Status and biology of Saimaa (*Phoca hispida saimensis*) and Ladoga (*Phoca hispida ladogensis*) ringed seals

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ABSTRACT

Saimaa (*Phoca hispida saimensis*) and Ladoga (*P. h. ladogensis*) seals are subspecies of ringed seals that live in freshwater lakes. The founding populations for these two subspecies became separated from Arctic ringed seals (*P. h. hispida*) during the last ice age. The Saimaa seal population currently numbers approximately 200 seals with 36 - 40 pups born annually. The Ladoga seal population contains at least 5,000 seals. The weight of adult animals in Lake Saimaa is 45-100kg (mean 62kg) and in Lake Ladoga adults weigh 32-56kg (mean 47kg). The lanugo of Saimaa seals is grey. Normally pups in Lake Ladoga are born with white lanugo, although some pups have been found that have black hairs in the natal pelt. Adult Saimaa seal vary a lot in colour, ranging from dark to pale animals, but all colour morphs have regular ringed patterns on the pelt. Ladoga seals are usually quite dark, with irregular, light ringed patterns. Saimaa seals are usually found hauled out alone or in pairs along shorelines. Ladoga seals haul out in herds of up to 300 animals, and are very vocal when they are hauled out. The lairs of Saimaa seals are situated in snowdrifts adjacent to shorelines of islets, which are the only places where snow piles up in Lake Saimaa. Most Ladoga seal lairs are situated near hummocked or ridged ice along the shoreline of the lake, but some lairs are also found along the shorelines of islets in northern Lake Ladoga. Saimaa seals are an endangered population. The main threats to these seals are fisheries conducted using nets and destruction of breeding habitat. The Ladoga seal is vulnerable, and it also is threatened by fishing. Mercury in both lakes presents an anthropogenic risk factor, but present levels probably do not affect the breeding of either seal population.

THE FRESHWATER RINGED SEALS OF LAKES SAIMAA AND LADOGA

The present landscape of northern Europe is very different from what it was 11,000 years ago. Towards the end of the last ice age ice and water covered areas that are now dry land. About 9,000 years ago the biggest lake in Europe, Ladoga, became separated from the sea, and about 1,000 years later, Lake Saimaa was isolated (Sauramo 1958).

Saimaa (*Phoca hispida saimensis* Nordqv.) and the Ladoga seals (*Phoca hispida ladogensis* Nordqv.) are the only ringed seals in the world that live in lakes. The Saimaa seal is included in the World Conservation Union's (IUCN) Red Data Book as an endangered species and the Ladoga seal is considered to be vulnerable (Reijnders *et al.* 1993).

The Saimaa and Ladoga seals were defined as a ringed seal subspecies by Nordquist (1899). The biggest differences among the ringed seal subspecies in Lake Ladoga, Lake Saimaa and the Baltic Sea are seen in the shape and dimensions of the skull. When the skull measurements of adult animals are examined through discriminant analysis, and the sex of the animal is known, individuals of the three subspecies can be separated into discrete groups with 100% accuracy (Fig. 1, Hyvärinen and Nieminen 1990). Furthermore, the seals in Lake Ladoga are significantly smaller than the seals of Lake Saimaa. The mass of adult animals in Lake Ladoga is 32-56kg (mean 47kg)

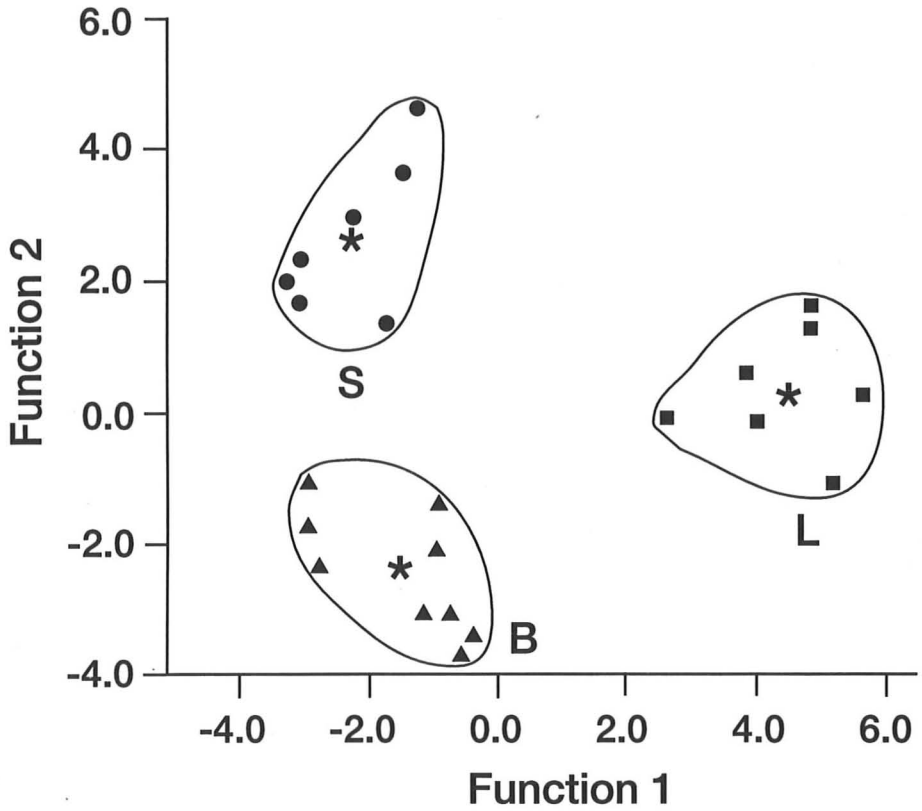

Fig. 1
Discriminant analyses of 2+ year-old, male specimens of Ladoga (L; ■), Saimaa (S;•) and Baltic ringed seals (B; ▲) based on 19 craniometrical measurements (Hyvärinen and Nieminen 1990). Asterisks denote function value means for each group.

and in Lake Saimaa adults weigh 45-100kg, (mean 62kg; Sipilä *et al.* 1996). Baltic ringed seals in the Bay of Bothnia are the largest of these three subspecies, ranging in mass from 60 -140kg (Helle 1980).

