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A Mark-recapture Estimate of 1983 Harp Seal Pup

Production in the Northwest Atlantic

by

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INTRODUCTION

Between 1978 and 1980, three mark-recapture experiments were conducted to estimate pup production of northwest Atlantic harp seals, Phoca groenlandica (Bowen and Sergeant 1983). These initial estimates and a subsequent update (Anon. 1983a) indicated that total pup production was in the neighbourhood of 475,000.

In October 1982, an Ad hoc Working Group of ICES examined the available data (including Bowen and Sergeant's estimates) on recent trends in pup production of northwest Atlantic harp seals. The report concluded that production in the late 1960s ranged from 320,000 to 420,000 and that production from 1977 to 1980 "was likely to be in the range 380,000 t to 500,000" (Anon. 1983b). Further, the Working Group concluded "that pup production in 1977-80 and 1+ population was likely to have been larger than the late 1960's pup production and 1+ population, but possibility of no increase or a slight decline is not negligble" (Anon. 1983b:7).

The purpose of the present was to estimate the 1983 pup production of harp seals in the Northwest Atlantic and thereby further test the notion that the harp seal population was continuing to recover from a period of over-exploitation between the late 1940's and early 1970's. As in previous studies (Bowen and Sergeant 1983), a modified Petersen model was used to estimate pup production. The experiment was designed to test major assumptions of the model which based on previous work were likely to be violated, namely 1) that seals do not lose their tags before the second sample, 2) that all

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recovered tags are reported (see Bowen, 1985), 3) that marking does not affect catchability and 4) that the second sample is a simple random sample.

METHODS

The basic design of the experiment follows that described in Bowen and Sergeant (1983). Two types of estimates are considered: 1) those derived from recoveries in the year of marking (short-term estimate) and 2) those based on recoveries from seals age 1 and older, known as long-term estimates. Short-term estimates use recaptures of mainly moulted pups, known as beaters, between approximately April 1 and and the end of the hunting season which is normally May 15 but was extended to June 15 at the Front in both 1983 and 1984. Most recaptures come from NAFO Subareas 4Vn, 4R, 3K and 3L. Long-term estimates use recoveries from 1+ seals killed between about January 1 and again the end of the Canadian hunting season in May or as in 1983 and 1984, June 15.

Harp seal whitecoats (age 2-12 d) were marked with individually numbered jumbo Roto-tags (Dalton). Tags were applied to the left hind flipper or, in the case of double-marked seals, to both hind flippers. Sex, pelage-type (i.e. approximate age) and tag number were recorded for most individuals, while hind-flipper length was also recorded for approximately 1,700 grey-coated pups at the Front.

Helicopters, working from land in the Gulf of St. Lawrence and from both land and an offshore vessel at the Front, were used to distribute tagging effort as widely as possible throughout the main whelping concentrations. Both in the Gulf and at the Front, our ability to distribute tags over the entire patch was greatly enhanced by the lack of an offshore large vessel hunt for whitecoats. Still, as in the past, it was necessary to tag seals in clusters of about 250-500 in order that all tags could be applied in the 10-day period during which pups are easily available.

To encourage the return of tags, hunters providing information on the date and location of tag recoveries were paid a reward of $12 per tag, an increase from the $10 paid in earlier experiments.

Information on the number of pups taken in 1983 and the number of 1+ seals taken in 1983 and 1984 in NAFO Divisions 3 and 4 was obtained from 1983 NAFO statistics (Anon. 1984) and 1984 catch statistics provided by DFO, Ottawa.

The Petersen method, described in Bowen and Sergeant (1983), was used to estimate pup production. The basic equation may be rewritten to adjust for tag loss and reporting rate as follows:

$$N_{adj} = M \frac{\sum_{i=j}^{k} n_{i,t+i}}{\sum_{i=j}^{k} m_{i,t+i}} \cdot (1 - \ell) \cdot r \qquad (1)$$

where M = number marked initially, n = number of seals examined for marks in the second sample, m = number of marked seals in n, ℓ = tag loss, and r = reporting rate of recovered tags. For short-term estimates j = 0 and k = 0, whereas for long-term estimates j = 1 and k = 1. An estimate of the variance of N_{adj} is given by:

$$Var (N^*_{adj}) = (N^*(1-\ell)r^2 [cv(N^*)^2) + cv (1-\ell)^2 + cv(r)^2] \qquad (2)$$

where cv = the coefficient of variation.

