smoothing parameter *h* might overestimate the home range area when locations have strongly multimodal distribution (Seaman & Powell 1996). Smaller smoothing parameter values could be obtained by using least squares cross validation (LSCV) of the mean integrated error (Worton 1989). In this study, however, LSCV failed to find a suitable smoothing factor in almost all of the range analyses and thus the reference *h* was used despite its tendency to overestimation (Kenward 2001).

The home range estimates presented in this study include only water area as all the land area was excluded from the final results. The 3-dimensional structure of the home range estimates was investigated by interpolating the values in depth curves to a new raster layer in ArcMap version 9.3.1 (ESRI, Inc.). Then the mean depth (± standard deviation, SD) of this raster layer was calculated for the area of overlaying 95 % MCP home range estimate.

2.4. Dividing and selecting data for home range analyses

Home ranges are highly sensitive on the sample size and other subjective decisions (Kernohan *et al.* 2001). The relationship between home range size estimates and the number of locationings was examined to investigate the effects of sample size on the home range estimates and to assess the adequacy of the sample size (Kenward 2001). This was done by plotting home range size estimates as a function of all consecutive locationings of each seal (Figure 3). Consecutive locationings were added to the analysis in groups of five. Ideally, when no excursions are made, this yields an asymptotic curve where a point of 'sampling saturation' can be defined (Kenward 2001). This is a point where the phase of rapid growth is passed and increase in the sample size increases the area estimate only slightly. The point of sampling saturation was investigated by determining the first point in the curve where adding 5 consecutive locationings changed the area of home range estimate by less than 2 percents of the total home range area estimated. This was done to the data sets of each seal by using both MCP and kernel home range estimators. According to this definition, the first rapid growth periods of home range size estimates were passed before 35 locationings in both MCP and kernel estimators. After this, home range size estimates also grow very rapidly at some points but this is due to the individual migrations or other changes in the behaviour. Home range size estimates of some seals also decreased when consecutive locationings were added. In MCP this is due to the 95 % method used in the estimation: some locationings drop out of the analysis when new locationings are added, which in some case may decrease the size estimate. In kernel estimator, the size estimate may also decrease because adding locationings to the analysis changes the UD and thus the 95 % boundary of UD, which is used as a boundary for the home range. In the case of MI99, the decrease in the MCP home range size estimate was substantial when the number of consecutive locationings was increased from 25 to 30. This is a result of adding locationings to central areas of the home range when locationings during one long distance excursion at the beginning of the tracking period get excluded from the analysis. After this point, the home range estimate grows rapidly again in the incremental analysis curve due to the migration to the wintering area. In the home range analysis of this study, 34 locations for MI99 in the summer were used and thus the results are close to the lowest value in the incremental analysis and the long excursion is within the 5 % of locationings excluded in MCP.

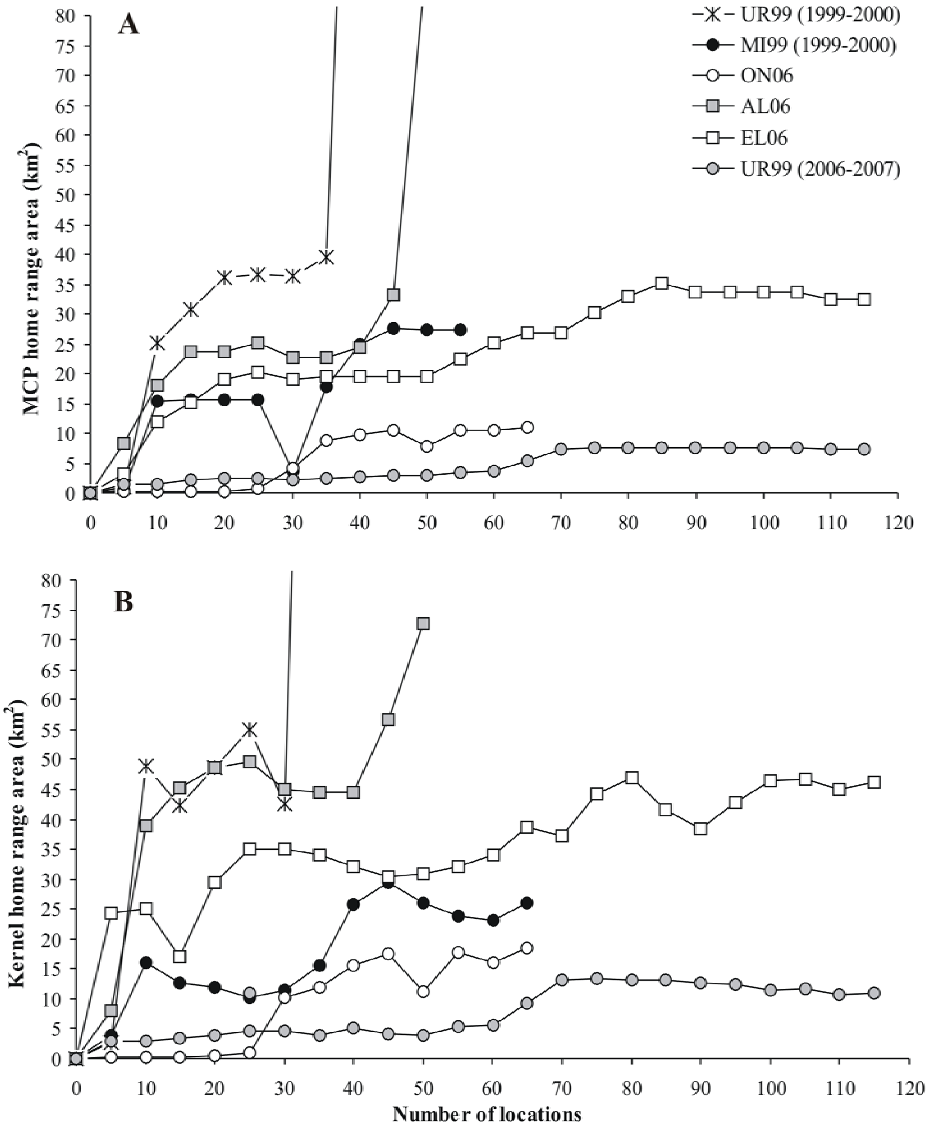

Figure 3. The 95 % MCP (A) and kernel (B) home range area estimates (km^2) of studied ringed seals (in years 1999-2000: UR99, MI99; in years 2006-2007: UR99, ON06, AL06 and EL06) in relation to the number of locationings used in the analysis.

However, home range size changes in relation to sample size in almost all the individual data sets which shows that setting certain fixed sample size for the home ranges is essential in order to be able to compare home ranges between seasons and between individuals. In this study, 35 locationings per summer and winter home ranges were selected when possible (Table 1). Both diving and hauling out locationings were used in the analyses. The time span of the data included within each period was chosen subjectively for each individual: firstly, by assuring sufficient number of data points if possible and secondly, by only including the period when no major changes in behaviour (such as migrations) were observed. The length of the study period (summer/winter) is not equal for each individual but only varies from 4 to 5 months in summer and 3 to 5 months in winter (Table 1). If there still were more than 35 locationings for a seal in the data set of the tracking period 2006-2007, one of all the locationings collected on the same day was randomly deleted from the data set until there were 35 locationings left. Data sets collected in years 1999-2000 (UR99 and MI99) were smaller and thus the whole individual data sets were divided into two periods by the time of the migration from summer home range to winter home range. This affects especially the duration of winter period in home range analyses: in tracking period 1999-2000, the winter period is from November until the drop of tags in March or April and in tracking period 2006-2007 the winter period is from January until the drop of tags in March or April. However, the winters were very different and in 1999-2000 the lake froze in the beginning of December and in 2006-2007 in the middle of January. Thus, in both tracking periods the selected months represent winter conditions quite equally and all the studied seals did not change their spatial behaviour substantially during these periods. Only 20 locations were obtained for UR99 during the winter period in the tracking period 1999-2000 and caution when interpreting those results should be taken.

2.5. Data handling and statistical analyses

Mean distance between consecutive locationings were used as a measure of movement during different seasons. This was done by selecting the distances that had 0-3 days between the two consecutive locations. The distances of all the individuals were then pooled and the mean distances for 4 different periods were calculated: June-September, October-December, January-March and April-May. The average number of days between locationings for each period was also calculated. June-September and January-March were consistent with the summer and winter periods in the home range analyses of seals tracked in 2006-2007 but differed somewhat to summer and winter periods of seals tracked in 1999-2000. No statistical analyses to compare these periods were done as the data did not meet the assumption of independence of observations.

Differences in home range and core area size estimates between summer and winter were examined with paired t-test or when data was not normally distributed with Wilcoxon signed rank test. Location data was handled using ArcMap and Microsoft Excel. Statistical analyses were done with Sigma Stat for Windows Version 3.5 (Systat Software, Inc.).

3. RESULTS

3.1. Home range and core area size estimates

The home range size estimates for the whole data set varied substantially between individuals with both minimum convex polygon (95 %) and fixed kernel (95 %) home range estimators (Tables 2 and 3). To consider the annual home range estimates, the results of ON06 and AL06 have to be left out due to the early detachment of the tags. Thus, the annual home range estimates for adult seals varied from 8 to 31 km^2 with MCP and from 10 to 41 km^2 with kernel estimator. However, the home range estimates of AL06 for all the data (May-November) were substantially larger than the recorded annual home range estimates indicating very likely also larger annual home range. The annual home range estimate of a subadult (UR06 in 1999-2000) was substantially larger than the annual home range estimates of adults seal in this study.

Mean summer home ranges estimated with both estimators were larger at summer than at winter (Tables 2 and 3). However, individual variation was substantial especially in summer home range estimates and no significant difference in the home range estimates of adult seals between periods were found with either estimators (paired t-test for MCP: t_2 =

0.0461, p = 0.69; paired t-test for kernel: $t_2 = 0.817$, p = 0.50). As a subadult, UR99 had substantially larger summer home range area estimate than other individuals. Also a subadult ON06 had relatively large home range area estimate. It is also noteworthy that kernel estimator gave somewhat larger home range estimates in general than MCP estimator.

