PUP PRODUCTION AND SUSTAINABLE YIELD OF WHITE SEA HARP SEALS

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ABSTRACT

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Pup production from 1962 to 1965 was estimated by a survival index method from age composition of Norwegian samples of moulting harp seals collected in the southeastern Barents Sea from 1964 to 1972.

Pup production decreased from 130 thousand in 1962 to 98 thousand in 1965. From these estimates production was projected forward to give an estimate of 172 thousand pups produced in 1978, corresponding to a total stock of one year old and older harp seals of about 800 thousand. Both the projection and the number of adult females in the whelping patches estimated from Soviet aerial surveys give an annual increase of about 5% since 1968. The sustainable yield for 1978 is estimated at 98 thousand pups and 8 thousand one year and older animals.

INTRODUCTION

Populations of harp seals *(Pagophilus groenlandicus)* breed in the spring at Newfoundland-Labrador, in the Jan Mayen area of the Greenland Sea and in the White Sea. These populations are separate. The White Sea harp seal has an annual feeding migration into the Barents Sea and the Kara Sea and has been seen as far north as 79° in the eastern part of the Svalbard area in summer.

The harp seal has been exploited by aborigines for centuries along the coasts of the White Sea and the southeastern Barents Sea. Norwegian sealers started hunting harps in the White Sea in 1867, the catch increasing slowly to 40 thousand by 1900 (IVERSEN 1927). At the beginning of the 20th century large Russian ships were introduced in the hunt while the number of Norwegian ships increased. The resulting increased catch reached a maximum of 460 thousand in 1925 with a mean of 347 thousand per year in the period from 1923 to 1927 (YAKOVENKO 1967). After 1925 the catch decreased with a mean catch of 222 thousand seals taken per year in the period from 1933 to 1937. According to YAKOVENKO (1967) this drop could only be explained by a decrease in the size of the stock. Only small catches were

taken during the Second World War, and after the war Soviet catches increased to 195 thousand by 1950 while Norwegian catches in the southeastern Barents Sea were kept at a level between 10 and 35 thousand per year.

After 1950 the stock declined rapidly, and a quota of 100 thousand harp seals for the Soviet catch was introduced in 1955, being gradually reduced to 60 thousand in 1963. In 1965 a total quota of 34 thousand was put into force, of which Soviet landsmen were allocated 20 thousand and Norwegian ships 14 thousand seals. In 1977 the total quota was increased again to 50 thousand, 34 thousand to Soviet and 16 thousand to Norway. Adult females have been protected in the whelping patches since 1963, and the Soviet catch of one year old and older seals was stopped in 1965.

Data on age and sex composition of Norwegian catches of moulting harp seals in the southeastern Barents Sea have been collected since 1963. Most of the age samples (sexed and dated) have been collected by observers from the Institute of Marine Research, some age samples without information on sex and date have been taken by sealers.

The purpose of this paper is to estimate pup production from Norwegian age samples of moulting seals and project the female population forward in order to calculate the present sustainable yield of the White Sea harp seal population. The projection is compared to aerial photography estimates of the number of adult females in the whelping patches as presented to the Northeast Atlantic Seal Commission (Norwegian-Soviet Seal Commission) by Soviet scientists.

MATERIAL AND METHODS

Catches of harp seals in the White Sea and the Barents Sea from 1958 to 1977 are listed in Table 1. The data are based on reports to the Seal Commision. The Table shows that catches were substantially reduced, in particular the catches of one year old and older animals, after the introduction of reduced quotas and other regulations in 1965.

Age group frequencies of moulting harp seals from Norwegian samples in the Barents Sea from 1963 to 1976, which have all been reported to the Seal Commission, are shown in Table 2.

Production estimates were obtained by a «survival index method» (SERGEANT 1971, ØRITSLAND 1971, BENJAMINSEN and ØRITSLAND 1975). The method involves a regression of the abundancy of successive year classes on pup catches of the same year classes. The survival index is expressed as the ratio of the relative frequency of each year class in individual samples to the mean relative frequency of the corresponding age group in all samples. To calculate the mean survival index for each year class, each age sample is weighted in proportion to the square root of the number of animals in the sample.

Table 1. Catches of harp seals in the White Sea and the Barents Sea from 1958 to 1977. Data on Soviet catches are from reports to the Norwegian Soviet Sealing Commission. (1 year + is catches of one year old and older animals).

