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A mark-recapture experiment to determine harp seal pup production on the Front, 1979

by

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Abstract

A total of 2,884 harp seal pups was marked with red Roto-tags from March 12 to 21, 1979 approximately 150 km east of the Spotted Islands, Labrador. For the period March 16 to April 30, all but one of the assumptions of the Petersen estimate are shown to be valid. I found that not all recovered tags were returned. However, a survey of all sealers (634) in eight communities showed that this non-reporting factor was 25%. Using Chapman's modified formula, the beater population is estimated to be 126,514. Therefore, pup production in the main (northern) whelping patch is 126,154 plus the large vessel pup kill (76,868) or 203,022. A smaller southern patch was roughly estimated to contain 20,000 to 25,000 pups. Thus total Front pup production is estimated to be near 220,000 in 1979.

Introduction

In the Front herd, most harp seal pups, Pagophilus groenlandicus, are born in 1 week in early March on the ice floes east of Cartwright, Labrador. 3 or 4 days after the peak of whelping, sealers operating from large vessels begin to hunt the pups. At 3 weeks of age the surviving whitecoated pups moult into their juvenile pelage and enter the water. Over the next 2 to 4 weeks the young seals, now known as beaters, drift southward to the rich feeding grounds in White and Notre Dame Bays. Here they are hunted from small boats and longliners.

The existence of these two distinct hunts suggests that there may be several ways of estimating pup production using mark-recapture experiments. One might mark pups on the ice floes prior to the start of the large vessel hunt and use the ratio of marked to unmarked pups in the catch to estimate production. This method has been used, but difficulty in obtaining a simple random sample of marked pups in the second sample seriously limits the reliability of these estimates (see Sergeant, 1975 for a summary of experiments). A second method takes advantage of the solitary behaviour of beaters in their first few months to increase the probability that marked animals will be randomly distributed in the population. Thus at the time of the landsmen hunt in April and May a simple random sample of tagged pups is much more likely. This method was first conducted in 1978 under the direction of Dr. Sergeant; however, unusual ice conditions resulted in low recaptures and the lack of a reliable estimate (see Bowen and Sergeant, 1979). Here I report on a second experiment designed to determine Front pup production from the recapture of marked beaters by landsmen.

Methods

The mark-recapture method used is commonly referred to as the Petersen estimate and is derived as follows:

$$\hat{N} = \frac{Mn}{m} \qquad (1)$$

where

M = number of marked animals released from the first sample;

n = number of animals examined for marks in the second sample; and

m = number of marked animals in the second sample.

The variance of $\hat{N}$ is

$$\text{Var } \hat{N} = \frac{M^2 n(n - m)}{m^3} \qquad (2)$$

This is expression (2.6) of Bailey (1951).

Bailey (1951) and Chapman (1951) have shown that expression (1) tends to overestimate the true population with direct sampling. Chapman's unbiased version is as follows:

$$N^* = \frac{(M + 1)(n + 1)}{m + 1} \qquad (3)$$

The large-sample sampling variance for N* is given by Chapman as approximately equal to:

$$V(N^*) = \frac{(M + 1)^2(n + 1)(n - m)}{(m + 1)^2(m + 2)} \qquad (4)$$

However, Ricker (1975) suggests that it is better to obtain approximate confidence intervals using m as the entering variable from tables appropriate to the binomial distribution. The 95% confidence intervals of m are given by $m + 1.92 \pm 1.96 \sqrt{m + 1}$ (Ricker, 1975: 343) for $m > 50$.

The Petersen estimate and its modified version (Chapman, 1951) are valid only to the extent that the assumptions of the model are satisfied. These assumptions taken from Seber (1973) and Roff (1973) are as follows:

1. The population is closed so that N is constant,
2. Animals do not lose their marks in the time between the two samples,
3. Marking does not affect the catchability of the animal,
4. Marked animals are randomly distributed throughout the population in the second sample,
5. All animals have the same probability of being caught in the first sample,
6. Sampled animals are correctly classified as marked or unmarked, and
7. All marks are reported on recovery in the second sample.

The extent to which these assumptions are met in the present study will be examined point by point. Details of the methods used to investigate the assumptions are presented with the results.