RESULTS

One small and two large harp seal whelping patches were found at the Front in March 1983. The "Southern patch" was first observed on 8 March approximately 39 km true east off Roundhill Island, Labrador (lat. 53°25'N, long. 55°00'W). At the time the concentration consisted of two patches each approximately 6 x 10 km in area separated by about 5 km. On 9 March the two smaller concentrations

of this Southern Patch had coalesed into one large group covering an area of about 160 km² at the same location. Also on 9 March, the "Northern Patch" was discovered about 20 km northwest of the Southern Patch (53°40'N, 55°10'N) with dimensions 10 km long and 5 km wide. On 10 March, the Northern Patch had grown to cover an area of about 160 km² (i.e. similar in size to the Southern Patch). The third patch at the Front was located about 90 km east of the Grey Islands (50°35'N, 54°15'W) on 19 March (K. Hay, pers. comm.). About equal numbers of seals were tagged in the large Northern and Southern patches. No seals were tagged in the patch located off the Grey Islands. By the time work in the large patches had been completed this small concentration could not be found.

Several concentrations of pups were located in the Gulf of St. Lawrence on 6 March 1983 in an area approximately 80 km southwest of the Magdalen Island (lat. 46°43'N, long. 62°36' W). Seals were tagged in all known concentrations.

A mark-recapture estimate of abundance is likely to be more reliable when the tagging density in different parts of a population is uniform. Based on limited data from various aerial surveys, it had been suggested that on average about 33% of total pup production occurs in the Gulf of St. Lawrence while the remainder occurs at the Front. In March 1983, 3,862 pups were tagged in the Gulf and 8,401 were tagged at the Front, for a total of 12,263 (Table 1). Of this total, 1,282 pups were double tagged. The number of pups tagged in the Gulf represents 31.5% of the total number marked. If relative production in 1983 was close to that estimated in the past, then our objective of uniform tagging density in both areas was likely achieved.

Although there was no large scale offshore harvest of pups in either area, a single ship did operate in whelping patches in each area in late March. To eliminate bias due to the clumped distribution of tags, large vessel catches and tag recoveries in whelping patches were omitted from the analysis. The effective number of pups tagged in each area is given in Table 2. Overall, 97% of tagged seals were considered effectively marked.

Validity of model assumptions was given considerable attention in previous experiments, therefore, except were new information is available the reader is referred to Bowen and Sergeant (1983).

To further test the assumption that animals do not lose their marks between the first and second sample, we double-tagged 1,282 whitecoats in March 1983. Of 148 double-marked pups recaptured at from 1 to 3 months of age (the period of recoveries for short-term estimates), 145 had retained both tags and 3 retained only a single tag. Over the first 3 months, $l = 0.0102 \pm 0.0059$ (mean $\pm$ SE). Estimated loss rate after approximately 1 year (recoveries from 11 to 16 months of age) was 0.0370 ± 0.0370 (n = 14) (Table 3).

The assumption that all marks are returned upon recovery was tested by a random stratified survey of 51 northern Newfoundland communities (Bowen, 1985). The results of the survey indicated a reporting rate of 0.693 ± 0.0351 (1sd).

Marked harp seals might be more conspicuous than unmarked ones and therefore might be selected by hunters because of the reward. To test this, sealers who had recovered one more beater tags were asked, during the 1983 fall survey, when they had discovered the tag. Responses were obtained from 136 sealers, clearly showing that tags were generally (99.3% of respondents) discovered after the seal had been shot (Table 4). Therefore, selective killing of marked pups appears unlikely. Similar results were obtained by Bowen and Sergeant (1983).