	Norway		Soviet		Total	
	Pups	1 year +	Pups	1 year +	Pups	1 year +
1958	2 733	12 369	84 995	27 997	87 728	40 366
59	2 257	6 286	48 257	47 982	50 514	54 268
1960	2 474	8 222	60 579	28 736	63 053	36 958
61	2 903	8 254	41 827	51 676	44 730	59 930
62	1 325	6 981	67 633	39 327	68 958	46 308
63	405	12 944	54 861	7 603	55 266	20 547
64	3 109	11 477	47 008	15 771	50 117	27 248
1965	4 537	1 899	20 135	0	24 672	1 899
66	1 932	10 319	20 012	196	21 944	10 515
67	9 648	2 004	20 000	0	29 648	2 004
68	11 960	3 150	20 000	0	31 960	3 150
69	5 241	6 697	21 588	593	26 829	7 290
1970	4 230	8 734	24 328	1 262	28 558	9 996
71	7 028	1 596	26 666	1 002	33 694	2 598
72	4 229	8 209	30 635	500	34 864	8 709
73	5 657	6 661	29 950	813	35 607	7 474
74	2 323	5 054	29 006	500	31 329	5 554
1975	2 255	8 692	29 000	500	31 255	9 192
76	6 742	6 375	29 050	498	35 792	6 873
77	4 129	3 383	34 007	1 488	38 136	4 871

The survival indexes were calculated for age groups 1 to 5 in the Norwegian samples of moulting seals collected in the Barents Sea from 1964 to 1972. Frequencies of age group 1 were calculated from the number of seals in the total samples while frequencies of age groups 2–5 were calculated from the number of two year and older seals in the samples. By linear regressions of survival indexes on pup catches, average estimates of production were obtained from the intercepts of the regression lines on the X-axis. Production estimates for various mid-years were obtained by regressions of different year class intervals.

An estimate of the total number of productively mature females was obtained by dividing pup production by pregnancy rate. Starting with the most up-to-date estimate, the number of productively mature females for the next year was calculated by substracting catch and natural mortality and then adding recruitment. Pup production was then calculated by multiplying by the pregnancy rate. In this way production was calculated for successive years. Recruitment was calculated by starting with a production estimate, substracting catch and natural mortality each year to productive maturity.

Table 2. Age group frequencies of moulting harp seals in Norwegian samples collected in the Barents Sea from 1963 to 1976. M = male, F = female, U = not sexed.

Age group	1963 U	1964 U	1965 M	1965 F	1968 M	1968 F	1968 U	1970 M	1970 F	1972 M	1972 F	1973 U	1974 M	1974 F	1976 M	1976 F
1	30	75	17	36	111	123	95	184	170	162	149	207	108	109	71	62
2	24	44	11	8	43	35	28	92	92	114	111	83	91	55	49	50
3	19	46	7	5	33	37	27	89	93	84	80	68	82	57	24	35
4	28	26	8	3	16	10	9	53	38	84	52	28	62	40	22	12
5	11	28	4	3	5	7	9	24	23	27	35	33	36	31	20	4
6	11	17	7	2	12	9	12	6	18	11	23	31	29	27	7	14
7	8	20	6	0	24	12	16	3	21	9	16	24	20	35	19	37
8	7	13	9	2	23	9	10	1	14	6	8	15	20	29	22	50
9	11	19	5	4	18	3	13	0	11	12	15	24	9	16	32	40
10	6	13	8	4	16	1	9	0	10	9	16	21	7	15	27	16
11	2	11	7	0	13	1	5	1	4	6	4	18	7	11	24	11
12	1	13	6	0	3	0	2	0	1	6	9	20	2	11	21	12
13	1	7	6	2	3	0	6	0	1	5	2	13	4	11	14	11
14	3	11	7	1	5	1	4	0	2	4	1	16	5	8	17	12
15	4	6	7	0	4	0	3	1	0	6	3	3	2	4	14	8
16	1	6	5	1	2	0	3	0	1	3	0	4	1	5	21	8
17	1	2	1	1	3	0	0	0	2	4	0	3	1	1	19	5
18	1	3	2	0	3	0	2	1	2	2	0	12	2	4	12	6
19	1	1	4	0	4	0	3	0	0	1	0	3	3	1	14	2
20	1	2	3	1	4	0	2	0	2	6	2	10	0	0	14	2
21	0	2	2	0	0	0	1	0	0	2	0	5	2	0	11	1
22	0	0	1	0	4	0	0	0	0	2	0	2	0	1	6	0
23	0	0	0	0	3	0	1	0	0	0	1	2	1	1	4	0
24	0	0	0	0	1	0	1	0	0	0	0	1	0	2	2	2
25	0	0	0	0	0	0	2	1	0	1	0	3	0	1	3	0
26+	0	0	0	0	3	0	0	2	0	4	0	3	2	2	8	0
Total	171	365	133	73	356	248	263	458	505	570	527	652	496	477	497	400

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No attempt has been made to include any possible density dependent effect on age of sexual maturity, pregnancy rate or natural mortality.

