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Further Estimates of Harp Seal Pup Production
Between 1977 and 1980 from Mark-recapture

by

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ABSTRACT

Pup production of the Northwest Atlantic harp seal population (Pagophilus groenlandicus) was estimated using a modified Petersen model. Approximately 9,200, 5,000 and 6,200 harp seal pups were effectively tagged in 1978, 1979 and 1980 respectively. Estimated production was 467,000 in 1978, 476,000 in 1979 and 434,000 in 1980. The 1978 and 1979 estimates are considered most reliable.

INTRODUCTION

Bowen and Sergeant (1980) calculated estimates of the pup production of the Northwest Atlantic harp seal; Pagophilus groenlandicus, population between 1977 and 1980 from mark-recapture data. In this paper, we re-analyse previous information and incorporate data on 1981 tag returns of the marked 1977, 1978, 1979 and 1980 cohorts to produce revised estimates of production.

MATERIALS AND METHODS

Harp seal pups were marked at whelping patches with individually numbered jumbo Roto-tags which were placed in the left hind flipper (single-tagged animals) or in both hind flippers in the case of double marking. The sex, pelage stage, and tag numbers of each double-tagged seal were recorded.

Helicopters, stationed in the Magdalen Islands, St. Anthony, Newfoundland, and aboard the M/V HUDSON, were used to distribute tags as randomly as possible throughout the Gulf, Strait of Belle Isle, and Front whelping patches, respectively. Brightly coloured water soluble dye was used to mark the ice at locations where tagging took place. In this way, the chance of concentrating tags in one part of the whelping patch was minimized.

Chapman's (1951) modification of the Petersen estimate was used to estimate pup production. When $M+n \geq N$, his estimate

$$N^* = \frac{(M+1)(n+1)}{(m+1)} - 1$$

(1)

is exactly unbiased, while if $M+n < N$, N^* is a biased estimate of N , although this bias is negligible when $Mn \approx 4N$ (Robson and Regier 1964) where M is the number of marked animals released at time t_1 , n is the number of animals examined for marks at time t_2 , and m is the number of marked animals in the second sample. An estimate of the variance of N^* is given by Seber (1973) as

$$V^* = \frac{(M+1)(n+1)(M-m)(n-m)}{(m+1)^2(m+2)} \quad (2)$$

Approximate 95% confidence limits for N are given by

$$N^* \pm 1.96 \sqrt{v^*} \quad (3)$$

However, according to Ricker (1958) in general it is better to base confidence limits on the probability distribution of m , by entering m as a Poisson variable and looking up approximate values from tables such as given in Ricker (1958:343). For values of $m > 50$, 95% confidence limits are calculated from the following:

$$m + 1.92 \pm 1.960 \sqrt{m+1} \quad (4)$$

In the present study both methods were tried and found to produce similar results. For convenience, we have reported only those confidence intervals based on Seber's formula (equation 3).

To estimate pup production in year t from recoveries in year $t+i$ where $i = 1, 2$, and 3 , we assume that marked and unmarked seals suffer the same rate of total mortality and that marked and unmarked seals are equally catchable. Although we cannot test these assumptions, we have no reason to expect that they are violated in these experiments. Previous work has demonstrated that the assumptions of no tag loss and complete reporting of recovered tags are violated, however, estimates of these parameters are available.

In 1979 and 1980, community surveys were conducted to estimate the proportion of recovered tags that were not returned for payment (Bowen 1979; Bowen and Sergeant 1980). It was found that 27.2% of recovered tags were not returned in 1979 and 20.2% were not returned in 1980. A community survey was not conducted in 1981 as there was evidence in 1980 that sealers in some communities were withholding tags, expecting that Fisheries personnel would collect them. In the absence of the community survey, a vigorous advertising program was developed to inform sealers in all communities that fisheries personnel would not collect tags in 1981 and to urge sealers to return tags promptly. In the present analysis, we have used the average value (22%) of the 1979 and 1980 surveys.

The problem of age-specific tag loss is more difficult. In 1975 (Sergeant unpubl. data) double-marked 903 harp seal pups with a letter-brand and a numbered Roto-tag. In 1979 and 1980, approximately 1,900 pups were double-marked with Roto-tags (Bowen and Sergeant 1980). To date 37 double-marked seals have been recovered at ages from 1 to 6 years. With the exception of age 1, and even here sample size is small, the data are insufficient to estimate age-specific rates. The annual rate of tag loss in the first year is 2 of 15, or 13.3%. The average annual rate of loss from age 1 to 6 years is 10.8%. However, this average may well over-estimate the rate beyond age 1 since a six-year-old seal may have lost its tag at any time up to the time of capture. For the present, we have assumed 10% per year over the first 3 years of life. In the absence of any data, Bowen and Sergeant (1980) arbitrarily assumed 5% tag loss.