The core area of home ranges was estimated with kernel (50 %) estimator. For the whole tracking periods there was substantial individual variation (Table 3). No significant differences between summer and winter core area size of adult seals were found (paired t-test, $t_2 = 0.284$, p = 0.80). In fact, the estimated core areas of adult seals were very similar in size. In all the t-tests the power of performed test with alpha 0.05 was less than 0.1.

Table 2. MCP (95 %) home range size estimates (km^2) of summer, winter and all tracking period (all data) for the VHF-tracked ringed seals (UR99, MI99, EL06, AL06, ON06). Mean home range estimates are presented for all individuals (Mean all) and for adults (*) (Mean adults) with 95 % confidence limits (± CL). The sample sizes and length of data collection are presented in Table 1.

		MCP home range (km^2)		
Tracking period	Seal	all data	summer	winter
1999-2000				
	UR99 ♂	115.5	35.6	2.7
	MI99 ♀ *	30.1	2.9	2.9
2006-2007				
	UR99 ♂ *	7.8	2.9	4.7
	ON06 ♂	8.4	7.9	
	AL06 ♀ *	85.5	15.2	
	EL06 ♀ *	26.4	6.4	2.1
	Mean all	46 ± 36	12 ± 10	3 ± 1
	Mean adults	37 ± 33	7 ± 6	3 ± 1

Table 3. Kernel home range (95 %) and core area (50 %) size estimates (km^2) of summer, winter and all tracking period (all data) for the VHF-tracked ringed seals (UR99, MI99, EL06, AL06, ON06). Mean home range estimates are presented for all individuals (Mean all) and for adults (*) (Mean adults) with 95 % confidence limits (± CL). The sample sizes and length of data collection are presented in Table 1.

		kernel home range (km^2)					
		all data		summer		winter	
Tracking period	Seal	95 %	50 %	95 %	50 %	95 %	50 %
1999-2000							
	UR99 ♂	179.5	76.7	37.0	12.5	3.8	1.1
	MI99 ♀ *	22.4	4.8	9.3	1.8	3.9	1.1
2006-2007							
	UR99 ♂ *	9.9	1.7	3.2	1.3	5.7	0.8
	ON06 ♂	15.1	0.5	14.7	1.4		
	AL06 ♀ *	62.8	4.6	26.6	1.8		
	EL06 ♀ *	40.6	4.7	11.2	0.6	8.4	1.4
	Mean	55 ± 51	16 ± 24	17 ± 10	3 ± 4	5 ± 2	1 ± 0
	Mean adults	34 ± 23	4 ± 1	13 ± 10	1 ± 1	6 ± 3	1 ± 0

3.2. Seasonal movements and differences in home ranges

Summer and winter home ranges were on clearly different areas and were not overlapping for MI99 and UR99 in study period 1999-2000 and for EL06 in study period 2006-2007 (Figure 4). However, in years 2006-2007 UR99 was encountered on the same area throughout the year. The distance between summer and winter home range centroids varied between individuals and in the case of UR99 also between years (Table 4).

The three-dimensional structure of the home range was investigated by comparing mean depths of the seasonal home range estimate areas (MCP 95 %). Mean depths of summer home ranges of the 3 individuals which made seasonal migration were statistically significantly deeper than winter home ranges ($t_2 = 15{,}746$, $p = 0{,}004$, Table 4). For UR99 in tracking period 2006-2007 the three-dimensional structure remained constant as the winter and summer home ranges were very similar and overlapping.

The combined seasonal mean distance between consecutive locationings for all the adult seals (years 1999-2000 and 2006-2007) was shortest in the winter (Figure 5). However, the mean distance between consecutive locations in the summer was only slightly longer compared to winter (1400 ± 390 m and 950 ± 290 m, respectively). In the autumn months (October-December) the mean distance between consecutive locations were longer (2240 ± 510 m), especially compared to winter.

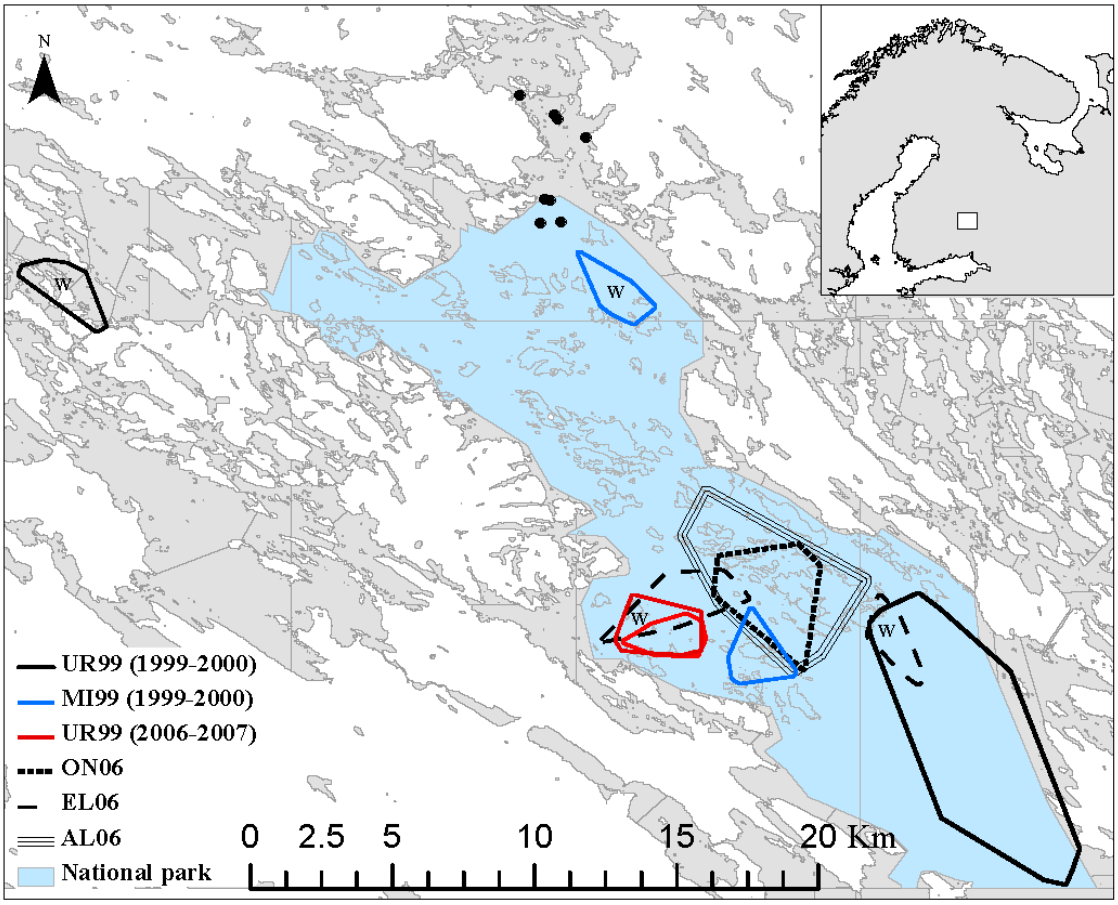

Figure 4. MCP (95 %) home ranges for summer and winter (W) of MI99, UR99 and EL99. For ON06 and AL06 only summer home ranges are presented. The last locations before the detachment of the tag of AL06 (in October and November) are indicated with black dots. Sample sizes and length of data collection in different seasons are presented in Table 1. (Map data: National land survey of Finland, permit no. 51/MML/10)

Table 4. Distance (km) between the centroids of summer and winter home ranges and the mean water depths (m) (± standard deviation, SD) of MCP 95 % home ranges for the studied ringed seals (UR99, MI99, EL06, AL06, ON06)

Tracking period	Seal	Distance (km)	Mean depth (m) Summer	Mean depth (m) Winter
1999-2000				
	UR99 ♂	35.7	15.1 ± 10.0	4.0 ± 2.2
	MI99 ♀	13.7	15.4 ± 9.5	6.5 ± 2.8
2006-2007				
	UR99 ♂	0.5	10.8 ± 5.8	11.1 ± 6.0
	ON06 ♂		12.3 ± 7.6	
	AL06 ♀		12.4 ± 8.1	
	EL06 ♀	7.7	18.2 ± 8.4	8.2 ± 6.4

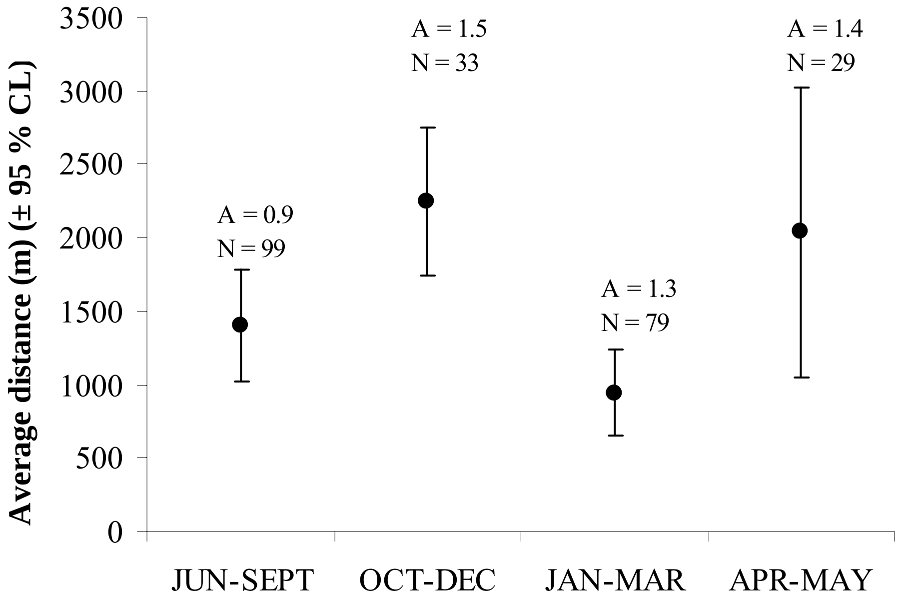

Figure 5. Seasonal average distances (m) between consecutive locationings for 4 adult ringed seals studied and all tracking periods (1999-2000 and 2006-2007). Only data points with 0-3 days between consecutive locationings were selected. Average numbers of days between locationings (A) and numbers of distance data points (N) are indicated above the bars.

