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ADDITIONAL DATA ON THE SEX RATIO, AGE COMPOSITION AND MORTALITY OF NEWFOUNDLAND HOODED SEALS, WITH AN ESTIMATE OF PUP PRODUCTION AND SUSTAINABLE YIELD

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Introduction

Age composition data from Norwegian samples of breeding hooded seals (*Cystophora cristata*), collected off Newfoundland - Labrador from 1964 to 1972, have previously been reported together with sex composition data and mortality estimates by Øritsland and Benjaminsen (1975). Two more age samples, collected from Norwegian catches at Newfoundland in 1973 and 1974, have now been analysed. The age compositions and mortality estimates from these samples are presented in this report together with recent data on the sex composition in catches of breeding hoods.

An attempt is also made to combine catch statistics and the year-class frequencies in all Norwegian age samples from Newfoundland in a catch and survival estimate of pup production. A tentative estimate of the sustainable yield of Northwest Atlantic hooded seals concludes the report.

Material and methods

Subsamples collected for age analysis of breeding hooded seals on the Front off Newfoundland - Labrador in 1973 and 1974 are listed in Table 1. An additional sample collected from about 620 hoods in the 1975 season has not been processed yet.

The samples were processed as outlined in the previous report (Øritsland and Benjaminsen, 1975), and age determinations were made by one person with a second checking all doubtful readings.

Mortalities have been estimated from mean ages of the fully recruited age-groups (Chapman and Robson, 1960; Robson and Chapman, 1961).

Age-group frequencies of sexed animals in all Norwegian samples from the Front, collected in 1964-1972 (Øritsland and Benjaminsen, 1975) and in 1973-1974 (this report), have been combined to produce average age frequencies which were smoothed and used to estimate the survival of year-classes of males and females in individual samples. The survival index (Øritsland, 1971) was calculated for each frequency in the individual samples as a ratio of the corresponding smoothed average frequency. Weighted means were calculated using weights approximately proportional to the number of specimens in each sample. The survival of indivudual year-classes was then compared to pup catches in the corresponding years, and production was estimated by simple linear regression of survival indexes over pup catches for the years 1966 - 1970.

The production (female) pups was also estimated on the basis of deviations from the linear 1966-1970 regression of survival indexes over pup catches. The established neonatal sex ratio was used to calculate the number of female pups produced in individual years, and the year-classes were followed, calculating the abundancy of females in later years with presumed natural mortalities of 10% during the first year and 8% later. Total catches of mature four years old and older hoods taken from the catch statistics for one year old and older animals in the Newfoundland area (ICNAF, 1972-1974; ICNAF Ass.Exec.Secr., 1974) were subtracted, dividing them between sexes according to the sex ratio in Norwegian catches and between age-groups according to the average frequencies in age samples of females. The number of 7 years old and older females were calculated from the female age-composition in the sample collected in 1971. These calculations resulted in an estimated age composition in numbers of breeding females in 1971. Annual production in 1971-1976 and the age specific abundancy of breeding females in 1972-1976 were then predicted by stepwise calculations from the number of productive females in 1971, using the mortalities mentioned above and reproductive performance data reported by Øritsland (1975).

The sustainable yield estimates are based on the basic requirement that if the population is to remaine at a constant level, the number of female pups which survive to productive maturity every year must equal the number of productive females which die through the year, included those which are caught in the breeding season.

This may be expressed by the following equation:

$$(B-C) \cdot F = (A-D) \cdot P+D$$

where B = production of female pups, C = catch of female pups, F = survival to productive maturity, A = number of sexually mature females D = catch of sexually mature females, and P = natural mortality rate. This equation was used in the estimates applying catch statistics (ICNAF, 1974; ICNAF Ass.Exec.Secr., 1974), the productive maturity rates reported by Øritsland (1975) and the natural mortalities of 10% in the first year and 8% in later years to calculate the parameters.