There is substantial colour variation among individual Saimaa seals. They are usually quite dark but lighter coloured animals also do occur. Some seals with a reddish face and breast have been found in southern Saimaa. Most of the seals in the northern parts of Lake Ladoga are dark and the individual ring patterns on the pelts are irregular and light.

The lanugo of pups is grey in Lake Saimaa (Fig. 2), whereas in the other subspecies it is creamy-white. It is possible that the colour of the lanugo is less important for protection in Lake Saimaa, compared to the more open habitats occupied by the other subspecies. According to Tormosov and Filatov (1979), the pups of the Ladoga seal are white, although in 1996 some dark pups with dark flippers were also found in northern Lake Ladoga (Kunnasranta *et al.* 1996a).

THE LAKES AND BREEDING HABITATS

The conditions in Lake Saimaa are different from those in Lake Ladoga, the Baltic Sea or the Arctic Ocean. Although the total area of Lake Saimaa is 4,400km^2, it is a highly divided body of water that has open areas that are seldom over 10km in diameter, although the length of the shoreline is about 15,000km (Fig. 3). This is partly due to the c. 14,000 islands and islets occurring in the lake. Ladoga is the largest lake in Europe with a surface area of 19,890km^2 (Fig. 4). This lake contains 660 islands, most of which are situated near its northern shore in the Sortavala and Lahdenpohja areas.

The main seal breeding habitat in Lake Ladoga is situated in the middle of the lake, 40-60km from the shore. The area resembles typical breeding habitats for high Arctic ringed seals, consisting of ridged or hummocked ice (Olofsson 1933, Antoniuk 1975, Smith and Stirling 1975, Tormosov and Filatov 1979). In northern Lake Ladoga most of the haul-out lairs

Fig. 2
Adult female Saimaa ringed seal with pup. (Photo: J. Taskinen)

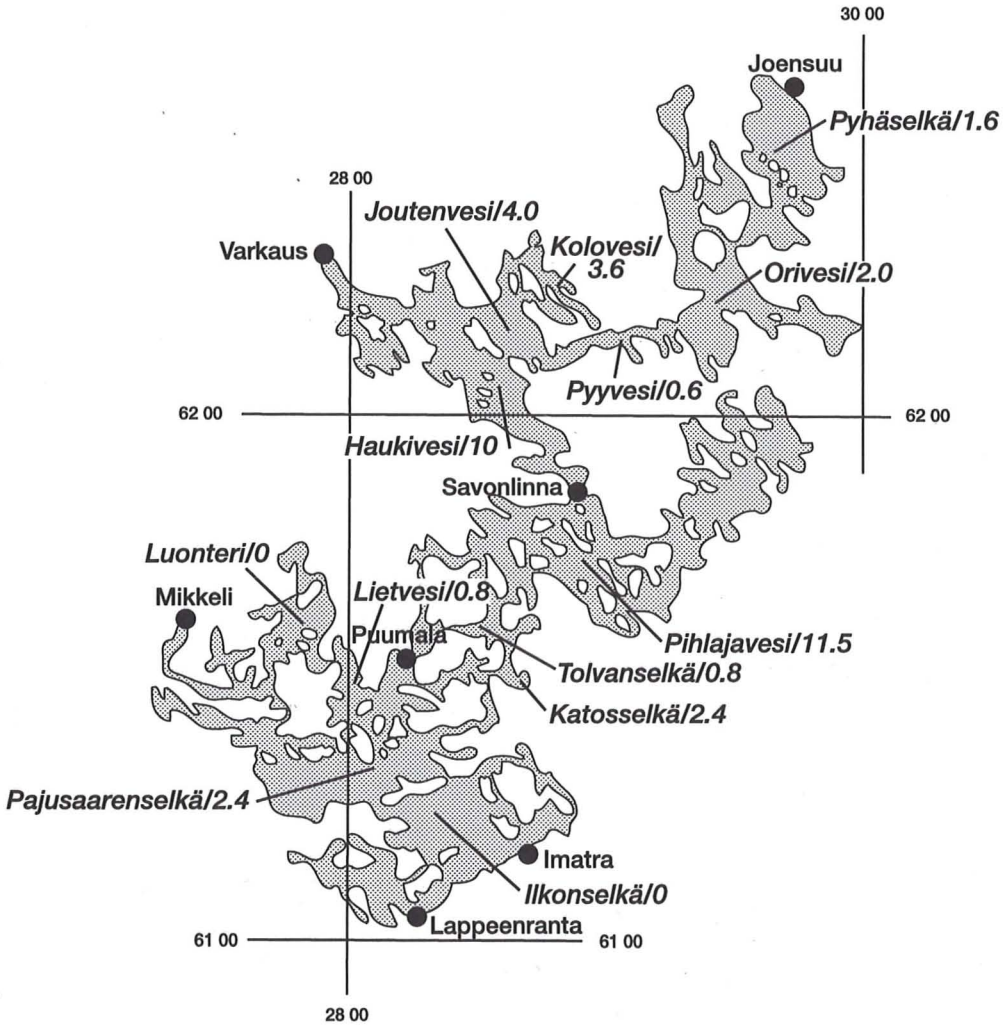

Fig. 3
Map of Lake Saimaa with ringed seal lairing areas and estimated mean annual pup production indicated (e.g. in Pyhäselkä area, the mean annual pup production is 1.6 pups). Sizeable towns are indicated by black dots. Total population size is about 200 seals. About 38-40 pups were born annually in the years 1994-96.

and birth lairs are found in snowdrifts along the shoreline (Sipilä 1993, Kunnasranta *et al.* 1996a). Due to the limited size of the open water areas in Lake Saimaa, hummocked or ridged ice mounds do not form and the only places where snow accumulates is along shorelines. Lairs of the Saimaa seal are thus located along the shorelines of the lake as well as on the shorelines of islands and islets (Fig. 5). The actual location of the lairs in a given year depends on the formation of thick snowdrifts (Sipilä 1990).

The building of lairs along shorelines, in shallow water, observed in these populations is unusual compared to other ringed seal subspecies. It is possible only because the water levels in both Lakes Saimaa and Ladoga are quite stable in normal winters. However, the water level can vary as much as 1-2m in the lakes over the period of a decade (e.g. Kuusisto 1982, Becker and Sipilä 1984). This sort of change can force relocation of lairs along gently sloping shores because the water depth at the holes of lairs is normally only about 1m. At sites with steep shores, relocation of this kind is not required when the depth changes in the lake.