3.3. Individual details

All the studied seals had several haul out sites based on the telemetry records (Figure 6). At open water period (1999-2000 May-November; 2006-2007 May-December, May 2007) 3-6 haul out sites for each adult seal were recorded. Subadults ON06 and UR99 had 3 and 9 haul out sites, respectively. In ice covered period (1999-2000: December-April; 2006-2007: January-April) adult seals were recorded to have 2-5 snow lairs and 0-2 other haul out sites on open ice. A female EL06 was observed to have ca. 5 snow lairs and one haul out site on an open ice after the collapse of the lairs. Two snow lairs were counted for female MI99. As an adult, the male UR99 had 3-4 snow lairs and after the collapse of the lairs it was observed to use 2 other haul out sites on the ice. As a subadult, UR99 was observed to have 2 haul out sites or lairs during the winter.

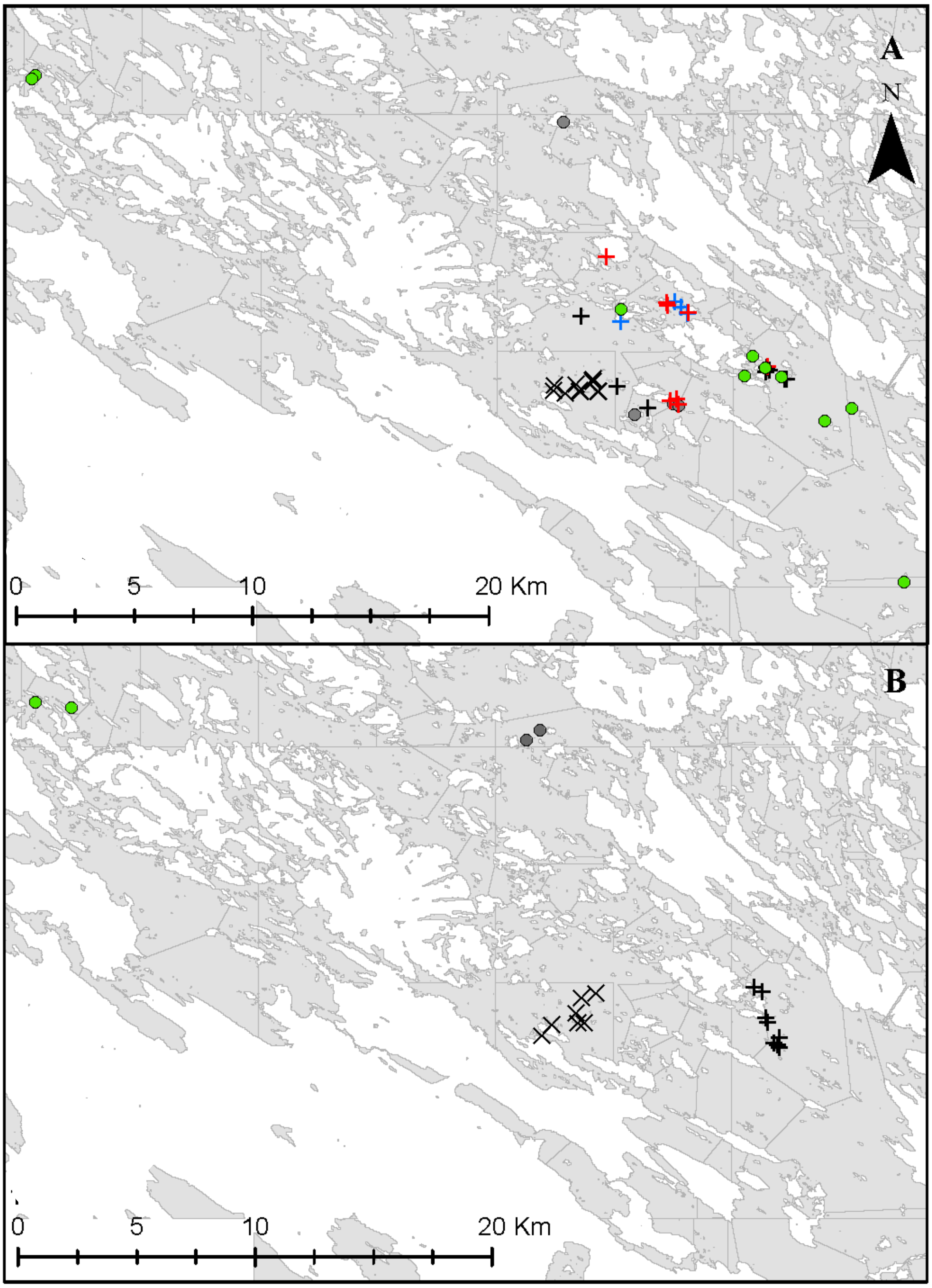

Figure 6. Haul out locations of all the 5 studied seals (UR99, MI99, AL06, EL06, ON06) in study periods 1999-2000 and 2006-2007. In 1999-2000: UR99 (green dot), MI99 (grey dot); in 2006-2007: UR99 (X), EL06 (black cross), AL06 (red cross), ON06 (blue cross). A: open water (1999-2000: May-November; 2006-2007: May-December and May 2007), locations of all studied seals hauling out on rocks and shores. B: ice covered period (1999-2000: December-April; 2006-2007: January-April), locations of seals hauling out in snow lair or on ice. (Map data: National land survey of Finland, permit no. 51/MML/10)

An adult female MI99 was located near its capture site in central parts of the national park almost throughout the summer and autumn until 10 November in year 1999 (Figure 7). A substantial part of the locationings was acquired when MI99 was hauling out. On 7- 8 June it was located hauling out 13 km north from its previous location, which later turned out to be MI99's winter home range. From 28 November onwards MI99 was located in its wintering grounds. MI99 had a snow lair in the centre of its winter home range and it gave birth during the study period. MI99 was in the snow lair during most of the locationing events. After the beginning of April MI99 was not found anymore and a stillborn pup was found inside the lair. MI99 was recaptured in 27 May 2006 in its summer home range near the place it had been captured previously (Figure 7A).

A clear change in the behaviour during the life span of a male UR99 was observed. UR99 was first caught in year 1999 and by the time it was a subadult. UR99 was moving relatively long distances during the summer and it had a wide home range (Figure 8). In the end of September UR99 was located in summer grounds for the last time and in November 1999 it was found 36 km southwest where it stayed over the winter. After the tag fell off in May 2000 it was observed hauling out with two other seals in the central parts of national park quite near its capture site in 1999. It was identified from the plastic ID tag attached to its flipper. In 2006-2007 UR99 was very stationary throughout the year and spent 95 % of its time in an area of 10 km^2 (95 % kernel) in the central parts of the Linnansaari national park throughout the year (Figure 9). It had 3 or 4 snow lairs. In spring after mid-April, UR99 was encountered hauling out on the remaining ice often with other adult seals. It was hauling out during the 6 locationings of the total of 7 locationings obtained between 22 April and 29 April (last locationing before the tag dropped off). In late May 2007 UR99 was re-captured and tagged in the same place as in 2006 (this data is not included in the study).

EL06, an adult female, was caught for the first time 21 May 2006. It was located in the central parts of the national park throughout the year (Figure 10). During the moult in May its haul out sites were clearly outside summer home range (Figure 10A). In the beginning of June a clear shift in the area occupied by the animal was observed. During the summer season (June-September) it was mostly encountered on an open and deep summer home range and only one haul out location was observed. Since 8 November 2006 it was mostly located near its wintering home range but it occasionally visited also the summer area. Based on the telemetry records, EL06 had about 5 snow lairs inside its winter home range in February and early March. It gave birth to a pup ER07. However, the snow conditions were very poor and already on 13 March EL06 and the pup were observed hauling out on the ice. It is not known weather EL06 gave birth in the lair or on the open ice after the lairs had collapsed. On 19 May 2007 EL06 was recaptured near the wintering grounds. It was located hauling out every day until the tag fell off after 7 days from the tagging. Haul out sites were not exactly same as in 2006, but they were still located quite near each other (Figure 10, Figure 6).

An adult female AL06 was located in the central area of the national park throughout the summer 2006 (Figure 11). However, in June it was not found on 6 occasions despite several hours of intensive search in the central areas of the national park. After July 7 AL06 was moving less based on the telemetry records and was mostly located on a relatively small area (core area, Figure 9B). At the end of September AL06 started moving more and was not found at all occasions when searched. In October AL06 moved about 14 km northwards and was encountered there until the tag dropped off in November.

A male subadult ON06 was only located on a very specific area at the end of the moulting season and beginning of summer (Figure 12). In 6 July ON06 moved to a more open and deeper water area nearby. In July (6.-20.), ON06 was moving longer distances between consecutive bearings until it settled near a group of islands from 26 July onwards (core area, Figure 12B).