Sex composition

A total of 111 seals were tagged at Newfoundland in 1975, included 65 hooded seal pups, and sex determinations were made for 33 male (55.0%) and 27 female bluebacks (45.0%) (Bergflødt, 1975). These figures change the neonatal sex ratio of 51.4% males and 48.6% females, reported for 1309 pups counted at Newfoundland in previous seasons (Øritsland and Benjaminsen, 1975), to 51.6% males and 48.4% females in a total of 1369 pups.

Adult sex ratios summarized in Table 2 average 40.1% males and 59.9% females in a total of 3608 breeding seals. Additional evidence has been made available to us from the grading of catches landed by five Norwegian ships from Newfoundland in 1975. The catches of adult hooded seals by these ships total 2697 skins, and 1618 or 60.0% of these were classified as light (weighing less than 12 kg) and 1079 as heavy (more than 12 kg). Presumably this classification corresponds to the sex ratio in the catches, and the agreement with the data in Table 2 is deceptively good.

However, one of these ships carried the Institute observer who sampled 99% of the catch (622 of 630 seals), finding a provisional sex composition of 42.8% males and 57.2% females (Table 2) whereas the grading for this ship resulted in 32.5% heavy and 67.5% light skins or 10.3% more light skins than females in the catch.

The reliability of grading data as indicators of the sex composition also was tested for the landings by 9 ships from the West-Ice (Jan Mayen area) in 1975. Sexed age samples were collected on two of the ships, and counts of skins by sex were made at the processing plant when the other ships landed their catches. These 9 ships caught a total 5007 adult hoods, and 3840 or 76.7% of these skins were classified as light. Sex determinations for 4215 animals (84.2% of the catches) show that 3068 or 72.8% were females. The deviation of grading data from the sex compositions varies between ships, possibly because of differences between individual graders or because of the segragation of age- and sex-group at the breeding lairs (Øritsland and Benjaminsen, 1975). Whatever the explanation, the average percentage of light skins was 3.9% ± 5.9% higher than the percentage of females among sexed animals (95% confidence limits). Grading data therefore must be used with caution, but they do suggest a difference of about 15% in the percentages of females in Norwegian catches of adult hooded seals between Newfoundland and in the West Ice.

Actual counts by sex indicate that the difference of 12.9% between the 59.9% females in catches at Newfoundland (Table 2) and 72.6% females in recent West Ice catches (a total of 4973 adult hoods sexed from 1972 to 1975) is significant at the 0.1% level ($t = 12.4$) .

The West Ice sex ratio of 47.7% females cited in the previous report (Øritsland and Benjaminsen, 1975) therefore is not representative of past or present Norwegian catches in that area, obviously bacause most of the data refer to Soviet catches.

Age composition

Age-group frequencies in the 1973 and 1974 samples are listed in Table 3, and relative frequencies are shown in Figure 1. They follow the same general pattern for each sex as found in previous samples (Øritsland and Benjaminsen, 1975), with full recruitment of females at about six years and of males at an age of nine or ten. The consistency of high or low frequencies is rather conspicious for some of the year-classes. The year-class produced in 1968 is particularly prominent among females in both samples, but has not yet been fully recruited to the male breeders. By comparison the year-classes of 1966 and 1964 appear to be small and those of 1965 and 1963 relatively large.

All sexed age samples, included those collected from 1964 to 1972 (Øritsland and Benjaminsen, 1975), have been combined in Table 4 to produce a set of average age frequencies for each sex of breeding hooded seals at Newfoundland. The combined samples comprise 1180 males and 1928 females. The actual relative frequencies are shown in Figure 2 together with graphs of smoothed frequencies.

Regressions were calculated for the recruited age-groups and used as guidelines in a graphic adjustment of actual frequencies. Data on productive maturity (Øritsland, 1975) were used to adjust the frequencies of 3-6 years old females, and only minor adjustments were made to fit the frequencies of younger males to a smooth line. The adjusted smoothed relative frequencies are given in the last two columns of Table 4.

Mortality

Male and female total mortalities estimated from the samples collected in 1973 and 1974 are given in Table 5. The estimates have been made only from the mean ages of the fully recruited age-groups (Chapman and Robson, 1969; Robson and Chapman 1961). Males in these samples seem to be fully recruited at an age of 9 years, females at 6 years. The strong 1968 year-class bias the mortality estimate for 6 years old and older females from the 1974 sample, and therefore the estimate for females in this sample has been calculated for 7 years old and older seals. As in the previous estimates (Øritsland and Benjaminsen, 1975) males have higher mortalities than females Differences between male mortalities and between female mortalities calculated for the two samples, are not significant at the 5% level.