Most of the lairs in Lake Saimaa are situated in snowdrifts around islands or islets. In these areas, the actual selection of lair sites depends largely on human activities; the seals avoid man-made disturbance such as those that occur around houses and roads near the shoreline (Sipilä 1991). In Lake Ladoga, the lairs which lie along the shorelines in the northern archipelago are situated as far away as possible from houses or roads. Hunting by humans in the past has probably also affected the locations of whelping areas.

Additionally, the number of predators (see below) in a particular area affects the selection of lair sites.

It is estimated that Saimaa seals currently use only about 15% of the shoreline that is potentially available for building lairs. Approximately 50% of the available lair-habitat is situated on the shorelines of the mainland, but during monitoring surveys since 1980 lairs have only been found occasionally on the shorelines of the mainland (Sipilä 1991). The area in Lake Saimaa where seals occur regularly has declined by about 50% during the 20th century (Sipilä *et al.* 1990, Sipilä 1994a).

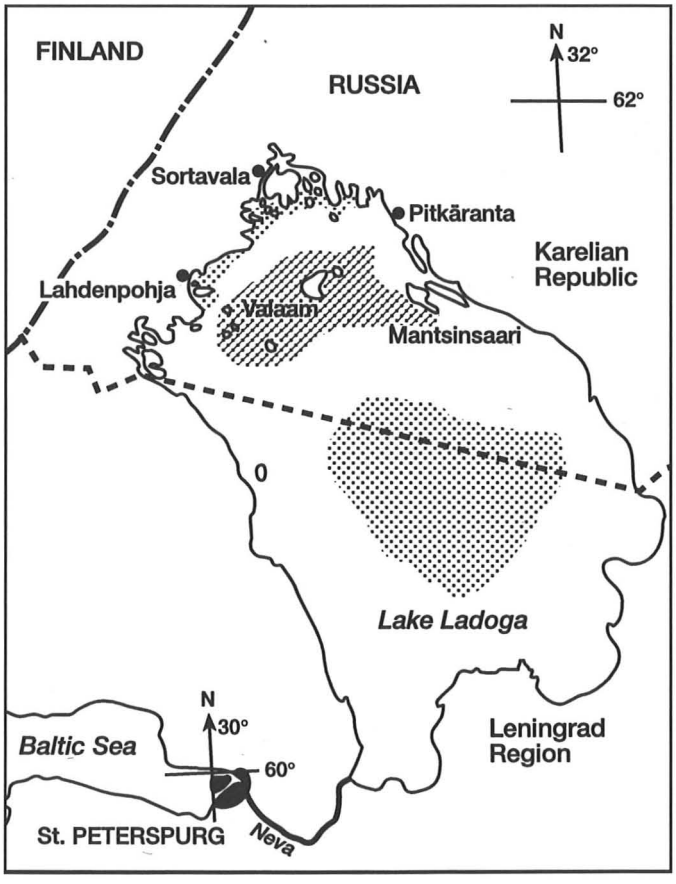

Fig. 4
Map of Lake Ladoga showing the main breeding areas (dotted) of ringed seals in the middle of the lake and along the northern shoreline. The area (hatched) around Valaam archipelago is where herds of seals appear regularly in summertime. The black dots indicate towns in the Karelian

BREEDING AND THE LAIRS

The pupping period in Lake Saimaa is from the end of February until early March. In the Baltic Sea, in the Gulf of Finland, the pupping period is at the end of February (Pälsi 1924) and is probably the same period in Lake Ladoga.

The duration of the lactation period of the Saimaa seal is 7-9 weeks. In April, when seals bask on the ice, the mean duration of suckling

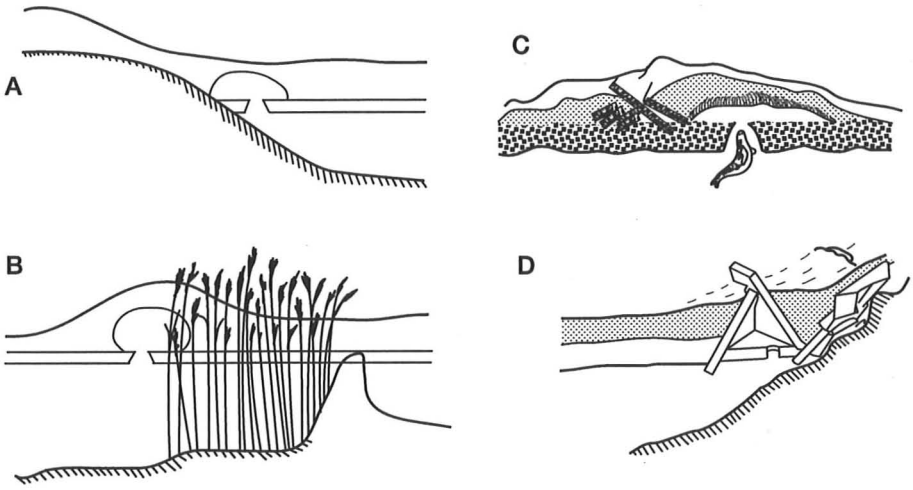

Fig. 5
Different ringed seals lair sites in Lake Saimaa, Lake Ladoga and the Arctic Ocean. A: Typical shoreline lair of Saimaa seal, this type of lair can also be found in northern Ladoga, B: Lair against common reed vegetation in Lake Saimaa. C: Typical lair of Ladoga seal, which resembles ringed seals lairs in the Arctic Ocean (see Smith and Stirling 1975). D: Lair in pressure ridge near the shoreline in the Arctic (McLaren 1958).

events is 19 ± 6min. (Järvinen and Sipilä 1992). Females wean their pups when the ice begins to melt in the lake. By the end of April pups are often seen basking alone on the ice or on the shoreline of islets. Lactation follows a similar time-course in Lake Ladoga (Tormosov and Filatov 1979). Mating occurs during the lactation period, at the end of March or at the beginning of April in both lakes.

