Population size and distribution of the Baltic ringed seal (*Phoca hispida botnica*)

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ABSTRACT

The study reviews earlier investigations on the distribution and abundance of ringed seals (*Phoca hispida botnica*) in the Baltic and presents the first statistically robust results for the entire area. A critical review of earlier counts of ringed seals from the Gulf of Riga and the Gulf of Finland reveals grossly exaggerated population estimates in these regions. This is confirmed by results from the first comprehensive surveys in the entire area carried out during 1994-1996. The estimated hauled-out Baltic population in 1996 was about 5,510± 42% (± 95% confidence interval). Of this estimate 3,945±1,732 (70%) were in the Gulf of Bothnia, 1,407 ± 590 (25%) in the Gulf of Riga and about 150 (5%) in the Gulf of Finland. Numbers in the Gulf of Bothnia have increased since 1988, but there are no data on trends in other areas, although numbers are low and half the local population in the Gulf of Finland may have died in a mass mortality in the autumn of 1991.

INTRODUCTION

The present population of Baltic ringed seal (*Phoca hispida botnica*) is found in three main areas: the Gulf of Bothnia, the Gulf of Finland and the Gulf of Riga (Fig. 1). Winter distribution of the species is largely determined by the occurrence of dense pack ice and fast ice. The main breeding areas are found in the central northern part of the Gulf of Bothnia (Härkönen and Lunneryd 1992), the eastern part of the Gulf of Finland (Stenman 1990a) and in the Gulf of Riga (Leis 1960). Outside these areas, low numbers of ringed seals are found in the Bothnian Sea (Härkönen and Heide-Jørgensen 1990) and in the south-western archipelago of Finland (Helle and Stenman 1990).

The Baltic ringed seal has been heavily exploited during the past century and bounty statistics provide some information on the magnitude of the population in the past. During the period 1909-1918 about 10,000 ringed seals were killed annually by Finnish sealers (Gottberg 1925). Between the two World Wars (1924-1939) an average of 4,000 ringed seals were killed annually in Finland (Bergman 1956) and about 1,500 ringed and grey seals (*Halichoerus grypus*) in Estonian coastal waters (Anon. 1939). In Sweden approximately 2,000 ringed seals were killed each year during the same period (Söderberg 1975). Later, in the period 1956-1975 about 1,400 ringed seals were killed annually in Finland (Helle 1979) and about 1,400 seals of both species in Estonia (Tormosov and Rezvov 1978), but less than a few hundred ringed seals in Sweden (Söderberg 1975). Since 1970 seal hunting has been very limited in the northern Baltic. All killing of ringed seals was banned in1980 in the Soviet Union, in 1986 in Sweden and in 1988 in Finland.