The mortality of 23% estimated for males in the samples collected in 1971 and 1972 (Øritsland and Benjaminsen, 1975), are somewhat lower than found in the present samples from 1973 and 1974. Female mortalities in 1973 and 1974 are nearly the same as in the 1971 sample (21.3%), but higher than the estimate for 1972 (15.9%).

One of the basic assumptions for these mortality estimates is that production remains constant. However, evidence from the survival of year-classes to be presented later, indicates an increasing production from 1960 on. In the period from 1960 to 1967 production seems to have increased on average by 3-5% per year. The total annual mortality of females calculated from the large 1974 sample therefore may be adjusted down to between 16 and 18%

Catches in the period 1960-1967 contained an average of about 2 thousand mature females per year. The total number of mature females in this period was between 23 and 32 thousand, and the catches therefore give an annual hunting mortality of females of between 9 and 6% and suggest a natural mortality of 7-12% per year.

Catch and survival

The calculated survival indexes and weighted mean indexes for the year-classes from 1952 to 1970 are given separately for males and females in Table 5.The weighted means for both sexes together and total pup catches in the corresponding years are also listed in this

The combined male and female survival indexes for year-classes 1960-1970 are plotted against the corresponding pup catches in Figure 3. Pup catches below 5 thousand per year up to and including 1965 have resulted in lower survival than catches of the same magnitude in 1968 and 1970. This indicates an increasing production during the 1960'ies.

The year-class produced in 1966 shows poor survival after a catch of nearly 17 thousand pups in that breeding season, whereas survival apparently has been good after catches below 10 thousand pups in later years.

Production

The average pup production in the years 1966-1970 was calculated by linear regression of the combined male and female weighted mean survival indexes against pup catches for these years. The regression line, $y = 1.4910 - 0.0475x$ which is shown in Figure 3, indicates an average production in this period of 31.4 thousand pups per year. A line through the highest (1968) and lowest (1966) survival indexes runs nearly paralled to the regression line, and suggest a production of the same magnitude (32.0 thousand).

The correlation coefficient of the regression for year-classes 1966-1970 is as high as 0.97, but decreases if earlier year-classes are included in the regression (Table 7). Again, this is an indication of lower production early in the 1960'ies than later in the period. The estimates of female pup production in Table 8 increase from 12.8 thousand in 1965 to 21.3 thousand in 1976 (66%). The total stock of females before the catch included age-group is estimated to 85,7 thousand for 1971. The corresponding number of females in 1975 adds up to 107.5 thousand, an increase of 25.4% (Table 8). Predicted age-group frequencies in Table 7, reduced by maturity data, are compared to actual frequencies in age-samples in Table 8. With two exceptions all estimated frequencies are within the 95% confidence limits of the actual age-sample frequencies.

Sustainable yield

Production of female pups in 1976 was predicted to 21.3 thousand (Table 8.) From the rates of productive maturity (Øritsland, 1975), natural mortalities of 10% in the first year and 8% later, the survival of female pups to productive maturity is estimated to 64%.

Total catches from 1966 to 1975 add up to 73.4 thousand pups and 53.1 thousand breeding adults. An average 48.4% of the pups and 60% of the adults were females. Therefore the total catches in this period include 35.5 thousand catches of mature females thus may be expressed as catches of pups multiplied by a factor of 0.9.

With the known parameters the equation of equilibrium or constant production is:

$$(21.3-C)0.64 = (45.4-0.9C)0.08 + 0.9C$$

and the equilibrium catch of female pups, C = 6.8 thousand.

This figure gives an estimated sustainable yield of 14.1 thousand female and male pups, 6.1 thousand mature females and 4.1 thousand adult males, or a total sustainable yield of 24.3 thousand hooded seals per year for the Newfoundland area .