Harp seal pups (whitecoats) were marked with individually numbered red jumbo Roto-tags. These tags were placed on the left hind flipper (single-tagged animals) or on the left and right hind flipper in the case of double-tagged individuals. Every fourth pup was double-tagged until approximately 400 animals had been tagged in this way. The sex and tag numbers of each double-tagged seal were recorded.

I used two methods to distribute tags as randomly as possible throughout the whelping patch. The first of these I will call vessel-tagging and the second helicopter-tagging. Vessel-tagging consisted of vessel-based researchers tagging pups in the immediate vicinity of the sealing vessels. The strategy here was to work behind the sealers, tagging a proportion of the pups remaining after an area had been hunted. This method has been successfully used by Norwegian scientists (Bergfløydt pers. comm.). The second approach involved the use of a helicopter to carry researchers to parts of the whelping patch remote from sealing operations. A team of four worked from the helicopter. At each stop, each member of the team tagged four or five seals in the vicinity of the helicopter. When tagging was completed, the helicopter moved the team approximately 1 km and the procedure was repeated.

Results

Tagging

A total of 2,896 harp seals was tagged from March 12 to 21 1979, 100 to 180 km east of the Spotted Islands, Labrador (Table 1). Of these, 2,884 were pups and 12 were adult females. We double-tagged 420 whitecoats.

The relative success of the two methods of tagging is presented in Table 2. Of 1,074 seals tagged from sealing vessels 31% were recaptured as whitecoats by sealers in the whelping patch. By contrast, only 10% of 1,810 pups tagged with the use of helicopters were recovered as whitecoats. Helicopter-tagging also used manpower more efficiently than vessel-tagging. A team of four working from a helicopter could easily apply a maximum of 1,000 tags in one day under fair weather conditions. However, from a vessel this same group would be limited to 300 or 400 tags of which fewer would survive. Tagged-pup escapement, defined as the number of tagged seals surviving the large vessel pup kill, was 2,365 or 82% of the pups tagged. This is a maximum estimate of escapement. Conversations with sealers revealed that although the $10.00 reward was paid for tags taken on the ice, some sealers discarded tags rather than admitting that they had killed a tagged seal. Also it is possible that certain sealers did not send their tags in for the reward. However, both sources of error are considered to be small.

Our target of 5,000 tagged whitecoats was not achieved for several reasons foremost of which was bad weather for flying. We were able to use the helicopter only three days before the HUDSON, which served as the helicopter base, left the whelping patch on March 18. Although our contract with the helicopter had not expired, we were too far out to sea for the helicopter to operate from a land base. Vessel tagging was only partially successful. Although the majority of vessels and sealers cooperated in not killing tagged pups, two Canadian vessels did not cooperate. As a result, tagging in the vicinity of these vessels was not possible. Of the 432 single-tagged seals recaptured on the ice, 297 or 69% were taken by these two Canadian vessels.

Validity of Assumptions

1. N is constant. This assumption is not easily tested. This year there were two whelping patches at the Front. We tagged the larger northern patch but not the southern patch in the Strait of Belle Isle. If these two patches randomly mixed as beaters prior to the second sample, this would not matter and we would be estimating total Front production. If the two patches incompletely mixed, this would produce a bias of unknown size. The addition of Gulf born pups would also bias the estimate in this way. Fortunately, a large number (2,670) of pups were marked in the Gulf of St. Lawrence in 1979. If we have an estimate of Gulf pup production and we assume that marked and unmarked Gulf pups are randomly mixed by the time they reach the Front, then the number of Gulf tagged pups recovered on the Front will allow us to correct the beater catch data for the number of Gulf seals present. This year no Gulf-tagged pups were recovered on the Front during the period for which the estimate is made. Thus the number of Gulf pups that were mixed with Front pups must be small. Unfortunately, there is strong evidence that the southern Front patch incompletely mixed with the northern patch and thus N increased (but see assumption 4) during the beater hunt.

2. Animals do not lose their marks. To test this assumption 420 pups were double-tagged. A total of 87 double-tagged pups was recaptured on the ice one to 10 days after tagging. Of 74 pups for which we have complete information from the sealer, none of these pups had lost a tag. We have written sealers about the remaining 13 tags, but have not received a reply. Ten double-tagged pups taken as beaters have been returned. None of these seals had lost a tag. I conclude that the

rate of tag loss during the first three months of life is small and can be ignored.