The Petersen model assumes that the second sample is a simple random. However, Seber (1973) has noted the Petersen estimate is still valid even if the assumption of random sampling is false provided there is uniform mixing of marked and unmarked animals so that the proportion (m/N) of marked through the population is constant. In practice, we cannot know if random sampling has been achieved, however, we can test for homogeneity in the proportion m/N by examining the ratio of marked to unmarked over time and space during the hunt. The number of marked and unmarked pups recaptured at the Front in 1983 by unit area and date are shown in Table 5. A 3-way G-test indicated significant heterogeneity in the proportion marked in the population over time and area. Hence, to the extent that random sampling was not achieved the presision of our pup production estimate will be subject to bias.

Estimated Production

i) Short-term recoveries - Table 6 shows the reported recoveries of Gulf-tagged pups between March and June 1983 which were returned for reward prior to September 1, 1983. Similar data is given in Table 7 for Front-tagged white coats. Of 367 recaptures of Gulf-tagged pups, 341 (93%) were killed in the Gulf and 26 were taken at the Front. Similarly, the majority (95%) of 655 Front-tagged pups killed in Divisions 3 and 4 were killed in the area in which they were initially marked.

Estimated total production in the northwest Atlantic from short-term recoveries is 534,000 + 33,000 (1SE) (Table 8). A rough idea of pup production in each area can be obtained by using only recoveries from the initial area of tagging and adjusting the catch in each area for migration between areas assuming that marked and unmarked animals are uniformly distributed. The results suggest that about 28% of pups were born in the Gulf in 1983.

It is unknown to what extent the smaller, unmarked whelping patch at the Front was hunted. This patch was observed by K. Hay on March 19 during a hood seal aerial survey approximately 50 nautical miles east of the Grey Islands and over 100 nautical miles from the southern most of the two main whelping patches in which tagging was conducted. Given the distance which the third patch was located offshore it seems unlikely that it was hunted to any extent. Hence it is possible that the estimate of production could be increased by 20,000 to 30,000 pups.

ii) Long-term recoveries - The estimated number of one-year-olds in the 1984 1+ harp seal catch must be determined before an estimate of production from long-term recoveries is possible. To do this the 1+ total catch was prorated using available age composition samples from each major component of the hunt (Table 9). The estimated age composition of the total 1+ catch in 1984 is given in Table 10. It is estimated that in 1984 only 1,346 one-year-olds were taken. From that catch, 117 tagged seals were reported recovered up to September 1, 1984, 42 from Gulf-marked pups and 75 from Front-marked seals.

If we adjust the number initially marked to the number surviving the beater hunt in 1983 (M = 11224) and use a tag loss of 3.7% (Table 3), then the estimate of production from returns at age 1 is 86,000 (rounded) plus the pup catch in 1983 of 50,058 for a total of 136,000 (rounded).

DISCUSSION

The estimate from recoveries at age 1 is clearly unreasonably low, given that the results from three previous experiments also based on long-term recoveries gave results which even if biased to some extent gave consistently higher estimates in the neighbourhood of 475,000 pups. One possible explanation lies in the structure of the hunt in 1984. In previous years (1979 to 1983), longliners caught from 35% to 59% of the 1+ catch mainly at the Front, where most of the 1-year-olds are taken. However, in 1984 longliners accounted for only 10% of the 1+ catch in Divisions 2, 3, and 4. Longliners are highly mobile and hunt substantial distances from their home ports, often well offshore. In contrast, landsmen operating on foot or from small open boats hunt locally, mainly within 5 to 10 nautical miles from shore. Thus, estimates from long-term recoveries may only be reliable when a substantial portion of the catch is taken by longliners operating in such a fashion that random sampling is approached more closely.

In addition, the estimate is believed to be negatively biased because 34 of the 75 recoveries of Front-tagged animals were made in mid-April from a small area of Bonavista Bay, Newfoundland, implying that sealers (operating from small boats or on foot) had selectively hunted for tagged animals. The unusual ice conditions (tightly-packed nearshore ice) in Bonavista Bay at this time made such selection possible.