Sustainable yield of pups can be estimated from the basic assumption that constant production requires an equilibrium between recruitment and mortality among productively mature females. For a stable population this may be expressed by the following equation:

$$\frac{1}{2} \cdot (B - C) \cdot S^a = \frac{B}{f} \cdot (1 - S)$$

where B is pup production, C is sustainable yield of pups, S is survival rate, a is median age of first whelping and f is fertility rate. A median age of first whelping of 5 years (YAKOVENKO and NAZARENKO 1967) was used in the calculations. No estimate of fertility rate or natural mortality is available for the White Sea harp seal. Therefore a fertility rate of 0.90 (ØRITSLAND 1971) and an annual natural mortality of 10% (MERCER 1978) as found for New-foundland–Labrador harp seals, were applied. Age distribution of the catch of one year old and older seals is assumed synonymous with the population structure as is an equal sex ratio. A 1:1 sex ratio of pups is also assumed on the basis of unpublished Norwegian data.

RESULTS

Pup catches and survival indexes for the year classes from 1959 to 1971 are listed in Table 3. The table shows that high pup catches before 1965 give survival indexes well below 1.00, and that the reduced pup catches from 1965 to 1970 produce indexes higher than 1.00. Weighted mean indexes were calculated for the year classes from 1960 to 1969. These are plotted against the pup catches of their respective year classes in Fig. 1. The inter-cept of the regression line on the X-axis gives an estimate of pup production in the mid-year 1964 of 103 thousand.

Pup production estimates with their 95% confidence interval for diffe-rent mid-years from 1962 to 1965 are listed in Table 4. The estimates show that pup production decreased from 130 thousand in 1962 to 98 thousand in 1965, with corresponding lower confidence limits of 94 and 74 thousand pups.

Estimated and projected pup productions from 1962 to 1978 are plotted in Fig. 2, showing that production increased from 98 thousand in 1965 to 172 thousand in 1978. Included in Fig. 2 are the number of adult females in the whelping patches estimated from Soviet aerial survey data. The two curves have the same shape, and both show a mean annual increase of about 5% from 1968 to 1976.

From a production estimate of 172 thousand, the sustainable yield in 1978 is calculated at 98 thousand pups and 8 thousand one year and older seals.

Table 3. Pup catches of the White Sea harp seal and the survival of corresponding year classes expressed by a survival index (frequency in sample/average frequency). Below the year of sampling is given the number of specimens and the weight given to the sample in calculating the weighted mean for 1–5 year old seals.

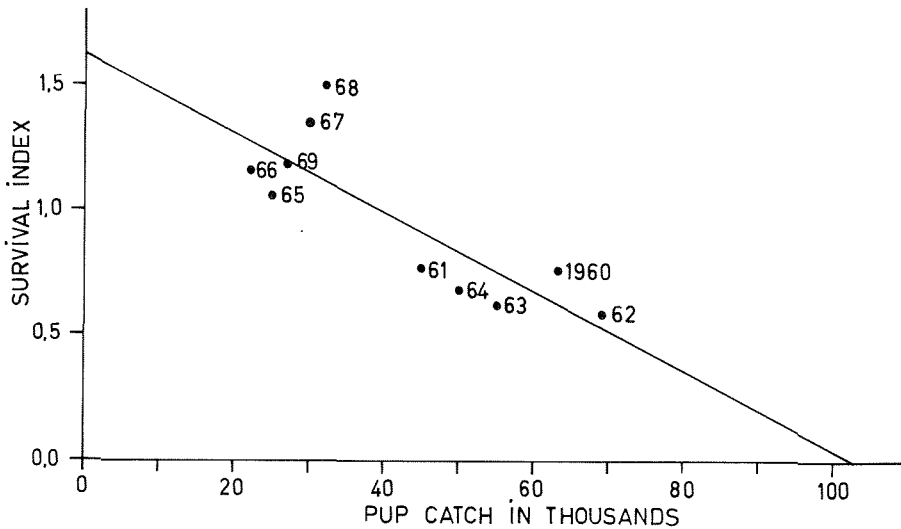| Year class	Pup catch x10^-3	Survival index					
		1964 368 1.3	1965 206 1.0	1968 867 2.0	1970 963 2.2	1972 1 097 2.3	Weighted mean
1959	51	1.43					
1960	63	0.82	0.68				0.76
61	45	0.86	0.65				0.77
62	69	0.72	0.42				0.59
63	55	0.69	0.59	0.58			0.62
64	50		0.86	0.59			0.68
1965	25			0.97	1.14		1.06
66	22			0.93	1.36		1.16
67	30			1.27	1.62	1.17	1.35
68	32				1.42	1.57	1.50
69	27				1.23	1.13	1.18
1970	29					1.35	
71	34					0.95	

Fig. 1. Total catches of harp seal pups in the White Sea and the Barents Sea and the survival of the year classes 1960–1969 as indicated by weighted mean survival indexes from Norwegian samples of moulting seals collected in 1964–1972.