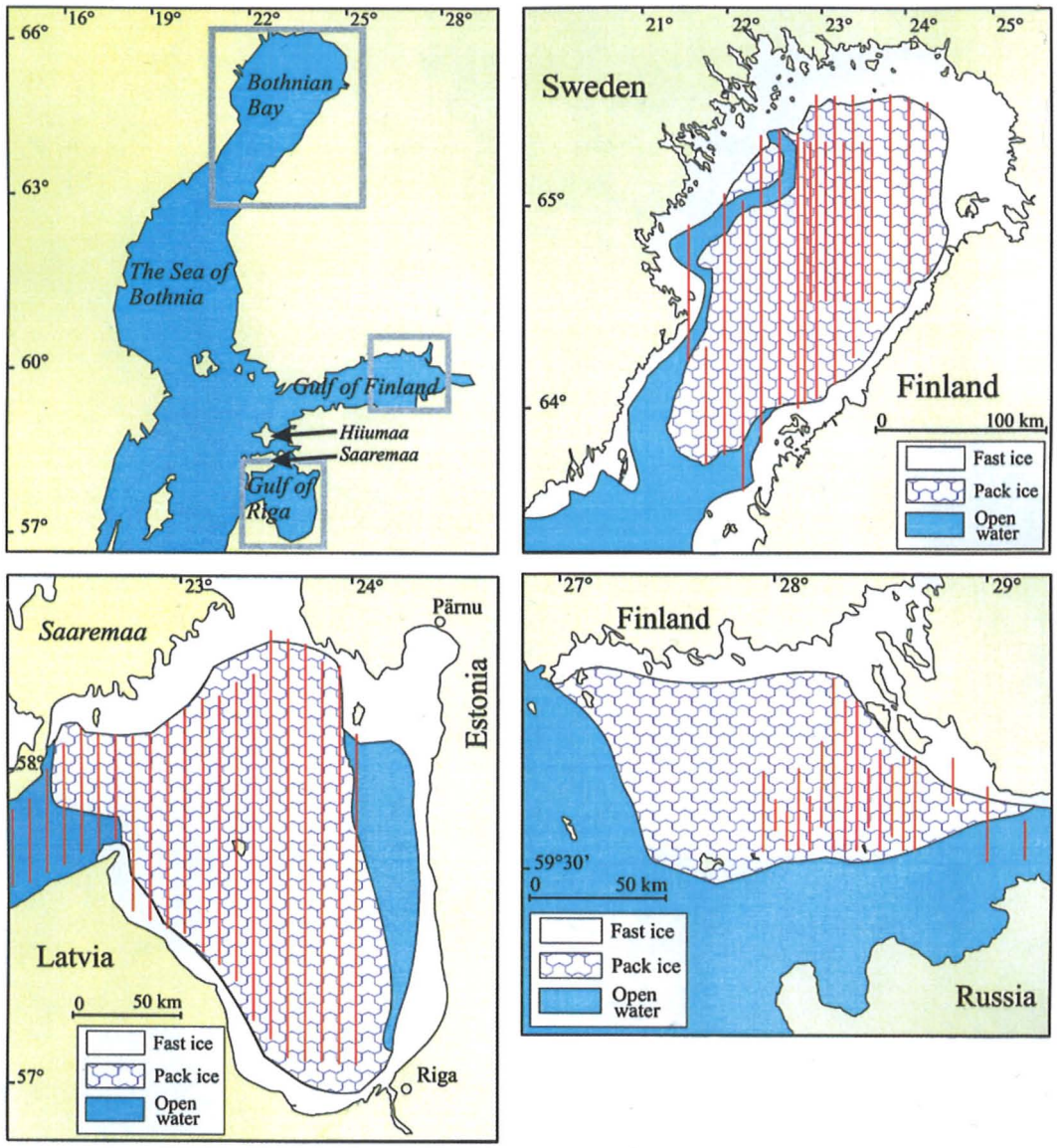

Fig. 1
Ice distribution in t he Baltic during censuses carried out 30 April-2 May 1996 in the Gulf of Bothnia, 4-5 May in the Gulf of Finland and 15-20 April in the Gulf of Riga. In areas denoted as "open water" ice coverage was less than 10%. Indicated surveyed strips also show the extent of the censused areas. Note: Regional maps are in different scales.

Hunting mortalities (not including seals taken in Estonia) together with data on reduced female fertility among ringed seals in the Gulf of Bothnia in the early 1970s (Helle 1980a) have been used to model the population development over the period 1900-1984. Depending on different assumptions made in models, estimates of population size for the year 1900 vary from 250,000 (Durant and Harwood 1986) to 100,000 individuals (Helle and Stenman 1990). Mainly due to extensive hunting, seal numbers decreased to 5,000-10,000 in the early 1970s (Durant and Harwood 1986, Helle and Stenman 1990). Documented reproductive failure and increased mortality rates caused by environmental pollutants may have contributed to a continued decline up to the mid 1980s in the Gulf of Bothnia (Helle 1986, 1990, Bergman and Olsson 1986).

Several surveys have been conducted during the last decades, but the differing methods used in the three main areas preclude an assessment of the population as a whole. They were mainly based on aerial censuses of seals hauling out on ice in the spring, the only time when ringed seals are visible in large numbers. The methods of sampling the ice and calculating results were

either incomparable (Helle 1980b, Härkönen and Lunneryd 1992) or unclear (Zheglov and Chapsky 1971, Rezvov 1975).

The main purpose of this study was to evaluate earlier counts and to provide the first comprehensive assessment of the number and distribution of the entire Baltic ringed seal population.

Review of earlier studies on population size

The Gulf of Bothnia

The first surveys in the Gulf of Bothnia (Fig. 1), conducted in 1975 and again in 1978, provided estimates of about 3,000 ringed seals (Helle 1980b, Table 1). A low-winged single-engine aircraft was flown at an altitude of about 30m over the ice where conditions were judged to be most suitable for seals. The distance and angle to each sighted seal was recorded and strip width was calculated retrospectively based on these measurements. The length of the strip was calculated from the air speed of the aircraft. Using the same method, surveys in 1984 and 1987 indicated a decreasing trend in abundance up to the mid-1980s (Helle 1990).

During 1988 and 1993 a new series of surveys was carried out in the Gulf of Bothnia, using a survey method with fixed strip width and systematically placed strips (Härkönen and Heide-Jørgensen 1990a, Härkönen and Lunneryd 1992). Estimated numbers of seals on the ice ranged between approximately 2,500 and 3,000 animals. During the period 1988-1993, an increasing population trend at about 5% was documented (Härkönen and Hårding 1995). Thus,

Table 1. Surveys of ringed seal abundance on ice in the Baltic 1970-1996.

Area	Year	Estimate	Reference
Gulf of Bothnia	1975	3000	Helle (1980b)
	1978	3280	Helle (1980b)
	1984	2000	Helle (1990)
	1987	2100	Helle (1990)
	1988	2033	Härkönen and Heide-Jørgensen (1990)
	1989	2191	Härkönen and Lunneryd (1992)
	1990	2266	Härkönen and Lunneryd (1992)
	1991	2778	Härkönen and Hårding (1995)
	1993	2862	Härkönen and Hårding (1995)
	1995	2540	Present study
	1996	3954	Present study
Gulf of Finland	1970	5000	Rezvov (1975)
	1970	? see text	Zheglov and Chapski (1971)
	1973	8200	Tormosov and Rezvov (1978)
	1979	1600	Tormosov et al (1980)
	1979	793	Present study
	1982	3700-4000	Tormosov and Esipenko (1986)
	1985	2000+	Tormosov and Esipenko (1989)
	1992	89	Present study
	1993	150	Present study
	1994	173	Present study
	1995	169	Present study
	1996	149	Present study
Gulf of Riga and Estonian west coast	1970	4500	Rezvov (1975)
	1977	1000-1500	Tormosov and Rezvov (1978)
	1979	450-500	Tormosov et al (1980)
	1979	215	Present study
	1994	340-1120	Present study
	1996	1407	Present study

in recent years the size of the hauled- out stock in this area is well described (Table 1).

The Gulf of Finland

Earlier surveys of ringed seal numbers in the Gulf of Finland (Fig. 1) are characterised by lack of clarity in methods and scanty presentation of primary data. Brandt (1856) and Smirnov (1908) mentioned only the existence of seals in the area, while Gottberg (1925) and Bergman (1956) presented detailed bounty statistics for the Finnish sea area. Statistics for the Estonian waters show that an average of 165 seals (species not determined) were killed annually in the period 1926-1939 and about 1,400 annually in 1940-1970 in the entire Soviet Baltic sea area (Anon. 1939, Tormosov and Rezvov 1978).