Lairs have been counted in April 1981-1997 in Lake Saimaa and in 1996-1997 in the northern part of Lake Ladoga, when their roofs collapse due to warm weather. The subnivean lairs can be located by infrared videothermography from a helicopter at night in March. But this technique is of limited value since there are other heat sources in the snowdrifts in Lake Saimaa such as subnivean boulders or bare ground or water between ice and snow, and it is not possible to differentiate the lairs from these other heat sources with this technology (Sipilä and Kurlin 1992).

Each seal usually has at least two lairs on Lake Saimaa. The typical haul-out lair of a non-breeding Saimaa seal is an oval cave with a mean length of 195cm and a mean width of 138cm. In Lake Ladoga, lairs are somewhat larger; on average they measure 208 x 145cm.

In Lake Ladoga large haul-out lairs were found with a maximum length of 1,000cm and a maximum width of 460cm. On the floor of these large lairs several nesting spots were found, made by heat from the seals' bodies. It appears that several non-breeding animals used these lairs simultaneously, hauling out together. In Lake Ladoga, some lairs were found soiled with seal faeces (Kunnasranta *et al.* 1996a).

The mean dimensions of birth lair complexes in Lake Saimaa are 294cm x 141cm and in Lake Ladoga they are 347cm x 187cm. The birth lairs are a complex of several chambers with several holes. In Lake Saimaa, several lairs were found in April that contained still-born pups. These structures had the same shape and size as haul-out lairs (Sipilä 1990, Kunnasranta *et al.* 1996a).

The mean distance between birth lairs in Lake Saimaa is 5,477m and the distance between haul-out lairs is 1,191m. Only occasionally are two birth lairs found along the same part of a shoreline. It seems that in Lake Saimaa females avoid breeding close to each other and haul-out lairs are found clustered around birth lairs (Sipilä 1992). In Lake Ladoga, clusters of lairs are not found.

The mean water depth at the holes of shoreline lairs is less than one meter in both lakes (Sipilä 1990, Kunnasranta *et al.* 1996a). In Lake Saimaa, lairs are often found at the same locality annually. This is probably because deep layers of snow tend to form at the same location on the shorelines of islands and islets from year to year (Sipilä 1990, 1991).

PREDATION AND HUNTING

The breeding habitat of the Saimaa seal, and to a lesser extent the Ladoga seal, is accessible to

terrestrial predators. However, the population sizes of large carnivores in these areas are currently quite small (Helle *et al.* 1984, Nyholm 1995, V.I. Bogdanov, Ministry of Environment, Karelian Republic, pers. comm.).

Tracks of red foxes (*Vulpes vulpes*) and lynxes (*Lynx lynx*) are found regularly around Saimaa seal lairs that occur along shores. However, seals are not normal prey items for these predators and hence the smell of the subnivean lair may not be recognised as a food source. In some cases, the red fox has been known to show an interest in lairs, but there is no clear evidence that this fox species digs holes through the roofs of lairs, as is common practise for Arctic foxes (*Alopex lagopus*). There are records of either dogs or foxes attacking lairs and killing some pups in Kolovesi National Park. During lair studies in April in Lake Saimaa some still-born pups, partly eaten by predators, were found, but it is likely that the pups were scavenged after the roofs of the lairs had collapsed (Sipilä 1992). In the northern part of Lake Ladoga, some attacks on lairs by dogs, red foxes or wolves (*Canis lupus*) have occurred (V.I. Bogdanov, Ministry of Environment, Karelian Republic, pers. comm.).

A significant harvest of the Ladoga seal population occurred from 1900-1940. According to the bounty statistics 15,236 seals were killed in northern Lake Ladoga during the years 1924-1939, which means about 950 seals annually (460-1,546) (Jääskeläinen 1942). This hunting pressure probably caused a dramatic decrease in seal numbers during the beginning of the century. In the 1970s, about 500 animals were hunted annually (Tormosov and Filatov 1979). Hunting in Lake Ladoga became prohibited by the state in 1980.

In Lake Saimaa, 140 seals were shot in the middle part of the lake during the years from 1909-1918 (Kilkki and Marttinen 1984). During the 1950s, seals were eradicated from some parts of Lake Saimaa by fishermen, e.g. at least 50 individuals were killed in the small Puruvesi area. The Saimaa seals were protected by law in 1955 because the population was so small. In Lake Saimaa two poaching cases were discovered in the early 1980s and in Lake Ladoga fishermen still kill some seals each year (pers. obs.).

THE SIZE AND STRUCTURE OF THE POPULATIONS

Earlier abundance estimates of the seal population in Lake Ladoga vary broadly from 3,000 to 20,000 (Antoniuk 1975, Tormosov and Filatov 1979, Makarov and Popov 1983, Volkov and Lapzin 1984). Aerial censuses in the early 1970s suggested between 3,500 and 4,700 animals (Antoniuk 1975). Currently the seal population in Lake Ladoga numbers at least 5,000 animals (Medvedev *et al.* 1996), of which about 1,500 gather around the Valaam and the Sortavala-Lahdenpohja Archipelagos in summer (Sipilä *et al.* 1996). The population size has probably remained quite stable during the last thirty years, but in the early 20th century the population size was probably much larger; it may have been over 10,000 animals.

It is estimated that between 2,000 and 4,000 animals lived in Lake Saimaa about 5,000 years ago, which produces a density estimate of 0.5-1 seal/km^2 in the lake (Hyvärinen and Sipilä 1992). At the beginning of the 20th century, the size of the population was about 700 animals. In the early 1980s, there were as few as 180 animals remaining. Recently, the population has increased to about 200 seals.

The sex-ratio in Lake Saimaa is 1:1, but the age structure of this population is somewhat unusual because so many young seals die in fishing gear (Fig. 6) (e.g. Sipilä 1995, 1996). The age of maturity of males in Lake Saimaa is 5-6 years (Sipilä *et al.* 1995). There are about 50 sexually mature females in the population and about 36-40 pups are born annually. The population size, its breeding success and number of seals that die in fishing gear are monitored annually. Because of the lake's sub-divided nature, the status of the population and the breeding environment in Lake Saimaa are monitored as a series of breeding areas. It is possible that the population is now divided into two sub-populations, with the southern population occurring between Lappeenranta and Puumala and the main population occurring between Puumala and Joensuu (Fig. 3, pers. obs.).