We examined two approaches to correct estimates of N for tag loss and non-reporting of recovered tags. Let \hat{r} = estimated reporting rate and \hat{S}^i = estimated survival rate of tags at age $i = 1, 2, 3$, then correcting n for tag loss we have

$$N_c^* = \frac{(M+1)(n\hat{S}^i+1)}{(m+1)} - 1 \quad (5)$$

and $N_{cr}^* = N_c^* r$ where N_{cr}^* is the estimate corrected for non-reporting. If we correct m for tag loss, then

$$N_m^* = \frac{(M+1)(n+1)}{\left(m \frac{1}{S} + 1\right)} - 1 \tag{6}$$

and we have $N_{mr}^* = N_m^* \hat{r}$ where N_{mr}^* is the estimate corrected for non-reporting. Confidence limits on N_{cr}^* and N_{mr}^* were calculated in the usual way from Equ. (3) because when tag loss is $\leq 10\%$, the resulting bias is in the order of only 3% (Seber pers. comm.). Similarly, because the variance of the reporting rate (78%) is small (1.62%), the effect on the variance of N^* will also be small.

Correcting m for tag loss resulted in about 8-10% smaller standard errors than correcting n . We chose to use the larger standard errors, recognizing that any confidence limits by these methods are only approximations.

The extent to which the other assumptions of the Petersen model are upheld in these experiments is discussed in Bowen (1979) and Bowen and Sergeant (1980).

Age-specific catches of the 1977, 1978, 1979 and 1980 cohorts in 1978 through 1981 were estimated by prorating the total annual catch of seals one year and older by age samples from the various components of the hunt collected each year. Total annual catches of harp seals in NAFO Areas 2, 3, and 4 were taken from ICNAF/NAFO Statistical Bulletins.

RESULTS AND DISCUSSION

Tag returns from the 1977-80 cohorts from January to late May, 1978-81 in NAFO Areas 2, 3, and 4 are given in Table 1. There were 48, 22, 16 and 5 recoveries in 1978 through 1981 respectively of the 1,230 seals tagged in 1977. Of the 9,167 marked pups in 1978, 214 were recovered in 1979, 105 in 1980 and 35 in 1981. A total of 4,939 marked pups survived the whitecoat harvest in 1979. Of these, 118 were subsequently recovered in 1980 and 38 were taken in 1981. In 1980, 6,351 tagged whitecoats survived the large vessel harvest and 64 were recovered in 1981.

Initially individual estimates of pup production were calculated for each cohort from recoveries at ages 1, 2 and 3 where possible (Table 2). Two values were computed for the estimate of 1977 production from recoveries at age 1 as we did not have an estimate of reporting rate prior to 1979. If one assumes the reporting in 1979 ($r=.73$) the production in 1977 was 321,641 pups, however, if we assume that the reporting rate prior to 1979 was lower (i.e. $r=0.50$) (Bowen and Sergeant 1980), then 1977 production was 242,866 pups. As it turns out, it probably does not matter which value is used as all the estimates of 1977 production appear to be low when compared to the 1978 through 1980 cohorts (Table 2).

The difference between the estimates of 1977 production and those of the 1978, 1979 and 1980 cohorts is perhaps more apparent when pooled estimates are considered. Because we know the number of tags applied at the Front and in the Gulf for 1978-1980 year-classes, we can test the hypothesis that the number of recoveries from each area is proportional to the number tagged. A non-significant χ^2 is evidence of random sampling and indicates that the estimates of production are likely unbiased.

Results of the χ^2 goodness-of-fit analyses are given in Table 3. Recoveries from the 1978 and 1979 marked cohorts were non-significant; however, there was significant heterogeneity in the returns from the 1980 cohort. Thus the pooled estimates in 1978 and 1979 are probably unbiased and should be given more weight than the less reliable 1980 estimate. It should be noted that 1980 estimate will likely improve over the next year or two as sample size is increased. We could not test the 1977 data in this way as tags were applied only in one area (i.e. the Gulf).

The pooled estimate of 1977 pup production is 316,300 with 95% C.L. of 253,000 to 379,300 (Table 4). These limits do not include the mean estimate of 1978, 1979 or 1980 production and overlap with only the lower 95% C.L. of the 1980 estimate. By contrast the estimates of production in 1978, 1979 and 1980 do not differ significantly.