3. Marking does not affect catchability. This assumption has not been tested in the present study. However, several lines of evidence suggest that marking does not affect catchability. Marked pups might be more conspicuous because of the mark and selected because of the $10.00 reward. However, sealers have stated that the tag cannot be seen on a seal in the water or at the distance from which beaters are normally shot. By contrast, marked beaters may be more wary as a result of being marked (handled) and therefore be harder to catch. This is also unlikely given the nature of the hunt. Beaters are generally shot at distances of 25 to 50 m or more. Thus, close approach of the hunter, to which a marked seal may be more wary, is unnecessary. I tentatively conclude that catchability is unaffected by marking.

4. Second sample is simple random sample. In practice it is difficult to know if random sampling has been achieved. However, Seber (1973:61) points out that "$\hat{N}$ is an intuitively reasonable estimate when the sample proportion of marked in the second sample faithfully reflects the population proportion". This means that $\hat{N}$ can be used even if assumption 4 is false, provided that there is uniform mixing of marked and unmarked so that the proportion (n/N) of marked through the population is constant, and animals are equally catchable. We have already seen that there is little reason to suspect that at a certain location all beaters do not have the same probability of being caught (assumption 3). To test for uniform distribution, I calculated the ratio of marked to unmarked pups by unit area and by two-week periods (Table 3). The results show that during the period March 16 to April 30, with the exception of two samples (March 16-31, 340 and April 16-30, 339), this ratio is reasonably constant with an average value of 1:84 (n = 7). In the period May 1-15, the ratio of marked to unmarked decreases markedly to an average value of 1:682 (n = 4). This was most likely caused by an influx of unmarked pups from the southern Front patch. Catches of pups (beaters) from this patch reached a maximum in the Straits of Belle Isle approximately one week earlier. Thus the timing of the apparent influx of beaters into White and Notre Dame Bays corresponds with movement of the southern patch from the Straits.

The extent to which marked and unmarked pups are randomly mixed can be determined in another way. If marked seal pups are randomly mixed in the population then the distributions of landsmen recoveries of pups tagged on different days in different parts of the whelping patch should be the same. On March 13 and 14, 436 pups were tagged in an area about 16 km north of the sealing vessels. A total of 467 pups was tagged on March 15 about 15 km east of the area tagged on March 13 and 14. On March 18, 907 pups were tagged in the southeast corner of the whelping patch. All of the above tags were applied with the use of a helicopter and the serial numbers of tags used each day were recorded. Fig. 1 shows that the distributions of recovered tags are the same from the three different parts of the whelping patch during the period March 16 to April 30. Further, the recovery rate of tags from these three areas is proportional to the number tagged. There were 7 (1.6%) recoveries from the March 13-14 tagging (2.1%) from March 15 and 18 (2.0%) from March 18; these frequencies do not differ significantly from the expected values (x^2 = 0.236, 2df, P > 0.80). I conclude that from March 16 to April 30 the estimate of $\hat{N}$ can be used. After April 30 an influx of unmarked pups probably from the southern Front patch invalidates assumption 4.

5. Same probability of being caught in first sample. With the exception of March 12 and 13, pups were tagged without regard for sex or age (size). Sex ratio of 356 double-tagged pups was 176 females to 180 males; not significantly different from 1:1 (x^2 = 0.04, df = 1, P > 0.80). On March 12 and 13, we selected small pups to increase the chance that sealers would miss the tagged seals. I conclude that assumption 5 is valid.

6. Animals are correctly classified as marked or unmarked. This assumption was checked during the whitecoat but not during the beater hunt. The hind flippers of 187 pup carcasses were examined for tags in an area where we had earlier applied tags. No tags were found, although the webbing on the hind flipper of 13 pups had been cut, indicating that the tag had been removed. This suggests that tags are not missed.

7. All marks are reported on recovery. A community survey conducted from August 28 to September 9, 1979 was designed to estimate the incidence of non-reporting of recovered tags. The beater hunt occurs in coastal areas from the St. Anthony area to Bonavista Bay. I selected eight communities to cover as much of the area as possible given constraints of time and manpower. Furthermore, I selected communities that landed more than 100 beaters to increase the probability that tags would have been recovered. The eight communities are: St. Anthony, St. Anthony Bight,