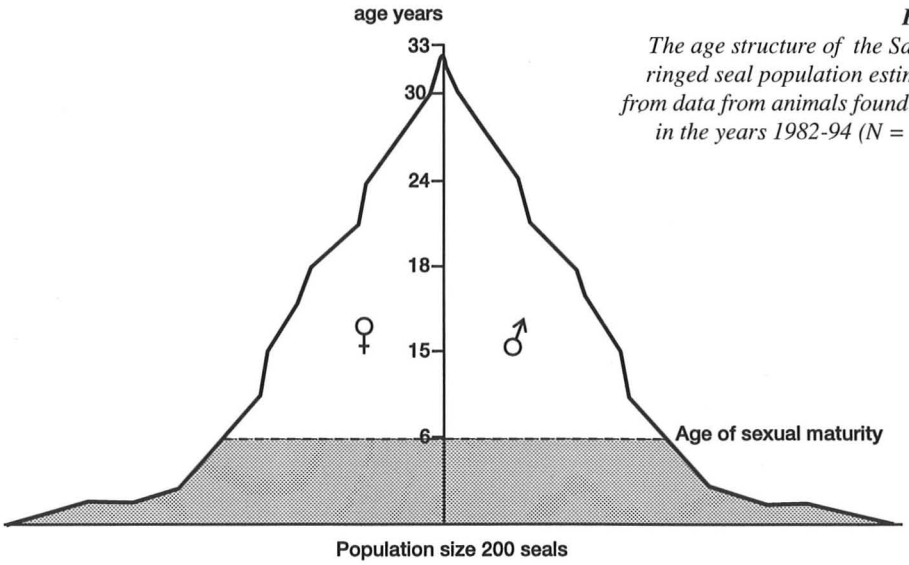

Fig. 6
The age structure of the Saimaa ringed seal population estimated from data from animals found dead in the years 1982-94 (N = 170).

FEEDING AND ENVIRONMENTAL TOXINS

Lake Ladoga is the home of 48 species of fish (Kudersky *et al.* 1996). The Ladoga seal eats mainly smelt (*Osmerus eperlanus*), vendace (*Coregonus albula*), ruffe (*Gymnocephalus cernuus*), burbot (*Lota lota*), three-spined stickleback (*Gasterosteus aculeatus*), perch (*Perca fluviatilis*), roach (*Rutilus rutilus*), whitefish (*Coregonus lavaretus*), trout (*Salmo trutta*) and four-horn sculpin (*Triglopsis quadricornis*). Occasionally, the seals also eat river lamprey (*Lampetra fluviatilis*) and crayfish (*Astacus sp*) (Tormosov and Filatov 1979).

The Saimaa seal usually eats only at the small end of the size range among the 33 fish species that are found in the lake. In one case, remarkable amounts of a small crustacean species, *Mysis relicta*, were found in the stomach of one seal. However, vendace and smelt are the most important prey species for the Saimaa seal. In years when vendace are scarce, other small fish such as whitefish, perch, roach and burbot are eaten (e.g. Hyvärinen *et al.* 1984, 1995)

Large differences have been found in tissue fat-soluble lipids and fatty acid compositions of Saimaa ringed seals, compared to marine dwelling ringed seals (Käkelä *et al.* 1995, Käkelä 1996). This is not surprising given the different fat compositions of prey species of ringed seals in these two systems.

Measurements of cadmium and lead concentrations in the tissues of the Ladoga seal are low, but mercury concentrations in the liver, and especially in the kidney are elevated (Table 1). The concentrations of mercury from the organs of seals from northern Lake Ladoga are similar to those presently found in the Saimaa seal (Hyvärinen 1992). In the natal hair of Saimaa seal the mercury concentrations can be over 30µg/g (Hyvärinen and Sipilä 1984, Hyvärinen *et al.* 1997). The mercury concentrations in the natal hair are highest in the northern Lake Saimaa where the humic matter concentration is highest (Hyvärinen et al. 1997). According to our preliminary results, the mercury content in the natal hair of northern Ladoga seals is as high as in northern Saimaa.

High concentrations of mercury in the Saimaa seal were measured in the 1960s and 1970s (Helminen *et al.* 1967, Henrikson et al 1969, Kari and Kauranen 1978) and it is probable that mercury pollution reduced pup production during the 1960s and 1970s in the southern part of Lake Saimaa (Hyvärinen 1992). High mercury concentrations in livers, and especially in the muscle of weaned Saimaa seal pups, are thought to have contributed to reducing their numbers by half during the last two decades

Table 1. Mercury concentrations (mg/g fresh weight) in muscle, kidney and liver of adult Ladoga and Saimaa ringed seals (Sipilä *et al.* 1996).

	Muscle		Kidney		Liver	
	N	x±SE	N	x±SE	N	x±SE
Ladoga	9	2.0 ± 0.40	7	15.1 ± 5.9	6	60.8 ± 25.5
Saimaa	12	1.4 ± 0.27	10	5.1 ± 0.9	12	76.8 ± 23.6

(Hyvärinen *et al.* 1997). However, no clear connection has been found between the incidence of stillbirths and mercury pollution in the 1980s (Hyvärinen and Sipilä 1984).

In Lake Saimaa, DDT concentrations have been reduced significantly in recent decades, but no clear reduction has been seen in PCB concentrations in the Saimaa seal (Helle *et al.* 1985, Hyvärinen and Sipilä 1992). However, the patterns observed in toxin concentrations are not straight-forward; there are major differences in concentrations of different pollutants in different parts of Lake Saimaa (Hyvärinen and Sipilä 1992). Seals from the Kolovesi area in Lake Saimaa show the lowest concentrations of different pollutants in the tissues (Fig. 7). PCB concentrations of 2.5-25mg/kg (mean 12.1mg/kg) were reported by Olsson *et al.* (1986) in the blubber of the Ladoga seal. These values are low compared to those in the Saimaa seal (mean 35.3, range 3.0-105mg/kg) or the Baltic ringed seal (Helle *et al.* 1983, 1985, Hyvärinen and Sipilä 1992).