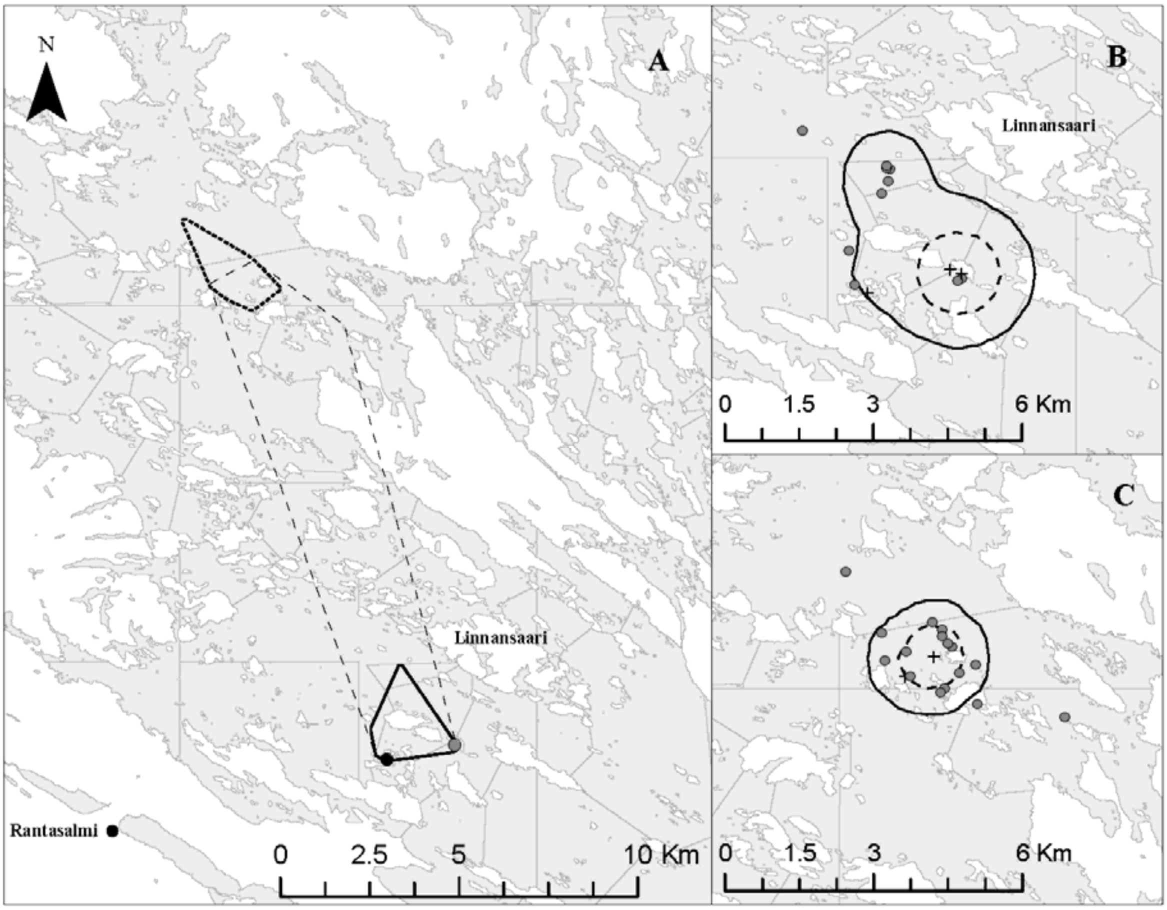

Figure 7. A (all data): all year, summer and winter MCP (95 %) home ranges for MI99 in years 1999-2000 and capture sites of 1999 (black dot) and 2006 (grey dot). (Summer= solid line, winter= dotted line, all data= dashed line). B (summer) and C (winter): seasonal home range (kernel 95 %, solid line) and core area (kernel 50 %, dashed line). Diving locationings= grey dots, hauling out locationings= crosses. (Map data: National land survey of Finland, permit no. 51/MML/10)

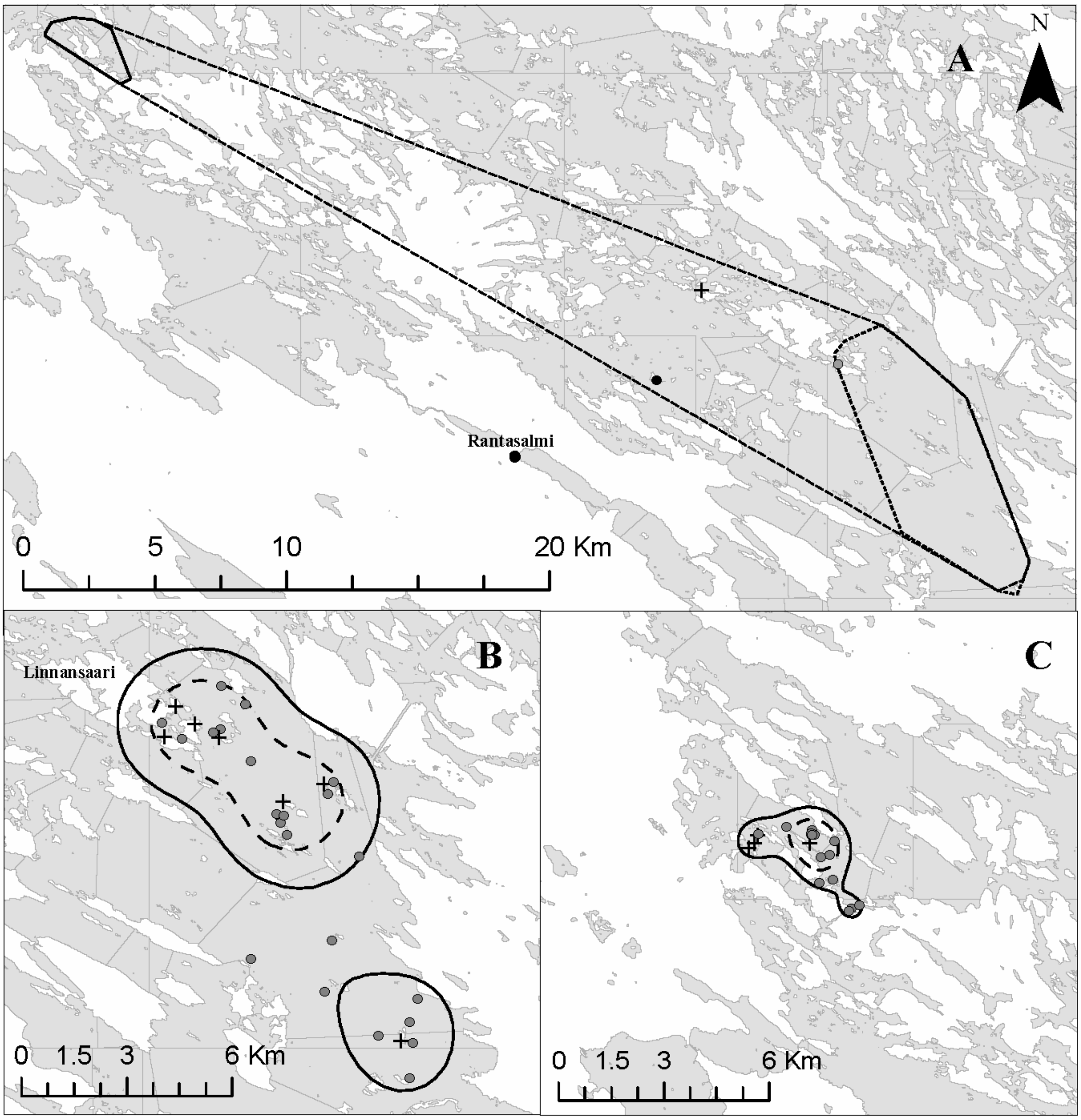

Figure 8. A (all data): all year, summer and winter MCP (95 %) home ranges for UR99 in years 1999-2000 (summer= dotted line, winter= solid line, all data= dashed line) and capture sites of May 1999 (grey dot) and May 2006 (black dot). Visually observed hauling out site after the detachment of the tag in 2000 is indicated with cross. B (summer) and C (winter): seasonal home range (kernel 95 %, solid line) and core area (kernel 50 %, dashed line). Diving locationings= grey dots, hauling out locationings= crosses. (Map data: National land survey of Finland, permit no. 51/MML/10)

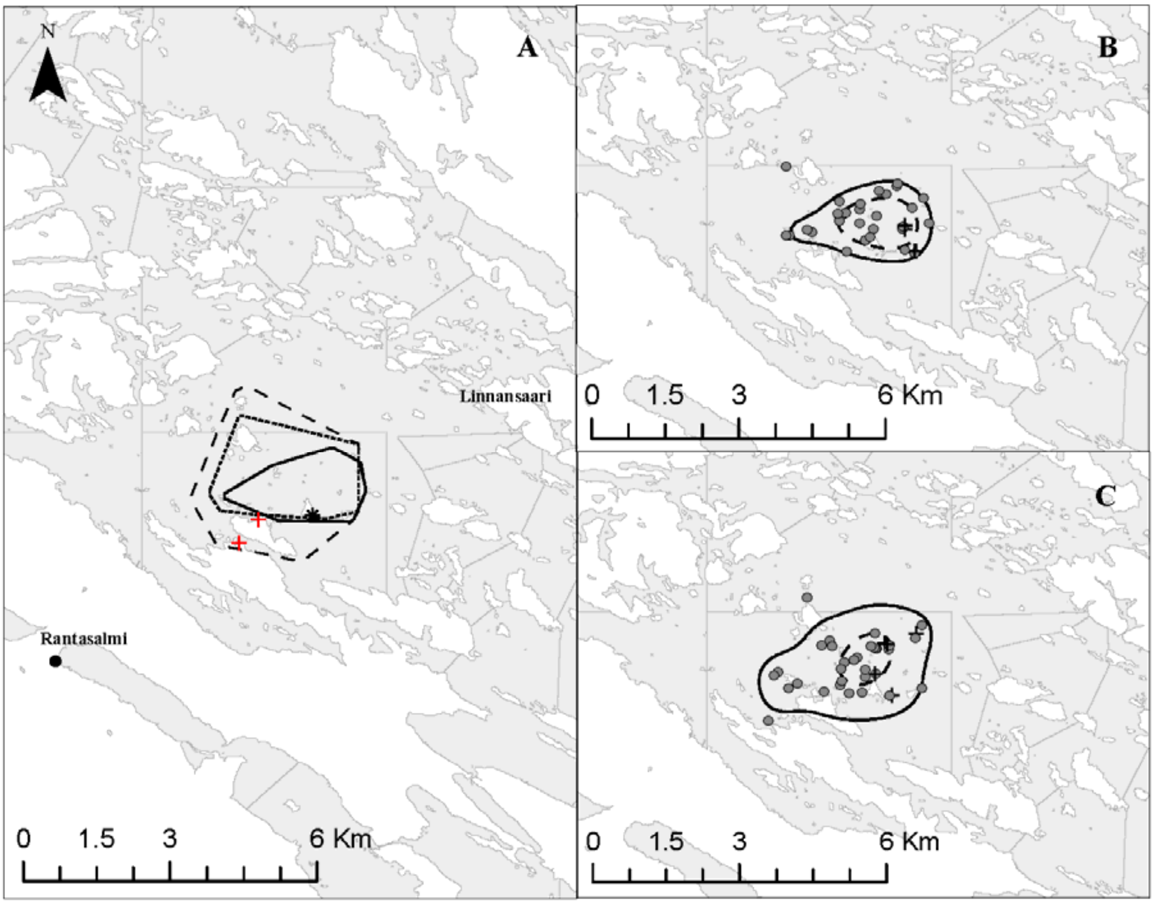

Figure 9. A (all data): all year, summer and winter MCP (95 %) home ranges for UR99 in years 2006-2007 (summer= solid line, winter= dotted line, all data= dashed line). Capture site in May 2006 and May 2007 is indicated with black asterisk and haul out sites of April 2007 with red crosses. B (summer) and C (winter): seasonal home range (kernel 95 %, solid line) and core area (kernel 50 %, dashed line). Diving locationings= grey dots, hauling out locationings= crosses. (Map data: National land survey of Finland, permit no. 51/MML/10)