Previous estimates of pup production based on short-term reported recoveries varied widely and for that reason were considered to be unreliable (Bowen and Sergeant 1983). Why, then, should the 1983 experiment produce reasonable results when the others have failed? Three reasons may be advanced. First and probably most important is the fact that in 1983 the absence of a large scale offshore hunt for whitecoats enabled researches to distribute tags more widely throughout the whelping patches than had been possible in earlier experiments. In each of the earlier experiments, the number of sealing ships operating in whelping concentrations ranged from 9 to 11 at the Front and 1 to 2 in the Gulf of St. Lawrence. Hence, tagging had to be conducted in quite restricted areas

of the patch where hunting was not taking place. This resulted in severe
clumping of marked pups, particularly at the Front. Second, the availability of
an offshore vessel dedicated to research meant that for the first time both
major concentrations of pups at the Front were tagged. Third, significantly
more pups were tagged in 1983 than in previous years and, more importantly,
tagging effort was distributed between the Gulf and Front more in proportion to
the estimated contributions of both areas to total production.

What can be concluded about recent trends in harp seal pup production from
these results? Taken at face value the estimate from short-term recoveries
would suggest that pup production has increased from about 480,000 (average of
1978 to 1980 estimates, Anon. 1983a) to about 530,000 in 1983, an increase of
10%. However, the examination of means alone may be quite misleading. Before
examining the precision of previous estimates, we must correct an error in the
formula used to estimate the corrected variance of pup production between 1978
and 1980. The correct formulation (Eq. 2) uses the CV $(1-\ell)^2$ and not
CV (ℓ^2) as was previously used. The new standard errors for these earlier
estimates are considerably smaller than reported (Table 11).

Based on the four mark-recapture studies between 1978 and 1983, there is no
significant trend in pup production. However, it is clear on the basis of these
estimates that pup production in the late 1970s and early 1980s is greater than
the estimates ranging from about 320,000 to 420,000 in 1967 (Anon. 1983b).

ACKNOWLEDGEMENTS

REFERENCES

Anon. 1983a. Scientific Council Reports 1983, Part B: 57-63. Northwest Atlantic
    Fisheries Organization, Dartmouth.

Anon. 1983b. Report on the meeting of an ad hoc working group on assessment of
    harp and hooded seals in the northwest Atlantic. ICES Cooperative Res. Rep.
    No. 121.

Anon. 1983c. Provisional sealing statistics for the northwest Atlantic, 1982.
    NAFO SCS Doc. 83/VI/9 (Revised). Serial No. N657.

Anon. 1984. Provisional sealing statistics for the northwest Atlantic, 1983.
    NAFO SCS Doc. 84/VI/7 (Revised) Serial No. N801.

Bowen, W.D. 1985. An estimate of the proportion of recovered harp seal tags
    not returned for reward: The 1983 mark-recapture experiment. NAFO SCR Doc.
    85/1/2, Serial No. N936, 7 p.

Bowen, W.D. and D.E. Sergeant. 1983. Mark-recapture estimates of harp seal pup
    (Phoca groenlandica) production in the northwest Atlantic. Can. J. Fish.
    Aquat. Sci. 40: 728-742.

Seber, G.A.F. 1983. The estimation of animal abundance and related parameters.
    Griffin, London. 506 p.

Table 1. Number of whitecoats tagged in March 1983 in the Gulf and Front harp seal herds.

| Date | Area | TAGGED | | |
		Single	Double	Total
March 6-17	Gulf	3369	493	3862
March 10-25	Front	7612	789	8401
	Total	10981	1282	12263

Table 2. Number of tagged harp seal pups surviving the kill by large vessel hunters operating in whelping patches, 1983.

| | Recaptures by large vessels | | | Effective no. tagged | | | % effectively |
Area	Single	Double	Total	Single	Double	Total	tagged
Gulf	138	45	183	3231	448	3679	95.3
Front	160	24	184	7452	765	8217	97.8
Total	298	69	367	10683	1213	11896	97.0

Table 3. Estimates of tag loss (1) from pups double-tagged in March 1983.

| Area Tagged | Approx. age at recovery (mon.) | Retained | | | 1 | SE |
		Both	Only one	Total		
Front	1-3	83	2	85	0.0119	0.0118
Gulf		62	1	63	0.008	0.0101
Total		145	3	148	0.0102	0.0059
Front	11-16	7	1	8		
Gulf		6	0	6		
Total		13	1	14	0.0370	0.0370

Table 4. Detection of harp seal tags by hunters in 1983, Front area. Based on
initial call and up to 4 callbacks.