BEHAVIOUR

Saimaa and Ladoga seals haul out on the ice in late April. Haul-out activity is most common in the afternoons, when up to 70% of the seals are on the ice. The mean duration of haul-out periods in Lake Saimaa is 8.9 ±1hrs. During haul-out, Saimaa seals raise their heads regularly; these checks of their surroundings are brief, lasting only about 6s. The mean period between head-raises is about 55s. Sometimes herring gulls (*Larus argentatus*) and hooded crows (*Corvus corone cornix*) disturb hauled-out seals on the ice (Järvinen and Sipilä 1992).

Saimaa and Ladoga seals haul out on the shores of islands and islets throughout the ice free period from late April or early May until December. In Lake Saimaa, haul-out activity on the rocks and stones is highest during the moulting period in late May and early June (e.g. Fig. 8, Hyvärinen *et al.* 1984, 1995), but in Lake Ladoga there are two periods when haul-out activity seems to peak; one in May-June and the other in September-October (pers. obs.).

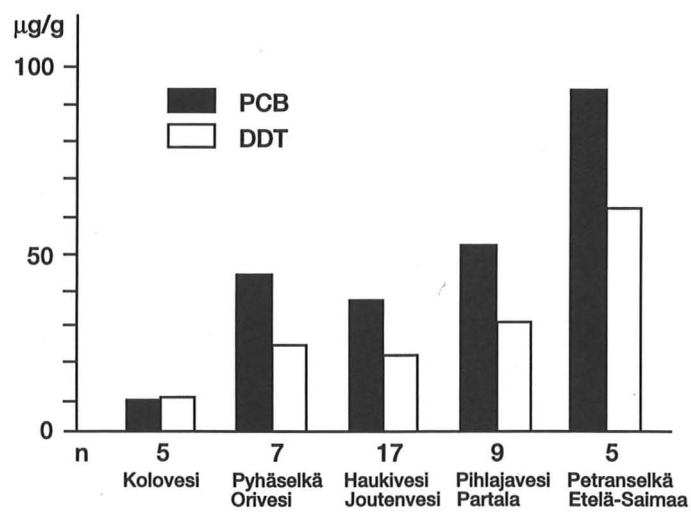

Fig. 7
PCB and DDT concentrations in blubber of Saimaa ringed seals from different parts of Lake Saimaa (see also Fig. 2).

According to stories from old fishermen, there used to be herds of seals hauled out on islets in Lake Saimaa (Seppovaara 1958). However, nowadays most of the seals haul out alone or in pairs. Up to four seals have been observed hauled out on the same shoreline, but this is exceptional because of the scarcity of seals in the lake.

During the ice-free period, Ladoga seals haul out in herds of up to 300 animals on shore-

Fig. 8
Saimaa ringed seal hauled out on shoreline stone. (Photo: J. Koskela)

lines in the Valaam Archipelago (Fig. 9, Sipilä 1993, Sipilä *et al.* 1996). The herds of seals seem to fish in the same area, but there is no evidence of co-operative foraging.

Ladoga seals use a variety of sounds while hauled out on the rocks in herds. Most of the vocalisations are different kinds of growling and snarling but more specialised sounds, e.g. a yowl or howling sound, are also heard (Fig. 10). When seals were found hauled out alone no sounds have been heard (Sipilä *et al.* 1996). Some sounds, e.g. "mock" and splashing sounds made using the flippers, are used as warning signals. Underwater vocalisation of Ladoga seals is also common. One interesting sound they produce is a strong "knock-knock" vocalisation (Kunnasranta *et al.* 1996b).

Fig. 9
Herd of Ladoga ringed seals hauled out on an island in the Valaam Archipelago. (Photo: J. Taskinen.)

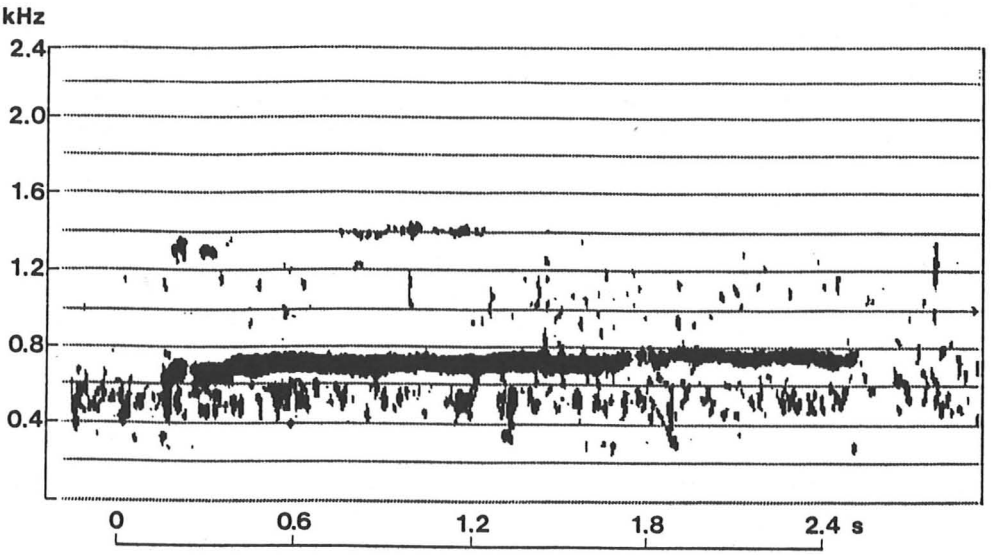

Fig. 10
Sonogram of a howling vocalisation of Ladoga ringed seal.

Saimaa seals rarely use sound although roars occur during agonistic encounters (Hyvärinen 1989). Only a few howling sounds have been heard from adult animals in Lake Saimaa during monitoring activities that have taken place over the past 15 years. Sometimes, pups on the ice in late April vocalise prior to nursing. Hydrophone recordings made in 1984-85, documented only a few underwater sounds of Saimaa seals, but one of these sounds was a "knock-knock" or "click-click"-sound quite similar to the one that is common in Lake Ladoga (Hyvärinen 1989).