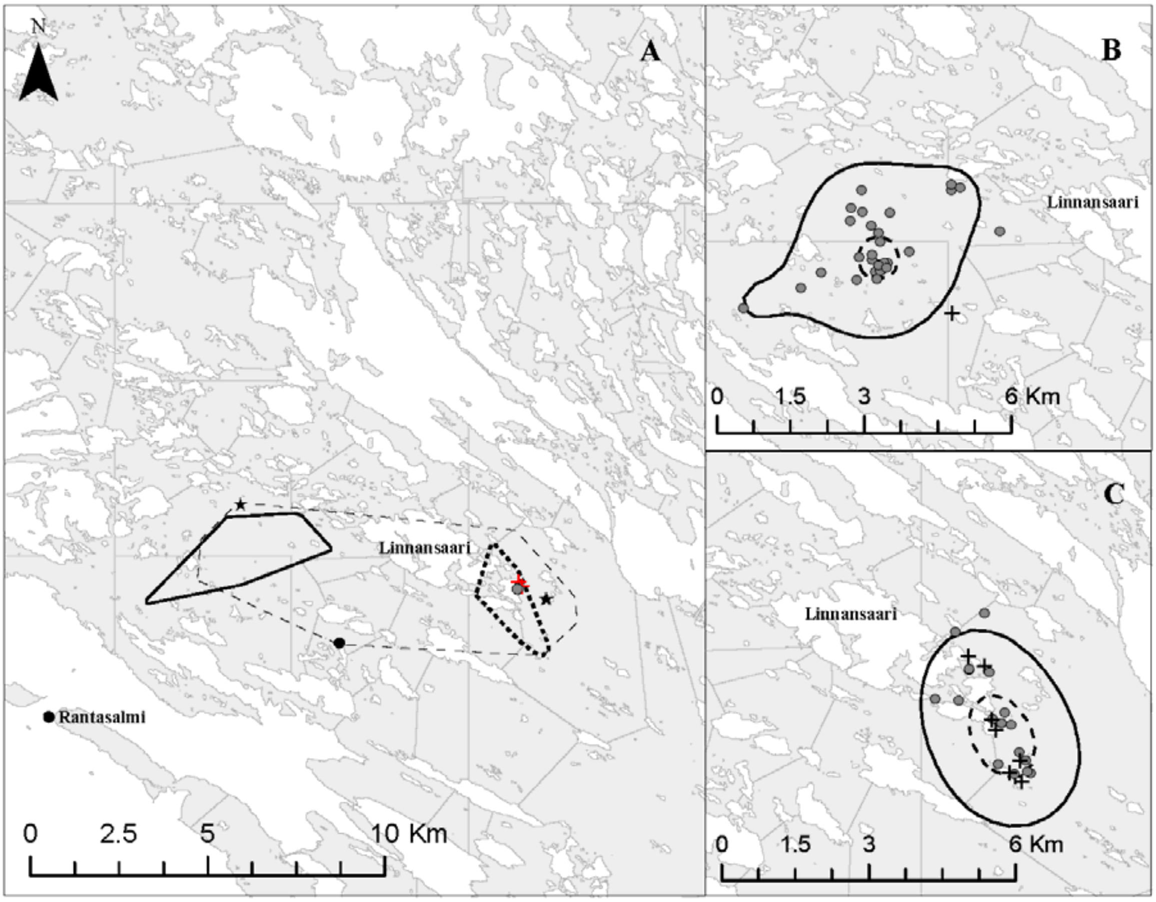

Figure 10. A (all year): summer and winter MCP (95 %) home ranges for EL06 in years 2006-2007 (summer= solid line, winter= dotted line, all data= dashed line). Capture site (black dot) and haul out sites (red cross) of May 2006 and capture site (grey dot) and haul out sites (black star) of May 2007. B (summer period) and C (winter period): seasonal home range (kernel 95 %, solid line) and core area (kernel 50 %, dashed line). Diving locationings= grey dots, hauling out locationings= crosses. (Map data: National land survey of Finland, permit no. 51/MML/10)

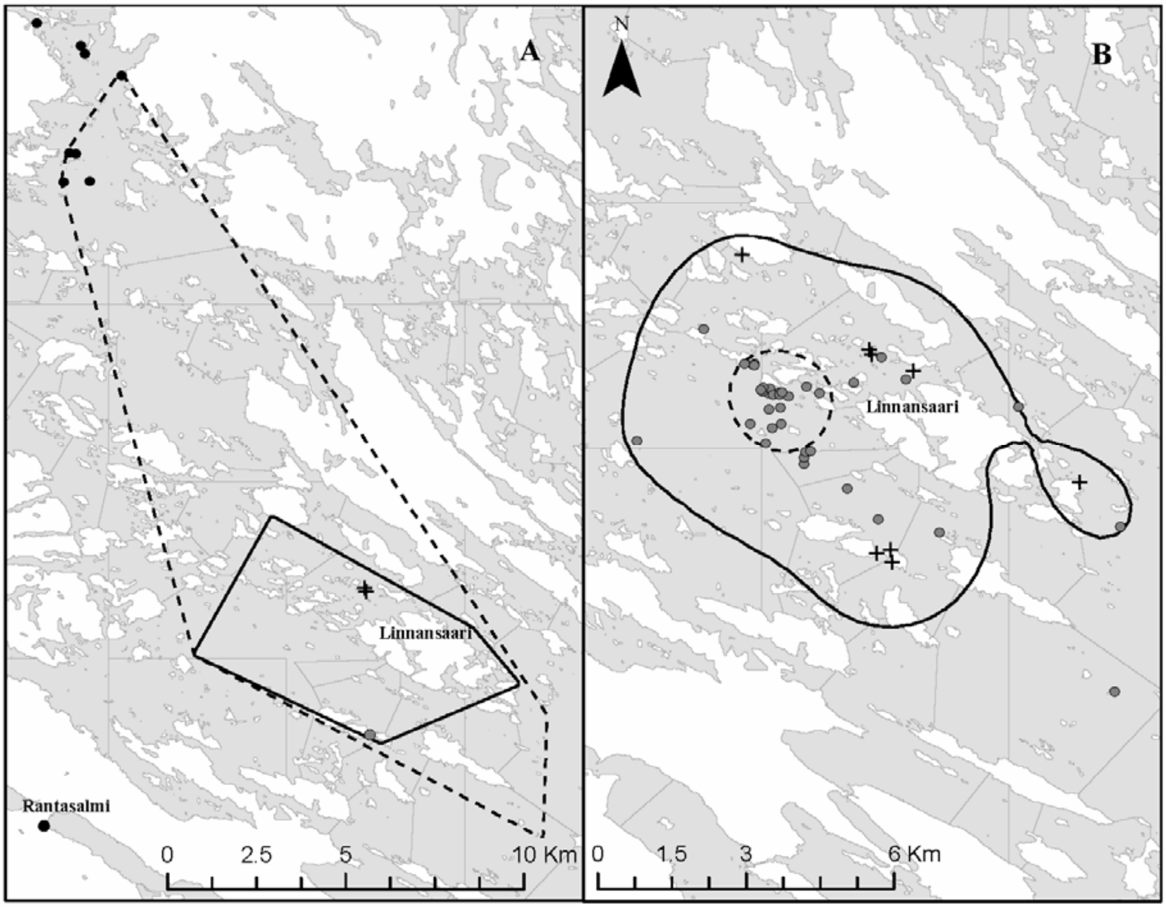

Figure 11. A (all data): MCP (95 %) home ranges for all data (dashed line) and summer (solid line) of AL06. The locationings in October and November after long migration and before detachment of the tag are indicated with black dots. Haul out sites of May 2006 are indicated with crosses. B (summer): seasonal home range (kernel 95 %, solid line) and core area (kernel 50 %, dashed line). Diving locationings= grey dots, hauling out locationings= crosses. (Map data: National land survey of Finland, permit no. 51/MML/10)

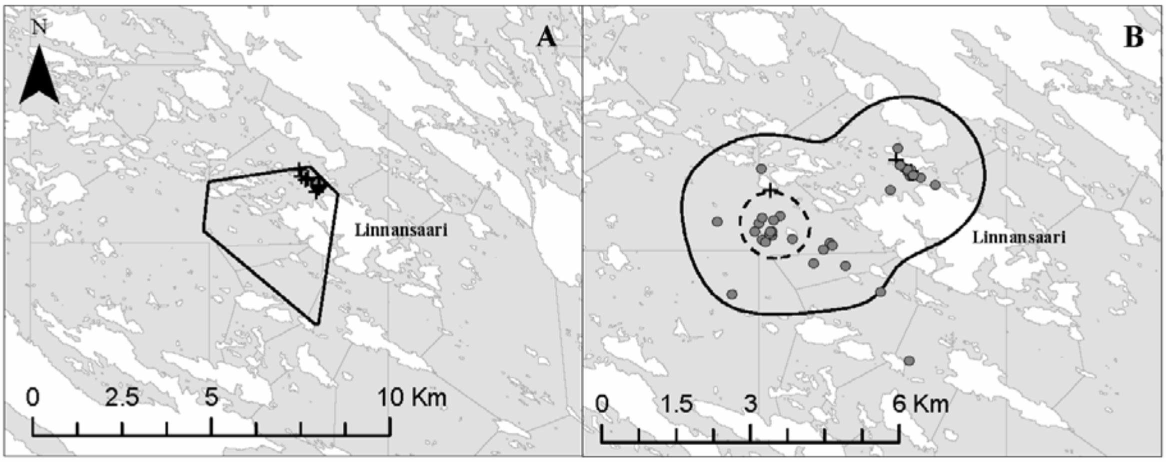

Figure 12. A (all data): MCP (95 %) home ranges for all data of ON06. Haul out sites of May 2006 are indicated with crosses. B (summer): seasonal home range (kernel 95 %, solid line) and core area (kernel 50 %, dashed line). Diving locationings= grey dots, hauling out locationings= crosses. (Map data: National land survey of Finland, permit no. 51/MML/10)

4. DISCUSSION

The main aim of this study was to investigate the spatial behaviour of the Saimaa ringed seal in detail. Movements of the Saimaa ringed seals were described by investigating the home range size, extent of seasonal migrations and suggested site fidelity. This study presents the first estimates on the Saimaa ringed seal home range size and gives insight into between-individual variation as well as seasonal patterns in the home range size and movements.