However, production and the stock will increase the first couple of years, even with catches at this level, because relatively strong year-classes produced after 1970 are recruiting the breeding stock.

Acknowledgements

We acknowledge with thanks the help given by captains and crews of the sealers *Norvarg*, *Polarstar* and *Veslemari* . We also are grateful to Bjørn Bergflødt who collected the bulk of the material, and to Gunn Nilsen who, together with Bergflødt made all age determinations and assisted in producing this report.

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Table 1. Age samples collected from Norwegian catches of hooded seals off Newfoundland - Labrador in 1973 and 1974 .

Year	Dates	Ship	No. of specimens		
			Male	Female	Total
1973 a	20-27 March	Norvarg	126	156	282
1973 b	23-28 March	Polarstar	37	43	80
1974 a	20 March- 8 April	Norvarg	303	520	823
1974 b	20-25 March	Veslemari	44	56	100

Table 2. Sex ratios of adult breeding hooded seals in Norwegian catches off Newfoundland - Labrador 1964 - 1975.

Year	Male		Female		Total
	No	%	No	%	
1964 - 72	670	39.4	1031	60.6	1701
1973[1)]	163	45.0	199	55.0	362
1974[1)]	347	37.6	576	62.4	923
1975[2)]	266	42.8	356	57.2	622
Total	1446	40.1	2162	59.9	3608

1) Revised from Øritsland and Benjaminsen (1975).

2) Provisional data.

Table 3. Age frequencies (numbers) of breeding hooded seals caught by Norwegian ships off Newfoundland - Labrador in 1973 and 1974 .

Age-group	Male		Female	
	1973	1974	1973	1974
2	0	0	0	0
3	0	1	0	4
4	0	0	25	78
5	2	3	44	96
6	7	16	27	118
7	5	21	20	59
8	27	23	21	39
9	33	67	13	41
10	33	41	18	28
11	15	46	11	19
12	14	41	6	21
13	6	22	3	16
14	9	25	2	19
15	4	8	2	11
16	2	7	1	5
17	2	7	1	7
18	1	9	1	3
19	1	4	1	3
20	0	1	1	3
21	0	3	0	0
22	1	0	0	3
23	1	0	0	0
24	0	0	0	0
25	0	2	0	1
26+	0	0	2	2
Sum	163	347	199	576
Max.age	23	25	37	27
Mean age	10.3	11.0	7.7	7.8

Table 4. Combined age frequencies (numbers) and smoothed average frequencies (%) of breeding hooded seals from Norwegian samples collected off Newfoundland - Labrador, 1964 - 1974.

Age-group	Combined frequencies(No)		Smoothed average (%)	
	Male	Female	Male	Female
2	0	0	0.0	0.0
3	2	12	0.2	2.5
4	6	274	0.5	10.9
5	16	277	1.4	12.2
6	48	281	4.1	12.2
7	79	200	6.8	11.8
8	122	160	10.4	9.4
9	175	143	15.0	7.8
10	155	116	13.3	6.3
11	141	87	11.3	5.1
12	114	66	9.8	4.2
13	67	56	7.2	3.3
14	74	53	5.3	2.7
15	42	36	3.8	2.1
16	37	29	2.8	1.8
17	23	23	2.1	1.4
18	19	17	1.5	1.2
19	14	13	1.1	0.9
20	9	18	0.8	0.7
21	5	11	0.6	0.6
22	6	13	0.4	0.5
23	4	6	0.3	0.4
24	4	8	0.2	0.3
25	6	3	0.2	0.3
26+	12	26	0.9	1.3
Sum	1180	1928	100.0	99.9

Table 5. Total annual mortality estimates of hooded seals from age samples collected off Newfoundland - Labrador 1973 and 1974. Mortalities (A in %) with 95% confidence intervals (B) were calculated from mean ages of the fully recruited age-groups.

Sample	Total No	A	B	Age-groups	No
Male:					
1973	163	30.6	±4.6	9 - 23	122
1974	347	25.5	±2.6	9 - 25	283
Female:					
1973	199	22.9	±3.5	6 - 37	130
1974	576	21.3	±2.3	7 - 27	280

Table 6. Pup catches of hooded seals at Newfoundland and the survival of corresponding year-classes of males and females expressed by a survival index (frequency in sample/smoothed 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 5-15 years old males and 4-15 years old females.