The underwater behaviour of ringed seals is an important component of their daily activity, but it is not well documented. Some studies have been conducted on the use of the whiskers when in water. The whiskers are an important sensory organ that provide a lot of information to the seal about its environment. The Saimaa seal can estimate the depth of a dive and the speed of swimming by using the vibrissal system (Hyvärinen 1989, 1995). The tissues around the vibrissal system are elastic and the fatty acids around the whiskers are more liquid than those of the blubber layer (Käkelä and Hyvärinen 1993). More than 150,000 myelinated nerve fibres enter the vibrissal system of the Saimaa seals and it is likely that they can even perceive low frequency sound via this system. The whiskers may also be important for spatial orientation in water and for prey capture (Hyvärinen 1989,1995).

The longest dive recorded for the Saimaa seal (via VHF-transmitters) is 23min. Dives of this duration are however irregular. Saimaa seals probably have an aerobic dive limit close to 15min., as they commonly perform bouts of dives of approximately this duration for several hours at a time (max. 6 hours, Hyvärinen *et al.* 1995).

The mean duration of dives increases from spring to autumn; e.g. one individual dove an average of 6min. in June and this increased to 10.5min. by October. The duration of the dives and the diving patterns differ among individuals in summer, e.g. one seal was submerged 80% of the time while another spent only about 45% of its time under water (Hyvärinen *et al.* 1995). Some seals probably sleep in the water, while others sleep on the rocks or boulders in Lake Saimaa.

Ringed seals in the Arctic Ocean (Frost and Lowry 1981, Smith 1987, Kapel *et al.* this volume), as well as juvenile Baikal seals (*Phoca sibirica*) (Stewart *et al.* 1996), have migrations of up to hundreds of kilometres. In contrast, in Lake Saimaa adult seals seem to remain within a small area. Often seals use the same shoreline or even the same rock on a year-round basis, and they appear to do so year after year. Maximum distances travelled by individual seals ranged from 3.4 to about 18km (J.T. Koskela, University of Joensuu, pers.comm.).

FISHING AND SEALS

It has been estimated that about 200-400 seals died annually in fishing gear in the early 1990s in Lake Ladoga (e.g. Sipilä 1993). But fishing practices in Lake Ladoga have changed a lot since 1992. Many large fishing enterprises have ceased operating, especially in the Karelian Republic, because of the changed market situation. A decrease in the total fish catch has occurred since 1990. This decrease may also be related to the deterioration of the environment of Lake Ladoga, caused by anthropogenic factors (Kudersky *et al.* 1996). Netting and trawling are the most common methods of fishing. These fishing methods are employed in areas where seal herds are regularly seen, e.g. near the islands in the Valaam archipelago. Since 1992 it has become increasingly difficult to estimate the by-catch of seals because small scale netting has become more common.

Fishing is not currently a serious threat to the Ladoga seal population. However, there is a possibility that this situation may change. The Ladoga seal is a small species and it lives in herds, so it is quite vulnerable to fishing practises such as driftnets or traps. It is possible that fishing pressure will increase to former levels in the Valaam Archipelago if the economic situation changes in the area.

Until the 1960s, people fished in Lake Saimaa using nets, small seines and small fykes made of cotton. This equipment was not particularly harmful to seals. However, in the 1960s the situation changed dramatically; the number of nets used increased rapidly and nylon and other strong-thread nets came into use. Small scale fishing is currently the most serious threat to the Saimaa seal population (Hyvärinen and Sipilä 1983, Sipilä 1991).

In the beginning of the 1980s, about 70% of the pups in Lake Saimaa were still-born or died before the age of one year. The months after weaning are a particularly critical period for the seals, with about 70% of net-drowning deaths occurring between the ages of 1.5-4 months (Hyvärinen and Sipilä 1983). In search of solutions, the State rented water areas from local

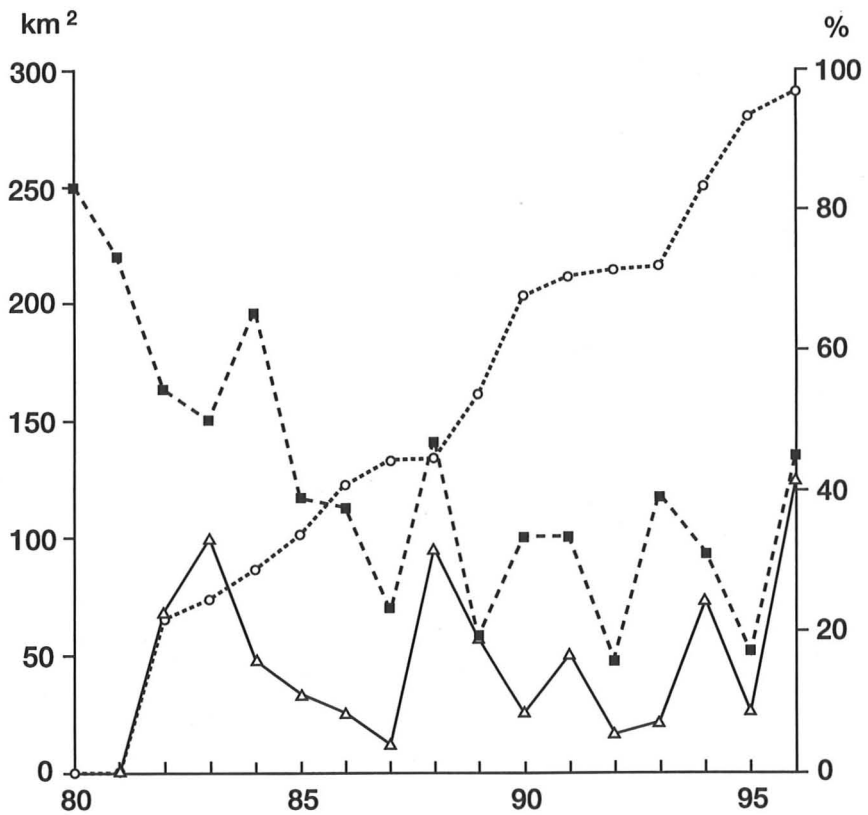

Fig. 11
Percentage of Saimaa ringed seal pups still-born or dead in lairs (Δ), percentage mortality for age classes 1 and 2 years (■) and the area in km² of Lake Saimaa restricted from fishing (15 April to 30 June) (○).

owners and restricted fishing with nets, fykes and hooks from 15 April to 30 June to protect the seals. Between 1982 and 1984, 38.9% of pups that were born inside the restricted fishing areas were captured in nets during their first two years of life. The comparable figure, outside these areas, was 50% (Sipilä *et al.* 1990).