The reason for this bias is not completely understood, but it appears to be related partly to the fact that only in 1977 were seals tagged in the Gulf area alone. To test this idea, we recalculated the pooled estimates of 1978, 1979 and 1980 production using only Gulf returns, then compared the results with the estimates using returns from both areas. In each case the Gulf-tags-only calculations underestimated production: 11.14% in 1978, 7.45% in 1979 and 26.25% in 1980. We conclude that the 1977 estimates are biased downwards due in part to the initial distribution of tagging effort. Another reason why the 1977 pooled estimate seems to be unreliable is that the number of pups marked in 1977 was small compared to the number marked in 1978, 1979 and 1980.

Given the foregoing analysis, we conclude that the 1977 estimate is unreliable and should not be used. It was noted previously that the 1979 and 1980 estimates of pup production from returns within the first three months are likely unreliable due to non-random sampling (Bowen and Sergeant 1980). Hence we are left with the pooled estimates of production in 1978, 1979 and 1980. To the extent that it is possible to test the assumptions of the model, the 1978 and 1979 estimates are unbiased; however the 1980 estimate, although not differing from the 1978 and 1979 values, must be given less weight because of significant heterogeneity in the ratio of Gulf/Front returns.

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Table 1. Tag returns from the 1977-80 marked cohorts in January-May, 1978-81, NAFO Areas 2, 3, and 4.

Year	Tagged Location	Recovered											
		1978			1979			1980			1981		
		G	F	T	G	F	T	G	F	T	G	F	T
1977	Gulf	4	44	48	-	-	22	5	11	16	2	3	5
1978	Gulf	-	-	-	21	69	90	19	44	63	15	10	25
	Front	-	-	-	17	107	124	7	35	42	5	5	10
1979	Gulf	-	-	-	-	-	-	23	53	76	2	12	14
	Front	-	-	-	-	-	-	1	41	42	12	12	24
1980	Gulf	-	-	-	-	-	-	-	-	-	12	37	49
	Front	-	-	-	-	-	-	-	-	-	3	12	15

G = Area 4
 F = Area 2 and 3
 T = Total

Table 2. Estimates of harp seal pup production from 1977 to 1980 by mark-recapture, using tag recoveries at age 1 to 3.

Cohort	Tagged seals killed	Estimate at age	M ¹	m	n	N _{nr} [*]	K	N _T [*]
1977	1978	1	1,230	48	15,147	250,025 (171,250) ²	71,616	321,641 (242,866) ²
	1979	2	1,230	22	5,848	185,106	71,616	256,722
	1980	3	1,230	16	5,212	220,450	71,616	292,066
1978	1979	1	9,167	214	13,490	377,959	72,021	449,980
	1980	2	9,167	105	6,652	372,873	72,021	444,894
	1981	3	9,167	35	2,954	428,496	72,021	500,517
1979	1980	1	4,939	118	13,925	416,235	112,064	528,299
	1981	2	4,939	38	2,848	227,999	112,064	340,063
1980	1981	1	6,351	64	4,938	333,222	100,895	434,117

¹Number of marked pups surviving whitecoat harvest

²Assuming reporting rate of 0.50

N_{nr}^{*} = estimated number of pups surviving whitecoat harvest, corrected for tag loss and reporting rate

K = kill of pups during whitecoat harvest

N_T^{*} = estimated total production

Table 3. Test for heterogeneity in long-term recoveries of Gulf- and Front-tagged seals, 1978-1980 cohorts.

location	1978		1979		1980	
	O	E	O	E	O	E
Gulf	178	161	90	82	49	37
Front	176	193	66	74	15	27
Total	354		156		64	
χ^2	3.292 ^{ns}		1.446 ^{ns, 1}		8,460 ^{***}	

¹with correction for continuity

Table 4. Pooled¹ estimates of production for the 1977 to 1980 cohorts of harp seals.

Cohort	M	m	n	N_{nr}^*	K	N_T^*	SE	95% C.L.	
1977	1,230	86	26,207	244,680	71,616	316,300	32,173	253,300	379,300
1978	9,167	354	23,096	396,550	72,021	468,571	26,179	417,260	519,882
1979	4,939	156	16,773	364,238	112,064	476,302	36,361	405,034	547,570
1980	6,246	64	4,938	333,214	100,895	434,109	51,926	332,334	535,884

¹An average rate of reporting of 0.78 was assumed for all years; annual tag survival rate of 0.9 used as in Table 2.