Tag detected	Frequency[1]	Percentage
Before death		0.7
On ice	1	0.7
In water	0	0.0
After death		99.3
On ice	5	3.7
In water	3	2.2
Coming aboard vessel	42	30.9
Onboard vessel	66	48.5
During sculping	18	13.2
After scuping	1	0.7
TOTAL	136	100.0

[1] Number of sealers responding

Table 5 Number of marked and unmarked pups at the Front in 1983 by unit area
and date. Only Front tagged pups included.

		Recaptures (R)		
Unit area (A)	Date (D)	M	NM	TOTAL
336-338	Mar 27-Apr 23	1	19	20
	Apr 24-May 21	11	605	616
	May 22-June 18	0	52	52
	Total	12	676	688
339	Mar 27-Apr 23	31	101	132
	Apr 24-May 21	63	8904	8967
	May 22-June 18	8	681	689
	Total	102	9686	9788
340	Mar 27-Apr 23	0[1]	0	0
	Apr 24-May 21	59	2955	3014
	May 22-June 18	7	753	760
	Total	66	3708	3774
341	May 27-Apr 23	0[2]	0	0
	Apr 24-May 21	87	2818	2905
	May 22-June 18	4	1203	1207
	Total	91	4021	4112
342-343	Mar 27-Apr 23	269	8770	9039
	Apr 24-May 21	73	7021	7094
	May 22-June 18	15	1157	1172
	Total	357	16948	17305

M = marked, NM = not marked

[1] 12 tags recovered, but no catch reported, therefore, tags added to April 24-May 21 period.

[2] 18 tags recovered, but no catch reported, therefore, tags added to April 24-May 21 period.

Factors A x D x R $G = 3 \times 10^4$ df = 22
D x R $G = 184$ df = 2
A x R $G = 264$ df = 4

Table 6. Recoveries of 1983 Gulf-tagged harp seal pups caught between March and June 1983 and returned for reward prior to September 1, 1983.

| Month Recovered | Area Recovered | | | | | |
| | GULF | | | FRONT | | |
	Single	Double	Total	Single	Double	Total
March	138	45	183	0	0	0
April	120	13	133	6	0	6
May	15	2	17	15	2	17
June	7	1	8	3	0	3
Total	280	61	341	24	2	26

Table 7. Recoveries of 1983 Front-tagged pups caught between March and June 1983 and returned for reward prior to September 1, 1983.

| Month | Front Unit Areas | | | | | | | | | Gulf Unit Areas | | | |
	336	337	338	339	340	341	342	344	TOTAL	401	402	419	TOTAL
March	0	0	0	0	2 (2,0)	0	76 (71,5)	0	78[1] (73,5)	2 (1,1)	0	0	2 (1,1)
April	1 (1,0)	0	1 (1,0)	50 (49,1)	18 (18,0)	20 (16,4)	244 (206,38)	12 (10,2)	346 (301,45)	22 (18,4)	0	0	22 (18,4)
May	0	5 (5,0)	4 (4,0)	38 (37,1)	48 (42,6)	47 (42,5)	46 (40,6)	2 (2,0)	190 (172,18)	4 (4,0)	1 (1,0)	1 (0,1)	6 (5,1)
June	0	0	0	2 (2,0)	1 (1,0)	2 (1,1)	5 (5,0)	0	10 (9,1)	1 (1,0)	0	0	1 (1,0)
TOTAL	1	5	5	90	69	69	371	14	624 (554,69)	29	1	1	31 (25,6)

1 total tags
(single tags, double tags)

Table 8. Estimated total harp seal pup production in the northwest Atlantic in 1983 from short-term recoveries.