Table 4. Pup production estimates in thousands of harp seals in the White Sea calculated from linear regression of survival index on pup catch *(A)*. *B* = the 95% confidence interval of pup production. r = correlation coefficient.

Period	Mid-year	Production		r
		A	B	
1960 – 65	1962	130	94 – 440	–0.87
1960 – 66	1963	118	94 – 186	–0.92
1960 – 67	1963	109	84 – 201	–0.86
1960 – 68	1964	103	79 – 211	–0.81
1960 – 69	1964	103	80 – 180	–0.82
1961 – 69	1965	97	74 – 194	–0.82
1962 – 69	1965	99	74 – 221	–0.82
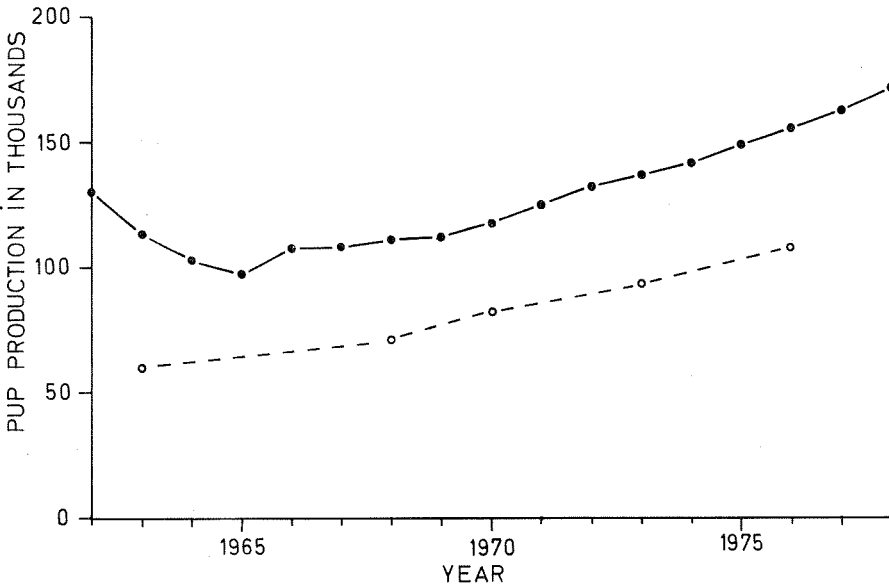
Fig. 2. Production of harp seal pups in the White Sea (closed circles) calculated up to 1965 by regression of survival indexes on pup catches. Production in 1966—1978 are calculated from a projection of the females population. For comparison, the number of adult females on the ice estimated from the Soviet aerial surveys is shown (open circles and stippled line).

DISCUSSION

The age and sex composition in the moulting lairs changes through the season as adult females gradually join the males and immature females through April and early May. Therefore the element of older animals in the Norwegian catches varies much from year to year, and survival indexes were only calculated for age groups 1 to 5.

BENJAMINSEN and ØRITSLAND (1975) showed that the moulting one year old harp seals of the Newfoundland–Labrador population to a large extent were segregated from older immatures and therefore were not sampled in any consistent relation to their abundancy in the population. The one year olds therefore were not included in their calculations of survival indexes. The one year olds in the Barents Sea, however, seem to be well mixed in with the older seals in the moulting lairs. The correlation between the frequencies of one year old seals in the Norwegian samples of moulting seals in the Barents Sea from 1964 to 1972 and the pup catches of these year classes is strong ($r = -0.93$).

The survival index method is only useful if pup production does not change too much during the period which is studied. The regression estimates also should be made only for periods with as high as possible variation in pup catches. In order to combine these two requirements it was decided to use only the age samples collected from 1964 to 1972 in the calculations. Survival indexes therefore could only be calculated for the year classes 1959 to 1971.

The pup production estimates obtained from survival indexes and the projection is about 50% higher than the number of adult females on the ice in the breeding layers estimated from aerial surveys. This difference may be explained by the fact that some females are always in the water. POPOV (1967) writes that on clear and windless days 45–55% of the adult females are on the ice in the day-time and 70–80% in the evening.

The projection is very sensitive to the input parameters. Mean annual natural mortalities of 9% and 11% instead of 10% would change the production estimate in 1978 from 172 thousand to 208 and 142 thousand respectively. A median age of first whelping of 6 instead of 5 years produce an estimate of 141 thousand pups in 1978.

A projection based on the lower limit of the 95% confidence interval indicates that production will increase from 74 thousand in 1965 to 91 thousand in 1978.

With the present total quota of 50 thousand, the White Sea harp seal stock will probably continue to increase at a rate of about 5% per year. The population is still small compared to the size at the beginning of the 20th century, and during the first decade the increase will probably not have any noticeable effect on natural mortality, age of sexual maturity or pregnancy rate. The abundance of fish in the Barents Sea, however, may have an effect on these vital parameters.

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