Two types of VHF-transmitters were attached to the studied individuals, backmounted transmitters and flipper transmitters. Backmounted transmitter proved to be relatively liable and provide robust information about the spatial behaviour of the Saimaa ringed seal. However, 2 backmounted tags dropped off at the time of first partial ice cover in November 2006. Reasons for the early detachment of the tags could be i) fur had grown under the clue during the late moulting and made the tag more transient and ii) weight gain during the summer and autumn months compared to moulting season (Ryg *et al.* 1990) stretches the skin, which might also make the tag more prone to fall off. The state of the moult around a certain date seems to vary individually. On May 21 2006 EL06 was tagged successfully and the tag stayed on until next March. On the contrary, MI99 was recaptured on May 27 2006 but it had no new fur. In contrast to backmounted transmitters, flipper transmitters proved to be very unreliable method to use in the conditions that seals experience in Lake Saimaa. All the flipper transmitters were detached before the onset of the duty cycle. The programmed duty cycle worked in all the flipper transmitters and they could thus be located. Apparently, the attachment with the plastic holder through a hole made to the flipper was not good enough. Two individuals (EL06, UR99) were also caught in the spring 2007 and markings in the flippers suggested that the plastic holder had slipped off. Attachment with a metal bolt through the plastic holder and the flipper has also been tried in Lake Saimaa in springs 2007 and 2008 but this has proven to be an equally unreliable technique.

4.1. Home range size and movements during seasons

Information of the area utilisation of the Saimaa ringed seal has been lacking. In this study, the estimated home range sizes were quite constant between open water and winter seasons (e. g. 95 % MCP: 3-36 km^2 in the open water season and 2-5 km^2 in the winter). However, some open water home range estimates were substantially larger than winter home range estimates. Subadults had quite large open water home range estimates whereas during the winter the home range of one studied subadult did not differ from the estimated home ranges of the adults. In general, movements of the Saimaa ringed seals during open water season are small compared to the arctic ringed seals, as was also shown by Koskela *et al.* (2002). In the study by Koskela *et al.* (2002), a male Saimaa ringed seal moved on an area of 20 km^2 and was observed to spend 90 % of its time within an area of 3 km^2. This is quite consistent with most of the open water home range estimates in this study, although the results are not exactly comparable. In comparison, ringed seal home ranges of even 49 000 km^2 during open water season have been reported in marine area between Greenland and Canada (Born *et al.* 2004). In the sea areas between Canada and Russia, ringed seals were observed to move on areas from tens to hundreds of kilometres during the open water foraging season (Kelly *et al.* 2010).

There is little knowledge on the home ranges and movements of other fresh water seals. Winter time home ranges less than 0.5 km^2 have been recorded for the Baikal seals (Phoca sibirica) (Martínková *et al.* 2001). In the marine areas, breeding time home ranges in the area of landfast ice in the coast of Alaska were recorded to be less than 3 km^2 in 94

% of the studied ringed seals (Kelly *et al.* 2010). In studies by Martínková *et al.* (2001) and Kelly *et al.* (2010), the home ranges were estimated on the basis of haul out locations on the ice and may thus not be exactly comparable but a little smaller to the home range estimates in this study. Nevertheless, this indicates that in the areas of stable fast ice, ringed seals may have quite restricted home ranges as well in the freshwaters as in the marine environment. The home range area is likely to be restricted by the maintaining of the breathing holes which provide access to the air above and food sources below. In contrast, in the arctic marine area which remains partially open during the winter, the meta-home range estimate for 2-3 ringed seals combined were recorded to range from 2500 to 7000 km^2 and this indicates also larger individual home ranges (Born *et al.* 2004).

Despite individual variation in the summer home ranges, small individual variation found in the core areas of adult seals indicates that these individuals spent substantial part of their daytime in a quite small area during both open water and winter seasons. The movements done outside this centre of activity were varying individually and as a result the home range estimates have more variation. However, the average movements made in these seasons seem similar in length when comparing the mean distances of consecutive locations between seasons although longer excursions were observed only in summer.

The home ranges reported in this study reflect more or less the space use during light hours of the day. Some differences to them might be expected if the observations were more evenly distributed throughout the day as the Saimaa ringed seal is known to have clear diurnal activity pattern and after the annual moult in the spring it is hauling out mainly during night (Kunnasranta *et al.* 2002). However, some observations were obtained also during dark hours and they did not indicate any large scale differences in the space use. The reported seasonal home range estimates also indicate the areas mostly visited by the animal even though they might exclude some areas of less importance. For example some excursions remained unrecorded because of the sampling protocol. There were some incidents where an individual was searched for days but then again encountered inside its home range and therefore the excursion was not recorded. The possible excursions made between the locationing sampling days also remained unnoticed. It can be concluded, however, that as sampling of the locationings was done quite randomly, the seasonal home range estimates reflect the actual space use during the daytime.

The main focus in this study has been in comparing the seasonal home ranges as both home range estimators were very likely overestimating the annual home range size for the migrating seals to some extent. Annual MCP home range estimations might contain substantial areas where the animal actually never visited between the two seasonal home ranges and kernel estimator also tends to overestimate especially when the distribution of locationings is multimodal (Seaman & Powell 1996), as is the case in migrating seals. Despite the possible overestimation, however, the annual home range estimates give indication of the total area used by the animal during the year.

In conclusion, home range size estimates were quite consistent between open water and winter seasons. In summer, however, there was more individual variation in the overall home range sizes. Maintaining the breathing holes during winter limits the extent of movements and excursions, which seems to be the case in several water areas with persistent winter ice cover. At open water season, the seals are less limited by such physiological and physical constrains as in winter and individual variation can play greater role in the sizes of the home range.

4.2. Seasonal migrations and site fidelity

Unlike suggested in a previous study by Koskela *et al.* (2002), this study indicates that the Saimaa ringed seals can make seasonal migrations between summer and winter grounds. In this study, only one of the three throughout the year studied individuals spent the whole year at clearly the same area (UR99 in years 2006-2007). Both adult females and UR99 as a subadult were observed to make seasonal migrations from summer to winter home range and to have clearly distinct seasonal home ranges. It is also very likely that the migration that AL06 did in October 2006 just before the detachment of the transmitter was from the summer home range to the wintering home range. In contrast, Koskela *et al.* (2002) made observations of 5 Saimaa ringed seal individuals during the winter months and they were all encountered at the same area as in summer. In the Arctic marine areas, seasonal migrations of ringed seals usually range from tens to hundreds of kilometres but migrations over 1000 kilometres have also been recorded (Heide-Jørgensen *et al.* 1992, Kapel *et al*. 1998, Teilmann *et al.* 1999, Gjertz *et al.* 2000, Born *et al.* 2004, Freitas *et al.* 2008, Kelly *et al.* 2010). Adult ringed seals can also be quite sedentary (Gjertz *et al.* 2000, Freitas *et al.* 2008, Härkönen *et al.* 2008, Kelly *et al.* 2010). In fact, in Spitsbergen ringed seals are suggested to have two large-scale movement tactics related to foraging: they either stay near the fjord systems moving relatively little throughout the year or leave to offshore areas for the open water season making more extensive migrations (Gjerz *et al.* 2000, Freitas *et al.* 2008). Therefore, it can be concluded that Saimaa seals are not necessarily site faithful throughout the year, but can have distinct home ranges in different seasons. They can make seasonal migrations, although not to the same extent as in marine areas, and there is little doubt that these seasonal migrations vary among individuals.

This study adds to the existing evidence that immature Saimaa ringed seals might do longer migrations and in general move more compared to adults (Koskela *et al.* 2002, M.Sc. Marja Niemi, University of Joensuu, unpublished manuscript). Immature ringed seals in the Arctic as well as juvenile Baikal seals are reported to make extensive migrations (Stewart *et al.* 1996, Teilmann *et al.* 1999, Freitas *et al.* 2008). In the case of arctic ringed seals, superior foraging skills and knowledge of an area or superior dominance were suggested to be the reasons why adults moved less than juveniles outside the breeding and moulting seasons (Freitas *et al.* 2008). The longer movements exhibited by a subadult (UR99) in this study might reflect a lack of knowledge of the resources making the seal to explore its habitat to greater extent. The role of dominance could also contribute to the movements of juveniles in Lake Saimaa, especially during the breeding season. The ringed seals are suggested to be territorial at winter and the territory of a breeding male contains either one or a few female territories (monogamous or polygynous) (Smith & Hamill 1981). A subadult UR99 moved away from the central breeding sites of Haukivesi region and spent the winter outside the principal breeding area of Haukivesi. At the spring when the territoriality is suggested to cease, UR99 was observed again in the central parts of Linnansaari National park. The winter home range was situated in an area of a channel, where flow of the water kept the ice thin or absent from the area. Therefore, the observed behaviour could also be the result of individual habitat selection: a young nonbreeding male does not necessarily need a very persistent ice and snow cover but it can be energetically better to stay in the place where the ice remains naturally open making the breathing holes easier to maintain. However, a subadult ON06 was not observed to move as much as UR99 during the summer period. ON06 had the third largest home range, but in fact, was very stationary most of the time. Unfortunately the tag dropped off and the winter movements of ON06 were not recorded. In conclusion, immature Saimaa seals might make longer movements than adult seals but individual variation likely plays a major role in this and larger data sets are needed to make firm conclusions.