The first estimation of population size based on actual counts was made in 1970 (Rezvov 1975). A figure of 5,000 seals was presented for the Soviet area of the Gulf of Finland, but only very limited information was supplied on survey methods and the location of the studied area. Rezvov's (1975) estimate for both areas combined (the Gulf of Finland and the Gulf of Riga) was 9,500, but this figure becomes more uncertain taking into account Zheglov and Chapski's (1971) earlier estimation of 12,500 seals for the same year. Also in the latter study information on methods could not be evaluated.

There are additional data on ringed seal numbers in the Gulf of Finland from 1973 (Tormosov and Rezvov 1978). The estimate of 8,200 in Soviet waters is again difficult to evaluate, because information on survey methods is lacking. This figure is probably too high given Tormosov's estimate of 2,100 ringed seals in the Gulf of Finland in 1979 (Tormosov *et al.* 1980, Tormosov and Esipenko 1989). The primary data indicate that the estimate is based on counts of 65 animals. As 8.8% of the total area was surveyed (Tormosov *et al.* 1980), the resulting estimate would be 793 hauled-out ringed seals for the Gulf of Finland. This number, also mentioned by the authors, is considered to be the best estimate. This result cannot be evaluated in more detail as further information on location of strips, and variance is lacking. However, it implies that ringed seal numbers in the 1970s were considerably lower than reported earlier.

A study in 1982 by Tormosov and Esipenko (1986), based on a survey fraction of about 3%, gave an estimate of 3,700-4,000 ringed seals for the Soviet part of the Gulf. In this case the authors reached the estimate using questionable extrapolations (Stenman 1990b).

With the exception of the present authors' review of the study of Tormosov *et al.* (1980) and an additional study from 1985 (Tormosov and Esipenko 1989) there is no reliable information on earlier population size in the area, and the published assessments are probably gross overestimates.

In 1992 and 1993, attempts were made by Finnish and Russian seal researchers to count ringed seals using a helicopter. Unfortunately, during both years only a small fraction of the easternmost part of the Gulf was covered by ice, making it impossible to estimate the population size for the whole Gulf. The aerial counts of seals (89 in 1992 and 44 in 1993), provide only an indication of the number of seals in the area northeast of Seskar Island (Fig. 2).

In addition to these surveys and observations, there is some information from exceptional events that affected the stock. In the beginning of April 1989 an early disappearance of ice had implications for the breeding success of the population. Those pups that survived the destruction of their breeding habitat in the Soviet part of the Gulf were vulnerable to fishing nets that were set a month earlier than usual (Stenman 1990a). Twenty seven pups, of which twenty one were dead, were reported found in fishing gear in Finland alone.

In the autumn of 1991 a high mortality was observed among ringed seals in Russian coastal waters. About 150 dead seals drifted ashore in Russia and Finland, and it was discussed whether natural or man-made neurotoxins could have been involved (Stenman and Westerling 1995). Since then, 2-7 corpses of adult ringed seals have been found annually up to 1996.

The Gulf of Riga and the Estonian west coast

Notes in the literature (Greve 1909) and seal hunting statistics (Anon. 1939) indicate that in earlier times ringed seals were numerous in the Gulf of Riga and Estonian west coast (Fig. 1). However, no estimates of seal numbers were published until 1970, when 4,500 ringed seals were estimated to reside in the area (Rezvov 1975). In a later paper an estimate of 1,000-1,500 animals was provided for 1977 (Tormosov and Rezvov 1978), but details of survey methods were not given. Data recalculated from Tormosov *et al.* (1980) show that 19 ringed seals were observed in the strips of the 1979 survey. The survey fraction was 8.8%, giving an estimate of 215 hauled-out ringed seals. Again, the earlier estimates are considered to be unreliable.

The concentration of ringed seals in certain areas during the ice-free period provides an additional opportunity to study the abundance and distribution of the species. The seals have been counted at the summer haul-outs and the result was presented as a minimum value for the population (Tormosov and Esipenko 1986). However, later studies in the area (Leito 1990) have shown that this kind of data could be erroneous, as at many sites scattered groups of both ringed and grey seals occur (Tormosov and Esipenko 1986: their Table 4). Such groups may include a large proportion of juvenile grey seals that can be mistaken for ringed seals. Thus, earlier data cannot be relied upon as a basis for estimates of abundance or distribution.

METHODS AND RESULTS

Censuses

Design

Strip census technique was used as described earlier by Härkönen and Heide-Jørgensen (1990a) and Härkönen and Lunneryd (1992). In this method strips are placed in a systematic manner to evenly cover the study area (Fig 1). The surveyed strips extended to 400m on either side of the aircraft, flying at an altitude of 90m. Observations of seals were noted at two-minute intervals, which permits positioning of observations within segments (Härkönen and Lunneryd 1992). When seal density is calculated for each segment, detailed mapping of ringed seal distribution is possible (Fig. 2).