St. Carrols, Griquet, Goose Cove, La Scie, Twillingate, and Durrell (Fig. 1). In each of these communities we obtained a list of all the individuals who had purchased a 1979 sealing licence. Subsequently, these people were contacted by phone to determine the following: (a) if they had hunted harp seals in 1979, (b) if they had killed a tagged seal and (c) if they had returned the tag for the $10.00 reward. However, prior to asking these questions, researchers identified themselves as conducting biological studies of harp seals for the Federal Department of Fisheries. Further, people were told that we were paying the $10.00 reward for any harp seal tags they had recovered in 1978 or 1979. If a hunter indicated he had a tag, a researcher visited the hunter and paid him the reward. In addition to these eight communities, researchers contacted a sample of hunters in Raleigh, Ship Cove, Shoe Cove, Nippers Harbour and Summerford (Fig. 2). However, the main conclusions of the study are based on the eight completely sampled communities.

A total of 634 sealing licences were issued in these eight communities. Of these licenced sealers, 604 (95%) were contacted in person or by telephone (Table 4). The remaining 30 were unavailable or did not hunt in 1979 (information obtained from Fisheries Officers) and thus were not contacted. Although the majority of people that obtained a licence hunted at some point during 1979, only 28% of 502 hunters questioned indicated that they considered themselves as full-time sealers (i.e. sealing occupied most of their time during February to April) (Table 4). Most seal-licence holders considered themselves occasional sealers; hunting mainly on weekends.

The percentage of 1978 and 1979 harp seal tags recaptured during the 1979 seal hunt and not returned at the time of the survey is shown for each community in Table 5. Prior to the survey we had received 143 tags from seals landed in these eight communities in 1979. During the survey we purchased 48 additional tags recovered during this same period which had not been returned. Thus 25% of recovered tags were not returned three months after the hunt had ended. It will be noticed that there is considerable variation in the incidence of non-reporting between communities. There is no correlation between either number of licenced sealers and percentage of non-reporting ($r = .24$, $t = 0.60$, $df = 6$, $P > 0.50$) or the catch of pups and bedlamers and percentage of non-reporting ($r = .37$, $t = 1.27$, $df = 6$, $P > 0.20$). Both of these variables to some extent characterize the "interest" of the community in sealing. However, the number of tags recovered is inversely correlated with percentage of non-reporting ($r = -0.64$, $t = 6.40$, $df = 6$, $P < 0.01$). Variation in knowledge of the amount of the reward or how to receive the reward might also be expected to be most important. However, only one of the 604 sealers contacted did not have this information. Clearly more work is required to determine why some areas have a better reporting percentage than others. One hypothesis which might be tested is that the level of education of the hunter population influences rate of return. I conclude that although the assumption that all recovered tags are returned is violated, we can estimate this source of error and make appropriate corrections.

Estimate of Pup Production

Assumptions 2, 3, 5, 6 and 7 are valid or can be corrected for, whereas assumptions 1 and 4 appear to be valid only for the period March 16 to April 30. Thereafter, the ratio of tagged to untagged pups changed markedly indicating the influx of unmarked beaters into the population. Thus it is possible to estimate pup production as the sum of the estimated beater population (Petersen estimate) and whitecoat pup kill.

The Petersen estimate requires that we know beater catch (n), the number of tagged beaters in this catch (m) and the number of pups marked in the first sample (M). I obtained the catch of beaters by landsmen from Economics and Intelligence Branch, Department of Fisheries and Oceans, St. John's (Table 6). The analysis is based on catch in unit areas 335 to 342 from March 16 to April 30. Beater catch during this period was 3,838. The number of tagged beaters recovered and returned during March 16 to June 15 is given in Table 7. The number of returns corresponding to the above catch is 57. However, this value must be corrected to account for non-reporting of recovered tags. Applying a non-reporting factor of 25% the actual number of tag returns becomes 71. Finally, the number of pups marked in the first sample is given on p. 3 as 2,365.