Year class	Total pup catch $\times 10^{-3}$	Survival index											
		Males					Females						Total weighted mean
		1971	1972	1973	1974	Weighted mean	1967	1971 a	1972a+b+c	1973	1974	Weighted mean	
		212	406	163	347		149	368	583	199	576		
		1	2	1	2		1	2	3	1	3		
1952	1.4						0.95					0.95	0.95
53	3.7						1.74					1.74	1.74
54	2.6						1.82					1.82	1.82
1955	4.0						0.95					0.95	0.95
56	6.6	1.61				1.61	1.06	0.67				0.80	1.00
57	0.1	1.15	0:97			1.03	0.95	0.89	1.00			0.96	0.98
58	4.7	0.65	1.11	0.66		0.88	0.95	0.82	0.89	0.48		0.82	0.84
59	4.2	0.43	0.89	1.04	0.61	0.75	0.86	0.79	0.82	0.37	0.90	0.80	0.78
1960	3.0	1.29	1.18	0.51	1.36	1.15	0.46	1.02	0.74	0.45	1.22	0.88	0.98
61	2.3	0.64	0.98	0.88	0.88	0.87	0.93	0.90	0.90	0.71	0.85	0.87	0.87
62	1.1	0.75	1.08	0.81	1.20	1.02	1.10	1.05	0.92	1.08	0.86	0.96	0.98
63	4.6	1.32	0.81	1.52	1.18	1.03	0.86	0.96	1.04	1.43	0.65	0.93	0.97
64	4.6	1.38	0.99	1.35	0.89	1.08		1.31	0.89	0.83	0.78	0.94	1.00
1965	2.9	1.73	1.04	1.60	1.29	1.33		1.36	0.75	1.13	0.91	0.98	1.12
66	16.8	2.00	0.29	0.46	0.63	0.72		0.75	0.75	0.86	0.72	0.75	0.74
67	8.4		0.71	1.05	0.90	0.85		1.19	1.11	1.11	0.86	1.04	0.97
68	1.2			0.86	1.12	1.03			1.67	1.81	1.68	1.69	1.49
69	8.8				0.64	0.64				1.16	1.37	1.32	1.09
1970	5.3										1.24	1.24	1.24

Table 7. Linear regression of survival indexes (S) in ratios of pup catches for hooded seals at Newfoundland, with an increasing number of year-classes included in the estimates. B = estimated pup production, r = correlation coefficient.

Year-class	S	B	r
1966 - 70	1.4910 - 0.0475.C	31.4	-0.97
1965 - 70	1.4048 - 0.0410.C	34.3	-0.90
1964 - 70	1.3530 - 0.0379.C	35.7	-0.84
1963 - 70	1.3105 - 0.0354.C	37.0	-0.78
1962 - 70	1.2338 - 0.0280.C	44.0	-0.66
1961 - 70	1.1767 - 0.0232.C	50.7	-0.53
1960 - 70	1.1574 - 0.0217.C	53.3	-0.50

Table 8 . Estimated production of female pups and age composition of females (included pups which have survived the catch) in the stock of hooded seals at Newfoundland - Labrador .

Year	Prod. ($\times 10^{-3}$)	Estimated age composition of females ($\times 10^{-3}$)							
		0	1	2	3	4	5	6	7+
1965	12.8	11.4							
66	15.7	7.6	10.3						
67	14.0	9.9	6.8	9.4					
68	15.8	15.2	8.9	6.3	8.7				
69	15.3	11.0	13.7	8.2	5.8	8.0			
1970	15.2	12.6	9.9	12.6	7.5	5.3	6.8		
71	15.9	12.0	11.3	9.1	11.6	6.9	4.8	6.2	19.9
72	16.7	13.4	10.8	10.4	8.4	10.6	5.9	4.1	21.0
73	17.5	15.3	12.0	10.0	9.6	7.7	9.2	5.0	21.0
74	19.3	16.3	13.7	11.1	9.2	8.8	7.0	8.2	23.0
1975	20.6	17.0	14.7	12.6	10.2	8.4	7.8	6.0	27.2
76	21.3		15.3	13.5	11.6	9.4	7.3	6.6	27.8

Table 9. Estimated age-group frequencies of productive female hooded seals at Newfoundland - Labrador (A, recalculated from Table 7), compared to frequencies of 4 years old and older females in age samples from breeding hoods (B, with 95%, confidence limits).