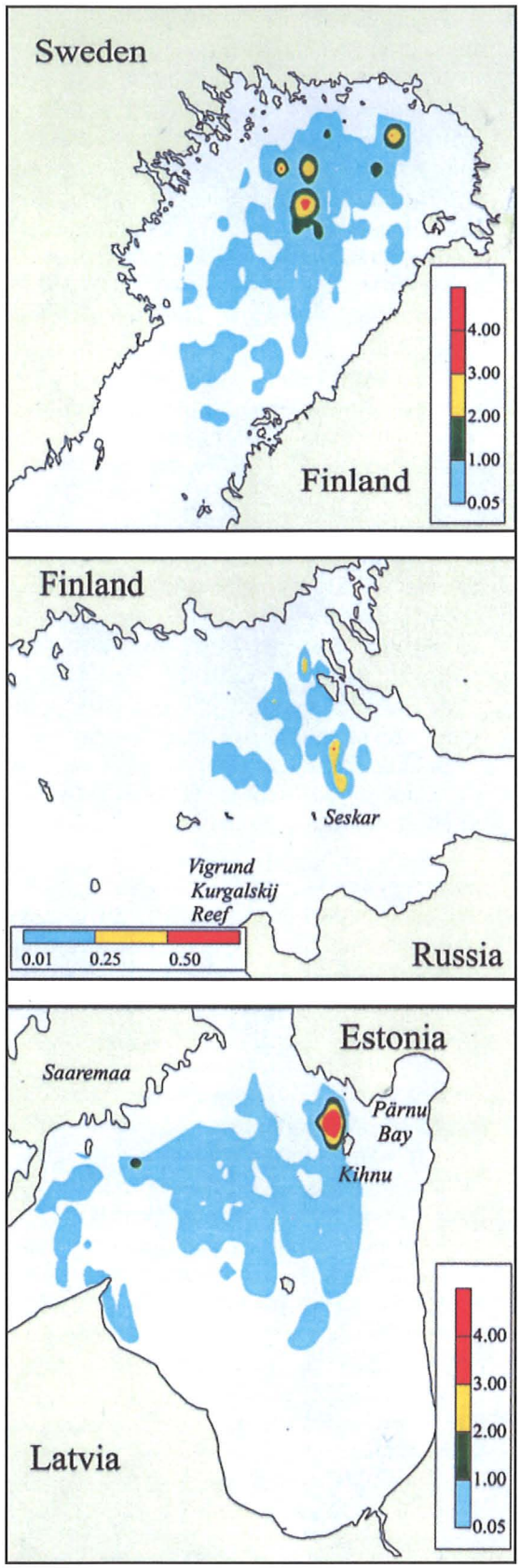

Fig. 2
Distribution of ringed seals (Phoca hispida botnica) in the Baltic 15 April-5 May 1996. Original fine scale density data (see text) processed by the linear variogram model using Surfer 5.01 (Golden Software). Densities shown as numbers of seals/km². Note: Regional maps are in different scales.

The method was implemented in all censuses in the Gulf of Bothnia, and also in censuses in the Gulf of Riga and the Gulf of Finland carried out in 1996. Before 1996 different or modified methods were used in the two latter areas due to logistic problems and changing ice conditions. Effective strip width in the 1994-1995 surveys in these areas was assumed to be approximately 1,600m for the following reasons:

1) In the 1988 and 1989 censuses in the Gulf of Bothnia, seals outside the 800m strip were also counted, and of the total 1,470 sighted seals, 665 seals were observed within the 800m strip. This implies that the effective mean strip width, when counting all visible seals, was (1,470/665) x 800m = 1,768m.

2) Based on measurements of the sighting angle to each observed seal, retrospective analysis showed that the effective strip width varied between 1,600m and 2,200m (Helle 1986).

3) As visibility of seals is affected by ice conditions, the broken-up ice fields in 1994-1995 would reduce the chance of sighting, and thus the width of the strip would be in the lower part of the range indicated above i.e. about 1,600m.

Statistics

The Poisson distribution provides the best approximation of the distribution of data arising from the type of strip censuses used in this study (See "Size of local populations"). However, earlier studies (Härkönen and Lunneryd 1992) have shown that when the basic unit of data treatment is extended to encompass larger sampling areas (e.g. 10 randomly chosen segments), the means of these larger sampling units will be normally distributed. This explains not only why the mean density of seals calculated from segments and larger sampling units are identical, but also why the computed 95 percent confidence intervals (95% CI) are identical and symmetric in both cases. The 95% confidence intervals are calculated as:

$L_1 = \text{mean} - t_{\alpha(n-1)} S_{\text{mean}}$ and $L_2 = \text{mean} + t_{\alpha(n-1)} S_{\text{mean}}$,

where L_1 and L_2 are the lower and upper limits and S is the standard error (Sokal and Rohlf 1981).

Distribution

Distribution during the ice free period

Limited information is available on distribution during the period spring to autumn, since ringed seals in the Gulf of Bothnia, the most intensively studied area, do not haul out in large numbers during the ice-free period. A contrasting pattern of behaviour is found in the southern distribution. In the Russian part of the Gulf of Finland several haul-out sites were found on islands, islets and rocks during boat surveys in spring and summer 1993-1996. Congregations of up to 80 individuals were observed on scattered rocks at the Kurgalskij Reef and Vigrund Island (Fig. 2) along the southeastern coast of the Gulf during late May, early June and in August. On the Estonian west coast several groups, comprising 10-40 animals, haul out on rocks around the islands Hiiumaa and Saaremaa (Fig. 1).

Late winter distribution

In the Gulf of Bothnia the largest numbers of ringed seals are hauled out on ice during the moulting period which occurs from April to May (e.g. Helle 1980b). Usually, ice conditions deteriorate a couple of weeks earlier in the Gulf of Finland and the Gulf of Riga which is the reason why the highest numbers on ice in this area occur somewhat earlier. In 1995 co-ordinated international censuses were carried out in mid April due to rapidly melting ice. In 1996 censuses were conducted in the latter half of April and the first days of May.