The estimated beater population is calculated as

$$N^* = \frac{(M + 1)(n + 1)}{(m + 1)} = \frac{(2365 + 1)(3838 + 1)}{71 + 1} = 126{,}154.$$

As the variance of N* (Var N*) is correlated with N*, 95% confidence limits of N* are better calculated by considering m as variable following the binomial distribution. The 95% confidence limits of the number of tags recovered m = 57, are 44 and 74. These values, corrected for non-reporting, become 55 and 92.5. Hence 95% confidence limits of N* are given as

$$\text{lower limit of } N^* = \frac{(2366)(3839)}{93.5} = 97{,}145$$

$$\text{upper limit of } N^* = \frac{(2366)(3839)}{56} = 162{,}198$$

Pup production of the northern whelping patch is 126,154 plus the large vessel pup kill of 76,868 (see Bowen and Sergeant 1979 for details of catch) or 203,022. The 95% confidence limits of this estimate are 174,013 to 239,066. This is a minimum estimate of total Front production since it does not account for the southern patch. This patch was observed on March 16 in the vicinity of Red Bay, Labrador by A. Ollerhead and H. Compton, Fisheries Officers from St. Anthony. On March 20, the patch was again observed approximately 70 km southwest of Blanc Sablon, Quebec. Ollerhead and Compton (pers. comm.) roughly estimated that there were 20,000 to 25,000 pups in the patch. Thus total pup production was likely near 220,000 in 1979.

Discussion

The results of this study clearly indicate that the assumption of random mixing of tagged and untagged pups must be examined before N* can be accepted. In practice we will never know whether or not marked animals are randomly distributed through the population. However, we can examine the extent to which (a) there is a uniform distribution of the proportion of marked to unmarked in the population and (b) all pups at a certain location are equally catchable. Given (a) and (b) are true, then the estimator N* may be used (Seber 1973). In the present study, (a) is true for the period March 16 to April 30, but not true thereafter. The most likely explanation for this change is that a group of unmarked pups from the southern Front patch arrived in the hunting area during the 2-week period, May 1-15. The arrival of these unmarked pups invalidated assumptions 1 and 4.

It is clear that future experiments of this nature must ensure that a sample of pups in all whelping patches on both the Front and in the Gulf of St. Lawrence are tagged. To achieve this we must have more helicopter time available and better communication between Fisheries Officers and scientists of information about the location of whelping patches.

The results of the community survey are important. In the first place, they demonstrate that past mark-recapture estimates of pup production are likely to be severely biased upwards. Further, it is unlikely for reasons discussed below that the rate of non-reporting found in this study can be applied to earlier experiments. In November 1978, the reward for harp seal tags was increased to $10.00 from $4.00. This increase was announced in newspapers and on CBC's Fisherman's Broadcast. Additional information in the form of posters and self addressed envelopes was sent to approximately 20,000 fishermen in Newfoundland. This means that the percentage of non-reported tags was probably lower this year than any time in the past. I would also point out that it is not known if the results of the Newfoundland study can be applied to the Gulf of St. Lawrence. I suggest that a study be conducted in the Magdalen Islands and Quebec northshore.

In addition to the assumptions I have discussed above, there is another consideration which must be dealt with to ensure that N* is unbiased. Chapman (1951) has shown that N* is unbiased only if the total size of the mark and recapture samples (M + n) is equal to the size of the population (N). This condition guarantees that the recapture sample includes at least one marked animal ($m \geq 1$). If $M + n < N$ then the estimator N* has a bias of approximately $100e^{-Mn/N}$ percent (Chapman 1951). This bias becomes negligible only when the product of the two samples (M X n) exceeds population size (N) by a factor of 3 or 4. If $Mn \approx N$, the Petersen estimator underestimates N by approximately 37% on average. When $Mn \approx 3N$ the bias is reduced to 5% and for $Mn \approx 4N$ this bias is less than 2%. Robson and Regier (1964:217) argue that the list of assumptions necessary to validate the Petersen estimate should include the following: "the product of the two sample sizes M and n must exceed 4 times the population size N." In this study, we have M = 2,365 and n = 3,838 and a general idea that N (i.e. the beater population) > 150,000. Thus $Mn \approx 60N$ and the bias of N* is negligible.

The final point to consider is the level of precision of the estimator N*. Let $(1 - \alpha)$ be the probability that the population estimate N* will not differ from the true population size N by more than 100p percent, where p denotes the level of accuracy. Three standard levels of α and p are suggested by Robson and Regier (1964):

1. $1 - \alpha = .95$, $p = 0.50$; recommended for preliminary studies where only a rough idea of population size is required.

2. $1 - \alpha = .95$, $p = 0.25$; recommended for more accurate management work,

3. $1 - \alpha = .95$, $p = 0.10$; recommended for careful research into population dynamics.