Year	Age-group	A	B	A-B
1971	4	12.2	13.2 ± 3.5	- 1.0
	5	10.9	9.4 ± 3.0	+ 1.5
	6	16.3	16.8 ± 3.9	- 0.5
	7+	60.6	60.6 ± 5.1	0.0
1972	4	17.5	18.3 ± 3.2	- 0.8
	5	12.5	13.6 ± 2.8	- 1.1
	6	10.1	9.1 ± 2.4	+ 1.0
	7+	60.0	59.0 ± 4.0	+ 1.0
1973	4	12.2	12.6 ± 4.7	- 0.4
	5	18.7	22.1 ± 5.9	- 3.4
	6	11.7	13.6 ± 4.9	- 1.9
	7+	57.3	51.7 ± 7.1	+ 5.6
1974	4	12.6	13.5 ± 2.9	- 1.0
	5	12.9	16.8 ± 3.1	- 3.9
	6	17.4	20.6 ± 3.4	- 3.2
	7+	57.0	49.0 ± 4.2	+ 8.0

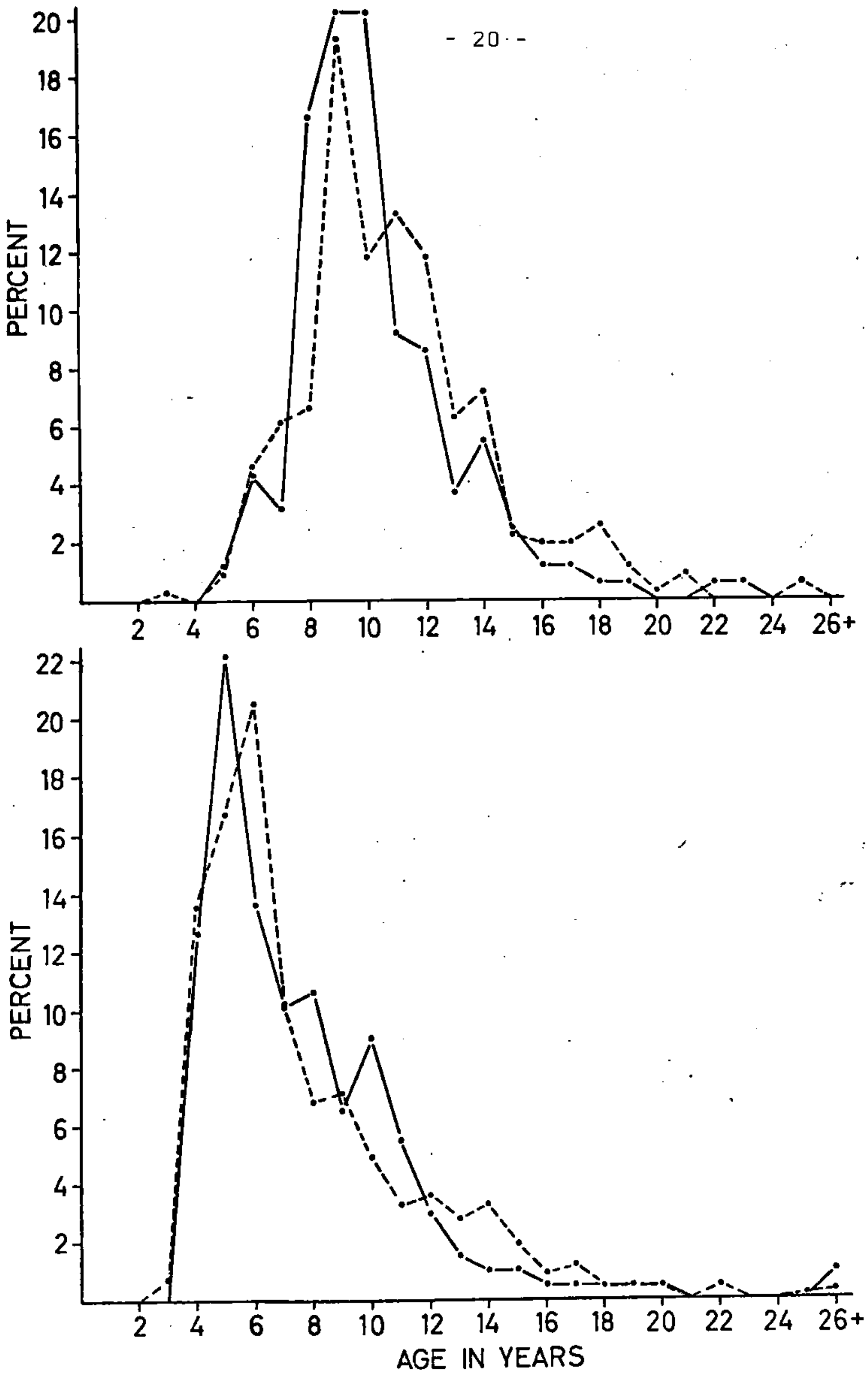