In contrast to juvenile seals, adult ringed seals are considered very sedentary (f. e. Koskela *et al.* 2002). Site fidelity is a term that can be used on many different spatial scales. In this study, I refer to the fine-scale site fidelity inside different basins of Lake Saimaa. On a larger scale, all individuals showed site fidelity to the basin they were captured (Haukivesi basin). Although fine-scale site fidelity throughout the year was not observed in other individuals than UR99 in this study, site fidelity to moulting sites was supported. Site fidelity between years in moulting areas has been reported also previously (Koskela *et al.* 2002). However, the exact moulting sites varied slightly in the studied individuals in this study while the overall area still remained quite the same. This could be due to the search of optimal moulting sites in relation to changes in ice cover, water level and wind directions for example. Ringed seals are observed hauling out in vicinity of other individuals on moulting time and many individuals may use the same rocks or same shores (Koskela *et al.* 2002, S. Oksanen, own personal observations). Therefore, also some kind of social behaviour may be involved in choosing the moulting site.

Site fidelity to breeding grounds has also been suggested (Helle *et al.* 1984, Sipilä 1990). UR99 was re-captured again in May 2007 and the results, although not presented in this study, showed very similar movement and behaviour patterns between years (M.Sc. Marja Niemi, University of Joensuu, unpublished data). Adult ringed seals are reported to show site fidelity to breeding and moulting sites also in the Arctic despite they might migrate to other areas to forage during late summer and autumn (Smith & Hamill 1981, Kelly *et al.* 2010). Also Baltic ringed seals are reported to be site faithful to different parts of the Baltic Sea, although more fine-scale fidelity has not been reported (Härkönen *et al.* 2008). Site fidelity to breeding and moulting sites is supported in many studies, yet many aspects of site fidelity between years remain unclear. It can be asked based on the observations of this study: how constant movement patterns adult seals have between years? Do they show site fidelity to the summer home ranges as well as to breeding and moulting sites? What is the role of individual variation in site fidelity of the Saimaa ringed seals?

4.3. Habitat selection

The observed seasonal movements raise the question of habitat selection: what kind of environmental factors contribute to the choice of habitat in different seasons? All three observed females made seasonal movements from summer home range to winter home range. It has been proposed that arctic ringed seal females would maximise their reproductive success by choosing a stable ice platform for breeding (Krafft *et al.* 2007) as the lair protects the pup from cold and predators as well as human disturbance (Smith & Stirling 1975). The ideal ice platform must therefore form well before the breeding to ensure the accumulation of snow drifts in the shores of mainland, islands or islets. Lairs of the Saimaa ringed seal are also typically situated to the northern to eastern shores which are more shaded and therefore more likely to last longer (Helle *et al.* 1984). Summer home ranges of all the females in this study were on the same exposed and open water area in the heart of the Linnansaari national park. This area remains open relatively long due to the winds and wave action. Thus, it is very likely, that the females migrated to the areas more suitable for breeding and were relying either on the environmental cues or on the former knowledge in selecting the wintering grounds. Availability of prey is also suggested to be a crucial factor in the search of optimal breeding habitat for the ringed seal (Kelly *et al.* 2010). Lactating ringed seal females are known to make frequent foraging dives in contrast to fasting which is reported in many other phocid seals (Kelly & Wartzok 1996, Lydersen & Kovacs 1999). Snow lairs of the Saimaa ringed seal are typically situated near to open and deep waters, which might reflect the importance of feeding during winter period (Helle *et al.* 1984). Also in this study, the lactating females were observed to dive in the vicinity of the lair and it is likely that this behaviour was related to foraging.

As an adult, a male (UR99) had a home range in the central parts of main breeding area of Haukivesi throughout the year. It was recaptured in the study period 2007-2008 and it stayed on the same area and showed very similar behaviour patterns as in the previous study year (M.Sc. Marja Niemi, University of Joensuu, unpublished data). This could indicate dominance of the old male, as it can be speculated that the quality of the home range was so good that UR99 could spent the whole year at the same quite limited area and the environmental conditions met its biological requirements throughout the year. At winter, UR99 had several snow lairs. At least two birth lairs were found quite near to home range of UR99 in winter 2006-2007 (Rautio *et al.* 2009). Therefore, at the home range of UR99 there were places where sufficient snow accumulates for lairs and females are present. The morphology of the home range was variable containing underwater slopes and deep areas probably suitable for foraging, in addition to the islands and islets of shallower water and snow drift accumulation. The annual home range was somewhat larger than summer and winter home ranges mainly because at autumn UR99 was moving outside its seasonal home ranges and at April it was hauling out on the remaining ice in sheltered and shaded location outside its seasonal home ranges.

Summer home ranges were in general deeper than winter home ranges. Also Baltic ringed seals were reported to move from shallow areas in late May to deeper waters (over 20 m) (Härkönen *et al.* 2008). This might indicate the importance of foraging during the summer and autumn months after losing weight in nursing and moulting. Adult Saimaa ringed seals forage mainly on the deeper offshore waters and typically foraging dives are to 17 m on average (Kunnasranta *et al.* 2002). Adult seals are assumed to prefer vendace (*Coregonus albula*) and smelt (*Osmerus eperlanus*) but as an opportunistic feeder the Saimaa ringed seal is reported to prey also on other schooling fish (Kunnasranta *et al.* 1999). Vendace and smelt are known to make up the majority of fish density and biomass in the pelagic area of Finnish boreal lakes and to spend the day time in depths of over 15 m (Jurvelius *et al.* 1988, Jurvelius *et al.* 2005). This is consistent with the average foraging depths of the Saimaa ringed seal during the open water season. The observed fine-scale movement in the beginning of July of subadult ON06 from shallow waters to the more open water area could indicate a shift in the diet. After the movement, ON06 was observed diving on an underwater slope very near to places where an adult female (AL06) was constantly diving and very likely foraging.

The results from this study provide information on the spatial ecology of the Saimaa ringed seal that can be used in planning the conservation actions of this unique freshwater seal. The population size estimates of the Saimaa ringed seal are based on annual lair countings during the spring and these results of the winter home range size can help in interpreting the lair data better. The growing tourism and other human activities around the lake are very likely to increase human caused disturbance on the Saimaa ringed seal. These results on the seasonal migrations of the ringed seals indicate that in order to plan conservational strategies information of the distribution of local populations in different seasons is needed. Adult seals are not as sedentary as previously thought but can do seasonal migrations and juvenile seals can move substantially more than adults. For example, to conserve the resting sites of the Saimaa ringed seal as is required in the habitats directive of European Union, information concerning haul out sites outside breeding seasons is needed.

This thesis presents the first results on the home ranges of Saimaa seals during winter and further information of several other individuals is clearly needed. Also information of the same individuals in different years is valuable in assessing the question of site fidelity. Saimaa ringed seals are known to have clear diurnal behaviour during open water but it is not yet known whether the same patterns in behaviour exist also in winter. The observed seasonal movements raise also the question of habitat selection: what kind of environmental factors contribute to the choice of habitat in different seasons? This kind of knowledge is crucial for understanding the biological requirements of the species and predicting the changes in environment to the status of the species. I recommend that in future studies the habitat selection of Saimaa ringed seals could be examined with satellite telemetry. With information on more fine scale movements, possible impacts of human disturbance in the habitat selection could also be studied. As the VHF-telemetry is proved to be quite liable and robust method to observe the overall movements of Saimaa ringed seals, I also suggest that satellite telemetry data could be used to assess the amount of possible bias, f. e. caused by the uneven distribution of sampling over the day, in the data sets collected with VHF-telemetry. This information could also be used in comparing the results obtained with different telemetry methods.

4.4 Conclusions

This study gives the first records of the Saimaa ringed seal habitat use throughout the year. Home range size estimates were quite consistent between the open water and winter seasons but there were more between-individual variation in the summer home range estimates. Maintaining the breathing holes during winter limits the extent of movements and excursions, which seems to be the case in several water areas with persistent winter ice cover. In contrast, during open water season, the seals are less limited by such physiological and physical constrains and individual variation can play greater role in the sizes of the home range.

The results of my study indicate that the Saimaa ringed seals show site fidelity to moulting and breeding areas, as has been also previously suggested. However, the results of this study also indicate that some Saimaa ringed seals are not necessarily as sedentary throughout the year as previously suggested but they can do seasonal migrations between summer and winter home ranges. Despite the fact that these migrations are small compared to the extent of those reported in marine areas, they can have important implications to the conservational strategies as well as future research challenges of the Saimaa ringed seal.

ACKNOWLEDGEMENTS

I want to thank my supervisors Marja Niemi and Mervi Kunnasranta for enabling me to do this work and introducing me to the fascinating world of the Saimaa ringed seal. I want to thank also my supervisor Timo Marjomäki in the University of Jyväskylä for valuable comments in improving my writing. This study was done as part of larger Saimaa ringed seal research project in Ecological Research Institute, University of Joensuu and I wish to thank the institute and all personnel involved in the project. I would also like to thank the other members of the field work team in 2006-2007 for nice and instructive days on field: Terho Laitinen, Päivi Paavilainen, Ari Kirjavainen, Anni Rautio, Juha Taskinen and Oskari Laitinen. I want to thank also Anssi Lensu from the University of Jyväskylä for helping with ArcGis. Many thanks also to Jari Syväranta for being my unofficial home supervisor. I am very thankful to Nestori-säätiö, Vanamo ry., Societas pro Fauna et Flora

Fennica, Kauko Haikaraisen Säätiö and Elma, Eino ja Veikko Jumppasen Säätiö for the financial support to do the field work and writing.

REFERENCES

Amano M., Hayano A. & Miyazaki N. 2002. Geographic Variation in the Skull of the Ringed Seal, Pusa hispida. *J. Mammal.* 83: 370-380.