Robson and Regier provide charts for determining M and n from a rough estimate of N for the above three levels of α and p. If the total Front beater population (pup production minus large vessel catch) is about 150,000 then Table 8 shows some combinations of M and n required to provide estimates of ± 25% and ± 10% of true population size N. From Table 8 we can see the probability is .95 that this year's estimate will differ from the true population size not more than 25%. To obtain a precision of 10% we would need to tag 5,000 or 8,000 pups and have a beater catch of 10,000 or 6,000. It is important to realize that this probability statement of precision assumes that conditions 1 through 7 are met. I conclude that we are unlikely to achieve an estimate with 10% precision but that 25% precision is possible with this method.

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Table 1. Number of seals tagged in March 1979 east of Spotted Islands, Labrador.

Type	No. Single-Tagged	No. Double-Tagged	Total No. Seals tagged	Total No. Tags used
Adult female	11	1	12	13
Whitecoats	2,464	420	2,884	3,304
TOTAL			2,896	3,317

Table 2. Escapement of tagged whitecoats by method of tagging.

Method of tagging	No. Single-tagged	No. Double-tagged	Total	Recaptures		Escapement
				Single	Double	
Vessels	866	208	1,074	273 (32)[a]	60 (29)	741 (69)
Helicopter	1,598	212	1,810	159 (10)	27 (13)	1,624 (90)
TOTAL			2,884			2,365 (82)

[a] Percentage.

Table 3. Ratio of tagged to untagged beaters in landsmen[1] hunt, March to June 1979 by unit area[2]

Date	Unit area				
	342	341	340	339	338-335
March 16-31	79[3]		10		
April 1-15	57	98	72		
April 16-30	71	53	158	28	
May 1-15	773	461	682	814	
May 16-30		15	20		62
June 1-15	23			83	

[1] including small boats, longliners and nets

[2] see Fig. 1

[3] to be read as 1 tagged : 79 untagged beaters

Table 4. Number of sealers contacted and their hunting status in a survey of eight communities in Newfoundland, August-September 1979.

Community	No. licensed sealers	No. contacted	Hunting Status	
			Occasional sealers	Full time sealers
Twillingate	81	77	49	28
Durrell	60	60	33	27
St. Anthony	250	228	133	25
St. Carols	15	15	1	7
St. Anthony Bight	36	35	22	7
Goose Cove	56	56	47	9
Griquet	78	77	47	17
La Scie	58	56	29	21
TOTAL	634	604 (95)[a]	361 (72)	141 (28)

[a]Percentage

Table 5. Percentage of 1978 and 1979 harp seal tags recaptured during the 1979 seal hunt and not returned.

Community	No. Tagged Seals Before (a)	After (b)	Total (c)	Non-reporting $\frac{b}{c} \times 100$
St. Anthony	17	8	25	32.0
St. Anthony Bight	0	5	5	100.0
St. Carrols	7	3	10	30.0
Goose Cove	0	2	2	100.0
Griquet	7	2	9	22.2
La Scie	26	15	41	36.6
Twillingate	59	7	66	10.6
Durrell	27	6	33	18.2
TOTAL	143	48	191	25.1

Table 6. Pup catch by landsmen and longliners in ICNAF subareas 3K and 3L in 1979

Date	Unit area								
	401	342	341	340	339	338	337	336	335	Total
March 16-31	854	157	16	10	3	18				204
April 1-15	1559	396	492	286	2		3			1179
April 16-30	1409	921	957	474	85	9	9			2455
May 1-15	137	1546	1843	2046	1627	76	97	7	1	7243
May 16-31	140	156	29	40	304	44	123	19	1	716
June 1-15	325	23	30		83	12	47	5		200
TOTAL	4424	3199	3370	2856	2104	159	279	31	2	11997

Table 7. Recaptures of beaters by landsmen in 1979

Date	Unit area									
	209	202	401	342	341	340	339	337	335	TOTAL
March 16-31				2		1				3
April 1-15			1	7	5	4				17
April 16-30			1	13	18	3	3		1	39
May 1-15		1	1	2	4	3	2			13
May 16-31				2	2			2		4
June 1-15	2			1			1			4
TOTAL	2	1	3	27	29	11	6	2	1	82

Table 8. Some combinations of number marked (M) and number of pups in second sample (n) required to provide an estimate of N with 25% and 10% precision for N = 150,000: from Robson and Regier (1964). $1-\alpha = .95$

p					
0.25	M	2,500[a]	3,000	4,000	5,000
0.25	n	4,500	3.000	2,500	1,800
0.10	M	8,000	7,000	6,000	5,000
0.10	n	6,000	7,000	8,000	10,000

[a] M = 2,500, n = 4,500 will yield same estimate as M = 4,500, n = 2,500.