Figure 1. Age-group frequencies of male (upper graph) and female (lower graph) breeding hooded seals sampled from Norwegian catches off Newfoundland - Labrador in 1973 (solid lines) and 1974 (stippled lines).

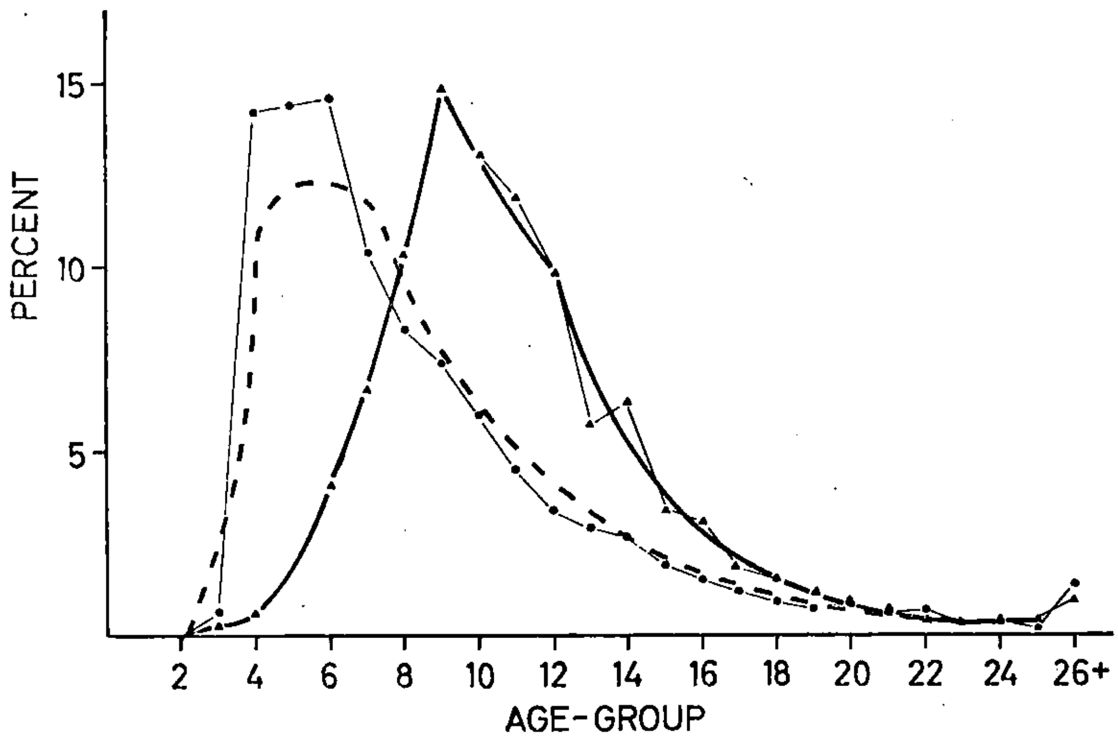

Figure 2. Actual and smoothed relative age-group frequencies of breeding male and female hooded seals from samples of Norwegian catches at Newfoundland - Labrador collected 1964 - 1974. Actual frequencies are represented by thin lines with filled triangles for males and filled circles for females. Smoothed frequencies are represented by heavy lines, solid for males and stippled for females.