The following analysis of the late winter distribution of Baltic ringed seals is based only on the 1996 survey, when all three areas could be studied with the same method. The distribution in the Gulf of Bothnia was found to be similar during all years 1988-1996, with the largest concentrations of seals found in the central northern drift ice (Fig. 2). Even in 1988, when ice fields extended as far as to the northern part of the Sea of Bothnia, a similar pattern was found, indicating that seal distribution in this area was not directly correlated to size of ice fields during these years.

In the Gulf of Finland highest densities were found in the east, with low densities elsewhere (Fig. 2). The westernmost part of the Russian coastal waters could not be surveyed due to mil-

itary restrictions. However, a survey in the Estonian coastal waters during 18 April 1996 indicated the presence of low numbers of ringed seals in the mid section of the Gulf of Finland. The concentration of seals to the east in the 1993-1995 surveys could be explained by the fact that they hauled out on the last remaining ice.

The whole of the Gulf of Riga was covered by ice in 1996, but ringed seals were concentrated in the northeastern part. Highest densities were found around Kihnu Island (a traditional seal hunting area) close to Pärnu Bay, and along cracks at the fast-ice edge in the northeast (Fig. 2). Only occasionally were seals found in the southern and western parts of the area.

Size of local populations

The Gulf of Bothnia

No acceptable surveys could be carried out in the area in 1994 due to unfavourable ice and weather conditions in late April and early May. In 1995 three censuses with a total sampling fraction of 18.5 %, had to be completed early in the season (11-15 April) because of rapidly deteriorating ice conditions. The abundance estimate was 2,246 ± 835 hauled-out seals in the area (Table 2). However, our data indicate that the number of seals hauled out increases towards the end of the moulting period, which makes it questionable whether surveys before mid April produce results that are directly comparable with those from surveys conducted later in the season. The 1995 estimate must therefore be treated with caution.

Ice conditions in 1996 permitted the field work to be carried out during 30 April -2 May. To increase precision, sampling intensity was doubled in the high density area compared with the low density area. The boundary of the high density area was based on results from earlier years. The estimate for the hauled-out population size was 3,954 ±1,732, considerably higher than reported earlier. The 95% confidence interval at ±44% was considerably wider compared with earlier surveys. The reasons for this were tested by fitting data to Poisson distributions, which can be used to investigate whether events occur independently with respect to each other (Sokal and Rohlf 1981). The coefficient of dispersion (CD) is expressed as CD = variance / mean, and a distribution with a CD value near 1 is essentially a Poisson. In clumped samples CD>1, whereas CD<1 is a strong indication of repulsion. The data from this study shows that CD values ranged between 0.70 and 0.88 during 1988-1990, which indicates that seals avoided each other in the censuses carried out during that period. In contrast, CD values increased from 1.36 in 1991 to 1.93 in 1996 (Table 3). Thus, it is concluded that ringed seals showed a more clumped pattern of distribution in 1996 compared with earlier years.

Table 2. Results of surveys of hauled-out ringed seals in the Gulf of Bothnia 11-15 April 1995, and 30 April - 2 May 1996. In 1996 the surveys were stratified into low and high density areas (see text). Ninety-five percent confidence intervals (CI) are given for the population estimates.

Year	1995	1996		
Stratum	-	High	Low	Total
Ice area (km²)	8211	4097	18863	22960
Mean seal density/km²	0.273	0.6	0.079	-
Standard deviation	0.643	1.072	0.396	-
Actual count in strips	466	413	124	537
Sampling fraction (%)	18.5	16.8	8.29	-
Population estimate	2246	2458	1496	3954
±CI 95%	680	892	886	1778

The population trend was analysed by linear regression using data from of all surveys between 1988-1996 (Table 3). Estimates of population size for each year were weighed by the inverse of their variances (see Table 3), and the regression was analysed by ANOVA (Sokal and Rohlf 1981). Including all data, an increasing population trend is shown only at $p<0.10$, but if data from 1995 are omitted, the trend is statistically significant ($F=912$, $p<0.05$, Fig. 3). The analysis also illustrates the necessity of long time series in studies of trends if significant and reliable results are to be achieved (Gerrodette 1987, Taylor and Gerrodette 1993, Bignert and Olsson 1997).