M	m	n	N_{adj}	k	N_t (rounded)	SE	95 % C.L. lower	upper
11896	655	42,247	526,410	7811	534,000	33,000	468,000	600,000

M = total number of seals (single and double tagged) effectively marked.

m = (total recoveries in Division 3 and 4 to June 15, 1983 reported before September 1, 1983.)-(large vessel recoveries)

n = (pup catch Divisions 3 and 4 to June 15, 1983)-(large vessel catch)

N_{adj} = pup production corrected for tag loss and reporting rate

k = large vessel.kill of pups in March

N_t = total production

SE = standard error adjusted for tag loss and reporting rate

Table.9. Harp seal age composition samples from various hunts at Front and in Gulf, 1984.

Age (yr)	Landsmen (Nfld, shot) f	%	Landsmen (Nfld, net) f	%	Research (Nfld, shot) f	%	Landsmen (Quebec, shot) f	%
1	47	20.7	5	7.6	83	15.3	16	5.5
2	85	37.4	4	6.1	91	16.8	25	8.6
3	37	16.3	7	10.6	47	8.7	15	5.1
4	28	12.3	7	10.6	50	9.2	30	10.2
5	10	4.4	7	10.6	74	13.7	27	9.2
6	6	2.6	2	3.0	45	8.3	30	10.2
7	5	2.2	5	7.6	29	5.4	35	12.0
8	2	0.9	2	3.0	21	3.9	31	10.6
9	2	0.9	2	3.0	10	1.8	27	9.2
10	2	0.9	2	3.0	15	2.8	15	5.1
11	1	0.5	2	3.0	11	2.0	10	3.4
12	1	0.5	2	3.0	7	1.3	5	1.7
13	-	-	-	-	13	2.4	4	1.4
14	-	-	2	3.0	4	0.7	3	1.0
15	-	-	2	3.0	9	1.7	4	1.4
16	-	-	1	1.5	4	0.7	-	-
17	-	-	1	1.5	4	0.7	2	0.7
18	-	-	-	-	7	1.3	1	0.3
19	-	-	-	-	6	1.1	5	1.7
20	-	-	1	1.5	2	0.4	8	2.7
21	-	-	3	4.5	-	-	-	-
22	1	0.5	-	-	1	-	-	-
23	-	-	3	4.5	1	0.2	-	-
24	-	-	2	3.0	1	0.2	-	-
25+	-	-	4	6.1	7	1.3	-	-
Total	227	100.0	66	100.0	541	100.0	293	100.0

Table 10. Estimated age composition of 1+ harp seal catch in Divisions 2, 3 and 4 in 1984.

Age	Large vessels (Research)	Longliners (all areas)	Landsmen (shot, Nfld)	Landsmen (net, Nfld)	Landsmen (Quebec)	TOTAL
1	84	1222[1]		19	21	1346
2	92	2207		15	32	2346
3	48	962		27	19	1056
4	50	726		27	39	842
5	75	250		27	35	387
6	45	154		8	39	246
7	29	130		19	45	223
8	21	53		7	40	121
9	10	53		7	35	105
10	15	53		7	19	94
11	11	30		7	13	61
12	7	30		7	6	50
13	13	-		-	5	18
14	4	-		8	4	16
15	9	-		8	5	22
16	4	-		4	-	8
17	4	-		4	3	11
18	7	-		-	1	8
19	6	-		-	6	12
20	2	-		4	10	16
21	-	-		11	-	11
22	-	30		-	-	30
23	1	-		11	-	12
24	1	-		8	-	9
25+	7	-		15	-	22
Total	545	712	5190	250	376	7073

[1] Longliners and NFLD landsmen shot samples combined.

Table 11. Estimates of harp seal pup production for 1978-80 and 1983.[2]

	Pup Production (000)	Standard Error (000)	95% confidence limits	
			Lower	Upper
1978	497	34	429	565
1979	478	35	408	548
1980	475	47	381	569
1983	534	33	468	600

[1] using long-term recoveries to 1982.

[2] using short-term recoveries, this study.