From 1982 to 1995 the area with fishing restrictions in spring has been extended from 60km^2 to 280km^2. During the 1990s, only 30-40% of young seals died before the age of two years (Fig. 11). Restricted fishing areas included about 50% of birth lair locations in 1995 and 1996 (Sipilä 1995, 1996).

Adult Saimaa seals are also at risk from modern fishing gear such as strong salmon nets, bait hooks and vendace traps. In recent years, 1-3 adult animals are lost annually to these types of gear (e.g. Hyvärinen 1994, Sipilä 1994b, 1995).

The growth rate of the Saimaa seal population from 1982-95 was estimated to be only 1.01 (Kokko *et al.* 1997), which is low compared to heavily exploited ringed seal populations such as that in the Eastern Canadian Arctic (growth rate 1.12; Smith 1973). The growth rate of small populations that exhibit late sexual maturity and low breeding potential such as the Saimaa seal, is very sensitive to adult mortality (e.g. Järvinen and Varvio 1985, Durant and Harwood 1992, Ranta *et al.* 1996).

STILL-BORN PUPS AND DISTURBANCE

The frequency of premature births, still-births and lair mortalities of pups is abnormally high in Lake Saimaa. The latter source of mortality is largely due to water level changes during winter and other human-induced disturbances. In the years 1982-83 and 1988-89, the water level of Lake Saimaa was artificially lowered during the winter, and many lairs situated along the shoreline were broken during the breeding period. In those years, 20-35% of the pups were found still-born. The artificial lowering of Lake Saimaa was prohibited by law in 1991 (e.g. Sipilä 1988, 1989a, 1991, 1992, 1996). During the years when the water level was lowered in the winter, the weight of weaned pups was lower than during winters with good lairing conditions. Weaning mass influences survivorship profoundly because the risk of young seals getting entangled in fishing nets depends partly upon their weaning weight (e.g. Sipilä 1988, 1989a, 1992).

In the winter of 1995-96, the water level of the lake fell naturally, about 31cm from freezing-up to the pupping period around the end of February, and 42% of the pups which were found had died in lairs (Fig. 11, Sipilä 1996, 1997). This sort of natural variation in the water level during winter was a natural hazard, which happened occasionally before artificial regulation of the lake level in 1991. Earlier, such drops in the water level occurred about 10-20 times per century. In recent years, the effect of the natural fall in the water level in winter on the breeding of seals has been reduced by artificial regulation of Lakes Pielinen and Kallavesi, which empty into Lake Saimaa (Sipilä 1997).

Another cause of pup mortality in lairs is disturbance caused by the increasing use of snowmobiles and the growing number of houses built on the shoreline in or near the breeding areas.

The years 1984-87 were comparable to the years 1991-95 in having quite stable lairing conditions. However, in the 1990s the amount of lair mortality was higher than in the 1980s (Fig. 11). Post-mortem examinations determined that some pups met violent death in the 1990s, e.g. fatal wounds in the livers or in the lungs and broken skulls. It is possible that these traumatic injuries were caused by snowmobiles. In general, man-made disturbance is increasing on Lake Saimaa (Sipilä *et al.* 1995, Sipilä 1996, 1997, Marttinen 1997).

CONSERVATION OF FRESHWATER RINGED SEALS

The Nature Protection Branch of the Forest and Park Service in Finland is responsible for the protection of Saimaa seal. There are two national parks in Lake Saimaa and the State has designated a special shoreline conservation program to prohibit the building of new houses on the shorelines in areas which are important to endangered species or biodiversity (Anon. 1993).

The program will include 70% of the islands and islets in breeding areas, but not bodies of water. The role of conservation areas cannot be underestimated in the protection and future breeding success of the Saimaa seal (e.g. Sipilä 1989b, 1991, Sipilä and Pelkonen 1994). It will be possible to limit the use of snowmobiles on the ice in areas managed by the Forest and Park Service, thus controlling a major source of neonatal mortality.

Another goal for the future, is protection via seasonal restriction of fishing in some areas from 15 May to 30 June, which would serve to protect about 80% of the birth lair locations (Sipilä 1995, 1996). It is also hoped that fishing methods dangerous to adult Saimaa seals will be restricted in the future. According to a new fishing law in Finland, enacted in 1997, it is possible to restrict the use of destructive fishing gear or traps in areas which are important to endangered species.

The conservation target is to have 400 seals in Lake Saimaa by the year 2025. They would still be an endangered, small population, but the risk of extinction due to natural hazards would be greatly reduced.

Formerly, part of the Valaam archipelago in Lake Ladoga was a Strict Nature Reserve, (museem-zapovednic) under the Soviet Ministry of Museums (Kravchenko and Sazonov 1992), but in 1992 the status of this area changed and it is now a unique historical area and nature reserve under the Council of Ministry of the Karelian Republic of Russia. The number of people camping in the Valaam archipelago has grown during the 1990s, disturbing the haul-out behaviour of the seal herds. Currently, there are proposals to restrict public access to six of the islands that are important areas for the seals of this region (Medvedev *et al.* 1996).

Proposals for the protection of the Ladoga seal also suggest that fishing practises that are dangerous for the seals (e.g. the use of drift nets), should be forbidden in the Valaam Archipelago (Medvedev *et al.* 1996).

The Karelian Republic has a plan to establish a reserve in the Sortavala-Lahdenpohja archipelago. The status of this area will be between a national park and a landscape conservation area (V.V. Kalamaev and M.A. Terekhov, Ministry of Environment, Karelian Republic, pers. comm.). This proposed protected area will consist largely of the shoreline used for lair construction by the Ladoga seal.

Annual monitoring of the population will continue in Lake Saimaa. This program will include: pup and lair counting; post-mortem examinations; and follow-up studies of the breeding habitat. Shorelines used by herds of Lake Ladoga seals in Valaam Archipelago and the shoreline lairing habitat in the Northern archipelago should also be monitored on at least a biannual basis.

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