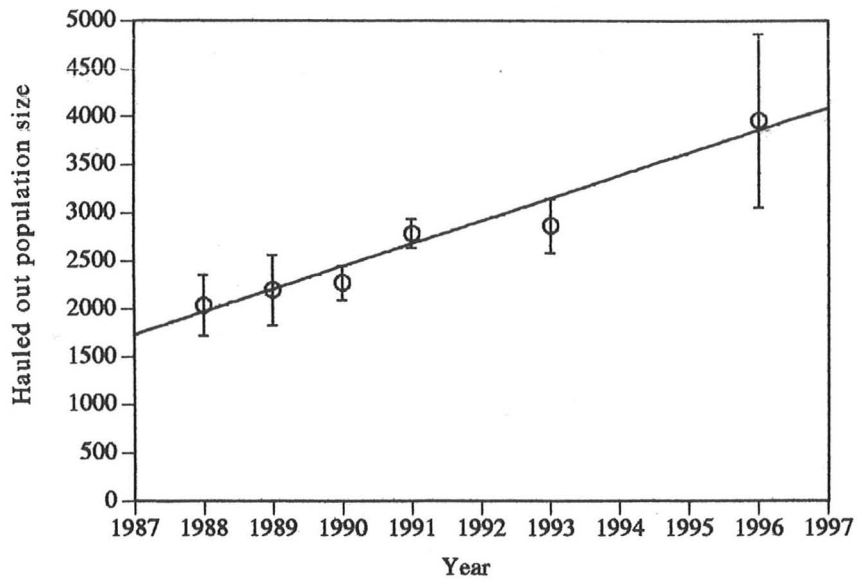

Fig. 3
Development of the local population of ringed seals (Phoca hispida botnica) in the Gulf of Bothnia during 1988-1996, based on data from Härkönen and Heide-Jørgensen (1990a), Härkönen and Lunneryd (1992), Härkönen and Hårding (1995) and this study. Vertical bars indicate the standard errors of the estimates. In the regression analysis annual point estimates were weighed by the inverse of their variances (Table 3), and the slope of the line was tested by ANOVA. Including the survey from 1995 the slope of the line does not significantly deviate from zero, but omitting the 1995 data (see text) the slope is positive ($P<0.05$). The latter regression line is given by $y = 235.8x - 466713$, $r^2 = 0.97$.

The Gulf of Finland

In the eastern part of the Gulf of Finland (Russian territory) an MI-8 helicopter was used for the surveys in 1992 - 1994. However, the strip census technique was not applied in 1992 and 1993. In 1994 strip width was assumed to be 1,600m and flight altitude was 90m. In 1995 a fixed wing AN-2 airplane was used. During all four years, surveys took place in the same areas and ringed seal distribution showed a similar pattern. Along the Finnish coast the method of Helle (1986) was used with a Piper PA 31 in 1994. In 1993, 1995 and 1996 no seal ice was present, and thus the area was not surveyed.

In 1992 and 1993 it was not possible to estimate the sampling fraction, and thus extrapolated numbers are not relevant. Results from the 1994 and 1995 surveys are more accurate, being based on strip widths of approximately 1,600m (Table 4). In 1994 ringed seal numbers in Russian territory were estimated at 169 individuals, and in Finnish territory at 4, totalling 173. In the latter area a 100% sampling fraction was

Table 3. Estimates of the Coefficient of Dispersal (CD) for surveys carried out in the Gulf of Bothnia 1988-1996. The CD is calculated as CD=variance/mean. Values close to 1 show that samples are essentially Poisson, whereas values exceeding 1 indicate clumped samples and values below 1 repulsion (Sokal and Rohlf 1981). The "n" indicates sample size (number of segments) and the "mean" the average density of seals in samples. For 1996, data are shown for high and low density areas (see text) separately and for the entire area. The inverted value of the variance ($1/s^2$) is used for weighing the linear regression in Fig. 3.

Year	n	mean	s^2	$1/s^2$	CD
1988	532	0.124	0.104	9.61	0.84
1989	545	0.132	0.092	10.87	0.70
1990	559	0.279	0.247	4.05	0.88
1991	417	0.346	0.471	2.12	1.36
1993	273	0.505	0.826	1.21	1.63
1995	373	0.273	0.402	2.49	1.47
1996 High	93	0.637	1.149	0.87	1.80
1996 Low	274	0.072	0.157	6.37	2.18
1996 Total	367	0.173	0.333	3.00	1.93

Table 4. Survey results of hauled-out ringed seals in the Gulf of Finland in 1992- 1996, and in the Gulf of Riga in 1994 and 1996. Sampling fractions for the surveys of 1992 and 1993 in the Gulf of Finland are not available, and thus the estimates are unreliable. In the Gulf of Finland a variant of the strip census method was used in 1994 and 1995 (see text), and the population assessments can be used as gross indications of population size. In 1996 the total ice covered area was 2,688 km², but only 60% (1,613 km²) could be covered by the range of strips due to military regulations (Fig. 1).

Area	Gulf of Finland					Gulf of Riga	
Year	1992	1993	1994	1995	1996	1994	1996
Date	3/4	31/3	30/4	15/4	4-5/5	14-21/4	15-17/4
Ice area (km²)		-	-	-	1613*	1000-4000	9945
Mean seal density/km²					0.057	varying	0.142
Standard deviation					0.135	varying	0.526
Actual count in strips	89	40	61	54	22	450	228
Sampling fraction (%)		< 30	36	32	24	**	16.2
Population estimate Russia		~150	169	169	92		
Population estimate Finland	-	-	4	-	-		
TOTAL		~150	173	169	92*	680	1407
±CI 95%					41	340	590

* If the mean seal density in strips west of 28°20'E at 0.053 seals /km² is applied to the remaining ice-covered area (1,075 km²) a calculated number of 57 seals results for that area. Therefore, the estimate for the entire ice-covered area would be 149.

** Sampling fraction uncertain because transect width could not be calculated exactly and due to changing ice conditions during surveys.

obtained due to the limited ice fields. In 1995 ice persisted only in Russian areas and the estimate was again 169 specimens.

The Estonian part of the Gulf of Finland was surveyed on 18 April 1996 using the standard method. Ice fields had broken up and were drifting to Russian territory, but 3 ringed seals were observed in strips that covered 24% of the area. The resulting estimate of 12 seals provides evidence that ringed seals are also found in the western part of the Gulf. This figure is not used for estimates of population size in the whole Gulf because Russian flights were made almost two weeks later, and could include seals counted earlier in Estonian waters.

Surveys over Russian territory were carried out 4-5 May 1996, using the standard 800m strip width. A total of 22 ringed seals were observed, and as the sampling fraction was 24%, the estimate of the total hauled-out population is 92. However, due to military restrictions in the westernmost part of Russian waters, only 60% of ice suitable for seals could be covered by strips. Earlier flights over Estonian territory gave evidence for the presence of ringed seals further west. If the average density of ringed seals in strips west of the longitude 28°20'E (only Russian territory) is applied to the remaining part, a new total estimate of 149 results. This estimate is similar to results of surveys made since 1992 (Table 4).