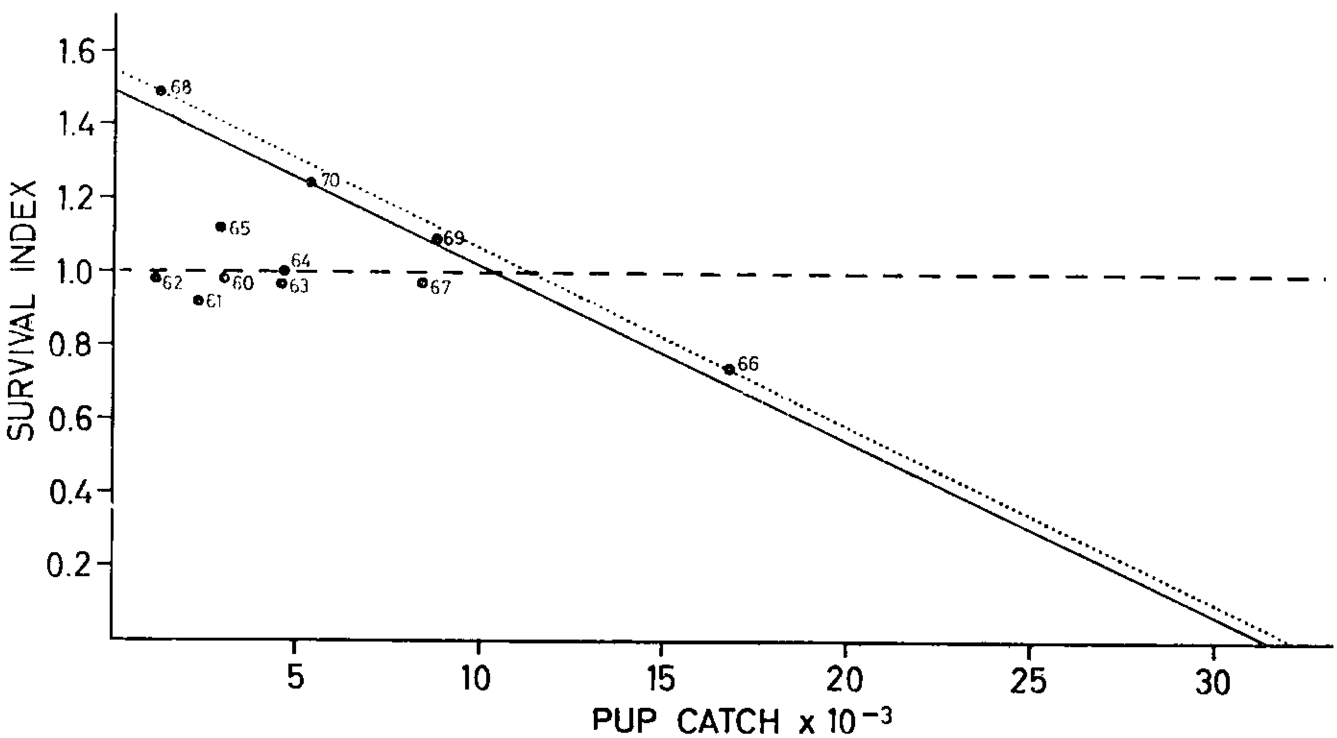

Figure 3. Total catches of hooded seal pups at Newfoundland and the survival of year-classes 1960-1970 as indicated by combined male and female weighted mean survival indexes (Table 6) from age samples collected from Norwegian catches in 1967 - 1974. The calculated regression for year-classes 1966-1970 solid line is $y = 1.4910 - 0.0475x$.