Anonymous 1991a. Asetus Neuvostoliiton kanssa Saimaan ja Vuoksen juoksutusäännöstä tehdyn sopimuksen voimaansaattamisesta ja sopimuksen eräiden määräysten hyväksymisestä sekä sopimuksen soveltamisesta annetun lain voimaantulosta. http://www.finlex.fi/fi/sopimukset/sopsteksti/1991/19910091 (8.4.2010)

Anonymous 1991b. Rantojen suojeluohjelman alueet. Selvitys 97/1991. Ympäristöministeriö, ympäristönsuojeluosasto, Helsinki, 142 p.

Anonymous 1992. Council directive 92/43/EEC. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:1992L0043:20070101:EN:HTML (8.4.2010)

Anonymous 2004. Maa- ja metsätalousministeriön asetus eräistä kalastusrajoituksista Saimaalla 258/2004. http://www.finlex.fi/fi/laki/alkup/2004/20040258 (8.4.2010)

Born E.W., Teilmann, J., Acquarone M. & Riget F.F. 2004. Habitat use of ringed seals (Phoca hispida) in the North Water Area (North Baffin Bay). *Arctic* 5: 129-142.

Forstén A. & Alhonen P. 1975. The subfossil seals of Finland and their relation to the history of the Baltic Sea. *Boreas* 4: 143-155.

Freitas C., Kovacs K., Ims R.A., Fedak M.A. & Lydersen C. 2008. Ringed seal post-moulting movement tactics and habitat selection. *Behav. Ecol.* 155: 193-204.

Gjertz I., Kovacs K.M., Lydersen C. & Wiig O. 2000. Movements and diving of adult ringed seals (Phoca hispida) in Svalbard. *Polar Biol.* 23: 651-656.

Harris S., Cresswell W.J., Forde P.G. Trewhella W.J., Woollard T. & Wray S. 1990. Home-range analysis using radio-tracking data – a review of problems and techniques particularly as applied to the study of mammals. *Mammal Rev.* 20: 97-123.

Heide-Jørgensen M.P.H., Stewart B.S. & Leatherwood S. 1992. Satellite tracking of ringed seals Phoca hispida off northwest Greenland. *Ecography* 15: 56-61.

Helle E., Hyvärinen H. & Sipilä T. 1984. Breeding habitat and lair structure of the Saimaa ringed seal *Phoca hispida saimensis* Nordq. in Finland. *Acta Zool. Fennica* 172: 125-127.

Hyvärinen H. & Sipilä T. 1984. Heavy Metals and High Pup Mortality in the Saimaa Ringed Seal Population in Eastern Finland. *Mar. Pollut. Bull.* 15: 335-337.

Hyvärinen H. & Nieminen M. 1990. Differentiation of the ringed seal in the Baltic Sea, Lake Ladoga and Lake Saimaa. *Finnish Game Research.* 47: 21-27.

Hyvärinen H., Hämäläinen E. & Kunnasranta M. 1995. Diving behavior of the Saimaa ringed seal (Phoca hispida saimensis Nordq.). *Mar. Mammal Sci.* 11: 324-334.

Hyvärinen H., Sipilä T., Kunnasranta M. & Koskela J. 1998. Mercury Pollution and the Saimaa Ringed seal (*Phoca hispida saimensis*). *Mar. Pollut. Bull.* 36: 76-81.

Härkönen T., Jüssi M., Jüssi I., Verevkin M., Dmitrieva L., Helle E., Sagitov V. & Harding K.C. 2008. Seasonal Activity Budget of Adult Ringed Seals. *PloS ONE* 3: e2006. DOI: 10.1371/journal.pone.0002006

Jurvelius J., Lindem T. & Heikkinen T. 1988. The size of a vendace, *Coregonus albula* L., stock in a deep lake basin monitored by hydroacoustic methods. *J. Fish Biol.* 32: 679-687.

Jurvelius J., Auvinen H., Kolari I. & Marjomäki T. 2005. Density and biomass of smelt (*Osmerus eperlanus*) in five Finnish lakes. *Fish. Res.* 73: 353-361.

Kapel F.O., Christiansen J., Heide-Jørgensen M.P., Härkönen T., Born E.W., Knutsen L.Ø., Riget F. & Teilmann J. 1998. Netting and conventional tagging used to study movements of ringed seals (*Phoca hispida*) in Greenland. In: Heide-Jørgensen M.P. & Lydersen C. (eds.), *Ringed seals in the North Atlantic*, The North Atlantic Marine Mammal Comission, 211-228.

Kelly B.P. & Wartzok D. 1996. Ringed seal diving behavior in the breeding season. *Can. J. Zool.* 74: 1547-1555.

Kelly B.P., Badajos O.H., Kunnasranta M., Moran J.R., Martinez-Bakker M., Wartzok D. & Boveng P. 2010. Seasonal home ranges and fidelity to breeding sites among ringed seals. *Polar Biol.* [In Press.]

Kenward R.E .2001. *A Manual for Wildlife Radiotagging*. Academic press, London, 311 p.

Kernohan B.J., Gitzen R.A. & Millspaugh J.J. 2001. Analysis of animal space use and movements. In: Millspaugh J.J. & Marzluff J.M. (eds.), *Radio tracking and animal populations*, Academic press, San Diego, 125-166.

Koskela J.T., Kunnasranta M., Hämäläinen E. & Hyvärinen H. 2002. Movements and use of haul-out sites of radio-tagged Saimaa ringed seal (*Phoca hispida saimensis* Nordq.) during the open water season. *Ann. Zool. Fennici* 39: 59-67.

Krafft B.A., Kovacs K.M. & Lydersen C. 2007. Distribution on sex and age groups of ringed seals (*Pusa Hispida*) in the fast-ice breeding habitat. *Mar. Ecol.- Prog. Ser.* 335: 199-206.

Kunnasranta M. 2001. *Behavioural biology of two ringed seals (Phoca hispida) subspecies in the large European lakes Saimaa and Ladoga.* PhD-thesis, University of Joensuu, 86 p.

Kunnasranta M., Hyvärinen H., Sipilä T. & Koskela J.T. 1999. The diet of the Saimaa ringed seal *Phoca hispida saimensis*. *Acta Theriol.* 44: 443-450.

Kunnasranta M., Hyvärinen H., Häkkinen J. & Koskela J.T. 2002. Dive types and circadian behaviour patterns of Saimaa ringed seals *Phoca hispida saimensis* during the open water season. *Acta Theriol.* 47: 63-72.

Kuusisto E. (ed.) 1999. *Elävä Saimaa.* Kustannusosakeyhtiö Tammi, Helsinki, 205 p.

Laita S. 2005. *Saimaannorppa kunnan suunnittelussa.* MSc-thesis, University of Helsinki, 100 p.

Lydersen C. & Kovacs K.M. 1999. Behaviour and energetics of ice-breeding, North Atlantic phocid seals during the lactation period. *Mar. Ecol.- Prog. Ser.* 187: 265-281.

Martínková N., Zahradníková A., Budeev J. & Vrsanský P. 2001. Surface home ranges of the Baikal seal (*Phoca sibirica*) during the solid ice cover period. *Biologia* 56: 219-224.

Müller-Wille L.L. 1969. Biometrical comparison of four populations of Phoca hispida Schreb. in the Baltic and White Seas and Lakes Ladoga and Saimaa. *Comm. Biol. Soc. Sci. Fennica* 31: 1-12.

Palo J. 2003. *Genetic diversity and phylogeography of landlocked seals*. PhD-thesis, University of Helsinki, 63 p.

Rahkola-Sorsa M. 2008. *The structure of zooplankton communities in large boreal lakes, and assessment of zooplankton methodology.* PhD-thesis, University of Joensuu, 41 p.

Rautio A., Niemi M., kunnasranta M., Holopainen I.J. & Hyvärinen H. 2009. Vocal repertoire of the Saimaa ringed seal (*Phoca hispida saimensis*) during the breeding season. *Mar. Mammal Sci*. 25: 920-930.

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.

Seaman D.E. & Powell R.A. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. *Ecology* 77: 2075-2085.

Sipilä T. 1990. Lair structure and breeding habitat of the Saimaa ringed seal (*Phoca hispida saimensis* Nordq.) in Finland. *Finnish Game Research* 47: 11-20.

Sipilä T. 2003. *Conservation biology of Saimaa ringed seal (Phoca hispida saimensis) with reference to other European seal populations*. PhD-thesis, University of Helsinki, 40 p.

Sipilä T. & Hyvärinen H. 1998. Status and biology of Saimaa (*Phoca hispida saimensis*) and Ladoga (*Phoca hispida ladogensis*) ringed seals. In: Heide-Jørgensen M.P. & Lydersen C. (eds.), *Ringed seals in the North Atlantic*, The North Atlantic Marine Mammal Comission, 83-99.

Sipilä T. & Kokkonen T. 2009. Saimaannorppakannan tila vuonna 2008 – Pieni ja pirstoutunut saimaannorppakanta on kriittisesti uhanalainen. Asiakirja 707/41/2009. Metsähallitus, Etelä-Suomen luontopalvelut, 18 p.

Sipilä T., Helle E. & Hyvärinen H. 1990. Distribution, population size and reproductivity of the Saimaa ringed seal (*Phoca hispida saimensis* Nordq.) in Finland, 1980-84. *Finnish Game Research* 47: 3-10.

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.

Smith T.G. & Hamill M.O. 1981.Ecology of the ringed seal, *Phoca hispida*, in its fast ice breeding habitat. *Can. J. Zool.* 59: 966-981.

Spencer W.D. & Barrett R.H. 1984. An evaluation of the harmonic mean measure for defining carnivore activity areas. *Acta Zool. Fennica* 171: 255-259.

Stewart B.S., Petrov E.A., Baranov E.A., Timonin A. & Ivanov M. 1996. Seasonal movements and dive patterns of juvenile Baikal seals, *Phoca sibirica*. *Mar. Mammal Sci.* 12: 528-542.

Teilmann J., Born E.W. & Acquarone M. 1999. Behaviour of ringed seals tagged with satellite transmitters in the north Water polynya during fast-ice formation. *Can. J. Zool.* 77: 1934-1946.

Worton B.J. 1989. Kernel methods in estimating the utilization distribution in home range studies. *Ecology* 70: 164-168.