The Gulf of Riga

The first modern surveys in the Gulf of Riga were accomplished during 14-21 April 1994. Poor ice conditions, that changed dramatically during the study period, combined with the fact that the standard survey method could not be used due to logistic problems, preclude a detailed analysis of these results. However, it is estimated that 500-1,000 ringed seals were hauled out in the northern part of the area (Table 4).

In 1996 the entire area was surveyed with the standard method resulting in an estimated hauled-out population of 1,407 ±590 ringed seals. As in the Gulf of Bothnia, clumping is

the main reason for the relatively wide confidence interval (95% CI= ±42%). The sampling fraction was 16.2%, comparable to that of the high density area in the Gulf of Bothnia.

Areas combined.
If results from all areas are combined, a total number of about 5,510± 42% hauled-out ringed seals can be estimated for the entire Baltic in 1996.

DISCUSSION

Earlier counts
Our review of earlier estimates shows that while substantial recent data is available from the Gulf of Bothnia, the information available for population estimates and trends in the Gulf of Finland and the Gulf of Riga is of dubious quality. One exception is the study of Tormosov et al. (1980), where the raw data suggest about 800 hauled-out animals in the Gulf of Finland and about 200 in the Gulf of Riga in 1979. However, these results are difficult to evaluate as no information is available on location of strips and variances of estimates.

Present situation
Surveys were carried out by a trained crew of scientists from participating countries. Crew configuration changed during flights in different areas of the Baltic, but this should not have affected survey precision as no significant difference in efficiency was detected between observers. The standard survey technique, used in the Gulf of Bothnia since 1988, was only fully implemented in the whole area in 1996 (except for the western part of the Russian territory of the Gulf of Finland). Therefore, earlier estimates on population size in the Gulf of Finland and the Gulf of Riga must be regarded as being approximations.

In 1994-1995 different variants of the standard technique were used. In the Russian territory of the Gulf of Finland a helicopter was used in 1992-1994. There is no earlier background data concerning a possible difference in level of harassment between helicopters and fixed winged aircraft in the area. However, no difference in behaviour of seals could be noted comparing helicopter and airplane flights. The 1995 survey, which was carried out by airplane, showed basically the same result as the 1994 study, suggesting that if there is a difference, it is of minor importance.

In 1994 a low winged aircraft (Piper Navajo) was used in the two first surveys in the Gulf of Riga and over Finnish territory in the Gulf of Finland. The intended survey technique was according to Helle (1980b), but strip width was not estimated due to severe difficulties in measuring the sighting angle to each seal in high density areas. Therefore, strip width was assumed to be about 1,600m also in these areas.

One major reason for choosing a certain survey technique is to reduce factors causing variance, which affect the precision of population estimates. In the standard strip census technique with systematically placed strips, variance can be reduced by stratification, as was the case in the Gulf of Bothnia in 1996. Here, survey effort was doubled in the high-density area, because earlier experience showed that the largest variance could be expected here. Still, the variance for the 1996 survey was larger than earlier. This fact has nothing to do with the survey technique itself, but is linked to ringed seal behaviour during moult.

In the Gulf of Bothnia, there are now indications suggesting that the proportion of the population which is hauled out increases towards the end of April and the beginning of May (see also Helle 1980b). This would therefore be the best period for surveys if the intention is to record the size of the largest possible proportion of the hauled-out population. The major disadvantage in choosing a late date for surveys is that ringed seals become more congregated, which has a strong negative effect on the precision of estimates on population size, and thereby renders trend analyses more difficult. An additional factor of importance is that the possibility of choosing a specific time for the surveys is limited by ice and weather conditions. An example of this is that by mid April in 1995 limited areas of suitable seal ice were left in the Gulf of Bothnia during surveys and there was no ice at all in the Gulf of Riga. Therefore, a large proportion of the recorded variance in the population estimates is due to biological and physical factors.

Distribution

The ringed seals in the Baltic are apparently separated into three local populations during moult. About 70% of the total population is found in the north, 25% in the Gulf of Riga and the remainder in the Gulf of Finland. The distribution of seals in the Gulf of Bothnia showed largest concentrations in the central northern drift ice, and a remarkably similar pattern was found for the fine scale distribution of 708 ringed seals shot on ice in 1930 (Fig. 4, Olofsson 1933). In the Gulf of Finland largest numbers were observed in the east, which also coincides with the geographic distribution of catches in the Gulf during 1924-1955 (Bergman 1956). The habit of ringed seals to concentrate to certain areas from year to year could be explained by the topography of bottoms and prey availability on one hand, and the predictability of suitable ice for over-wintering on the other. An on-going project using satellite-linked time-depth recorders will provide more details on over-wintering behaviour.

In the Canadian Arctic it was shown that ringed seals are not randomly and independently distributed (Stirling et al. 1982), and stratification was not very effective in improving the precision of the population estimate because not only are more groups seen, but the groups get larger with increasing population size. In the present case stratification increased the precision of the estimate in the Gulf of Bothnia, as the 95% CI decreased from ±56% to ± 44%. Our analysis of clumping showed that during some years the CD value was considerably below 1 while substantially over 1 during other years. One possible explanation may be that if ice fields are intact during surveys, over-wintering seals remain close to their winter territories also during moult. During the establishment of the over-wintering territories, and in the breeding season adult animals show strongly agonistic behaviour (Smith and Hammill 1981, Smith 1987), which would result in repulsion (CD<1). If ice fields are broken up in spring, resulting in destruction of the winter habitat, ringed seals could move to more stable ice for moulting. This would explain both the large congregations of seals in, for example, newly opened cracks, and the tendency to clumping (CD>1) under such conditions.

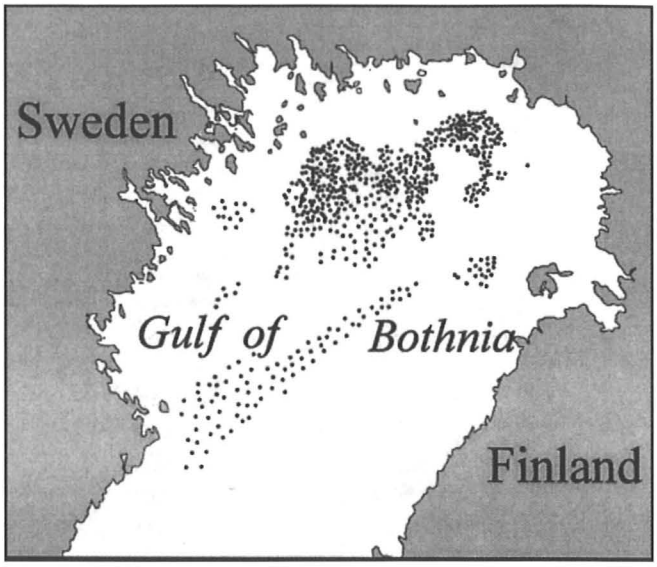

Fig. 4 *Distribution of 708 ringed seals (Phoca hispida botnica) and 3 grey seals (Halichoerus grypus) killed in the Swedish hunt in the Gulf of Bothnia 12 March - 20 May 1930. Re-drawn from Olafsson (1933)*

Data are scarce on movements of ringed seals during the ice-free period, but summer surveys in the southern areas indicate that the seals are relatively sedentary. Additional indications that ringed seals in the Baltic could be stationary within regions are provided by observed differences in behavioural traits. Group haul-out behaviour on rocks is not a common feature in ringed seals in the northern area, although this type of habitat is abundant in the area. In contrast, ringed seals in the eastern and southern parts of the Gulf of Finland and the Moonsund archipelago haul out on stones in large numbers during the ice-free period.

This marked difference in summer haul-out behaviour could be due to the following factors: 1) in the north there is always enough ice for haul-out during moult. In the south, break up of ice occurred before completion of the moulting period in one year out of four as an average during the period 1930-1995 (Hook and Johnels 1972, Seinä and Palosuo 1996). During those years the only opportunity for moulting ringed seals to haul out, was to use rocks, a behavioural pattern they tend to maintain also during early summer and late autumn; 2) in Soviet waters of the Baltic, shooting of seals was not common. Even in the 1970s ringed seals were mainly harvested professionally by use of nets

(Popov 1978). In contrast, hunting by use of rifles was carried out in Finland to some extent until 1988. Ringed seals hauled out on rocks in Finnish areas were, according to tradition, likely to be killed; 3) a third factor could be differential levels of human harassment other than hunting. Until the early 1990s, Soviet waters were almost empty of boats and yachts. Small scale fisheries were restricted, and vast areas in coastal regions were seldom visited by man. In contrast, intensive human activities occurred especially during summer in Finnish and Swedish areas.

Whatever the reasons, this behavioural difference persists, and indicates that ringed seals do not migrate in large numbers between local populations. An alternative explanation would be that ringed seals move around in the Baltic and change behaviour as they enter into different regions, but this seems unlikely because none of ten seals equipped with satellite transmitters at the Estonian west coast, and none of five from the Gulf of Bothnia, moved out of the regions during the ten month period 15 May -24 March (Härkönen unpublished data).

Seal numbers and trends

This study provides the first reliable estimate of the hauled-out ringed seal population size in the entire Baltic at 5,510± 42%. However, additional studies are required to improve the precision of the estimate. The size of the hauled-out local population in the Gulf of Bothnia was about 4,000, and there is evidence of an increasing trend since surveys started in 1988. Data for the two other areas are insufficient for trend analyses.

True population size

Existing information on the fraction of ringed seals that haul out during moult is fragmentary and limited, and the few investigations providing data are all based on small numbers. Estimates vary between 50% (Smith 1973, Smith and Hammill 1981) and 84% (Fedoseev 1971). Thus, it is possible that about 70% of the population is basking under optimal conditions. If this is true, the present population size of ringed seals would exceed 6,000 animals. However, until more details on haul-out behaviour during moult are available, this figure must be regarded as tentative.

Factors affecting the population

It is evident that all local populations are still under stress. The northern stock is affected by a disease complex (Bergman and Olsson 1986), and 30-40% of adult females are sterile (Mattson and Helle 1995). The presence of uterine occlusions has also been demonstrated in ringed seals from the population in the Gulf of Finland (Westerling and Stenman 1992). In both southern populations, pup mortality has been high during the almost ice-free winters of 1989-1995. Reports of about 150 dead ringed seals in 1991-1992 in the Gulf of Finland imply that about 50% of the stock in that area died during those years.

ACKNOWLEDGEMENTS

The surveys were financed by WWF Finland, WWF Sweden, the Swedish Environmental Protection Agency, the Ministry of Agriculture and Forestry in Finland, the Estonian Environment Fund, and the St. Petersburg State University. We thank Sven Gunnar Lunneryd for participation in the survey of 1995, and Karin Hårding and Colin Wheatley for valuable comments on the manuscript.

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