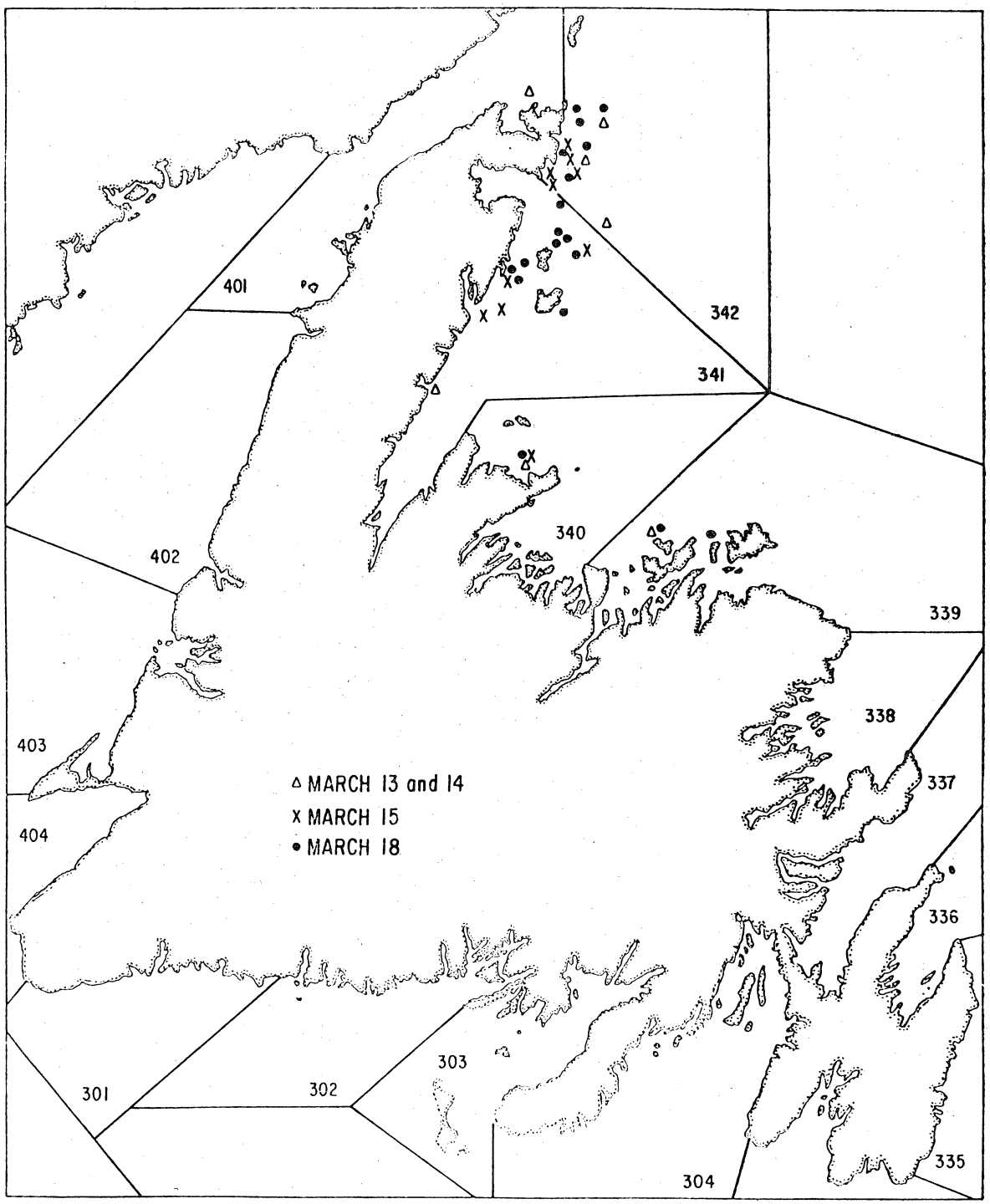

Fig. 1. Distribution of tag recoveries from March 16 to April 30. Tags originally applied to pups in three distinct parts of northern Front whelping patch during March 1979.

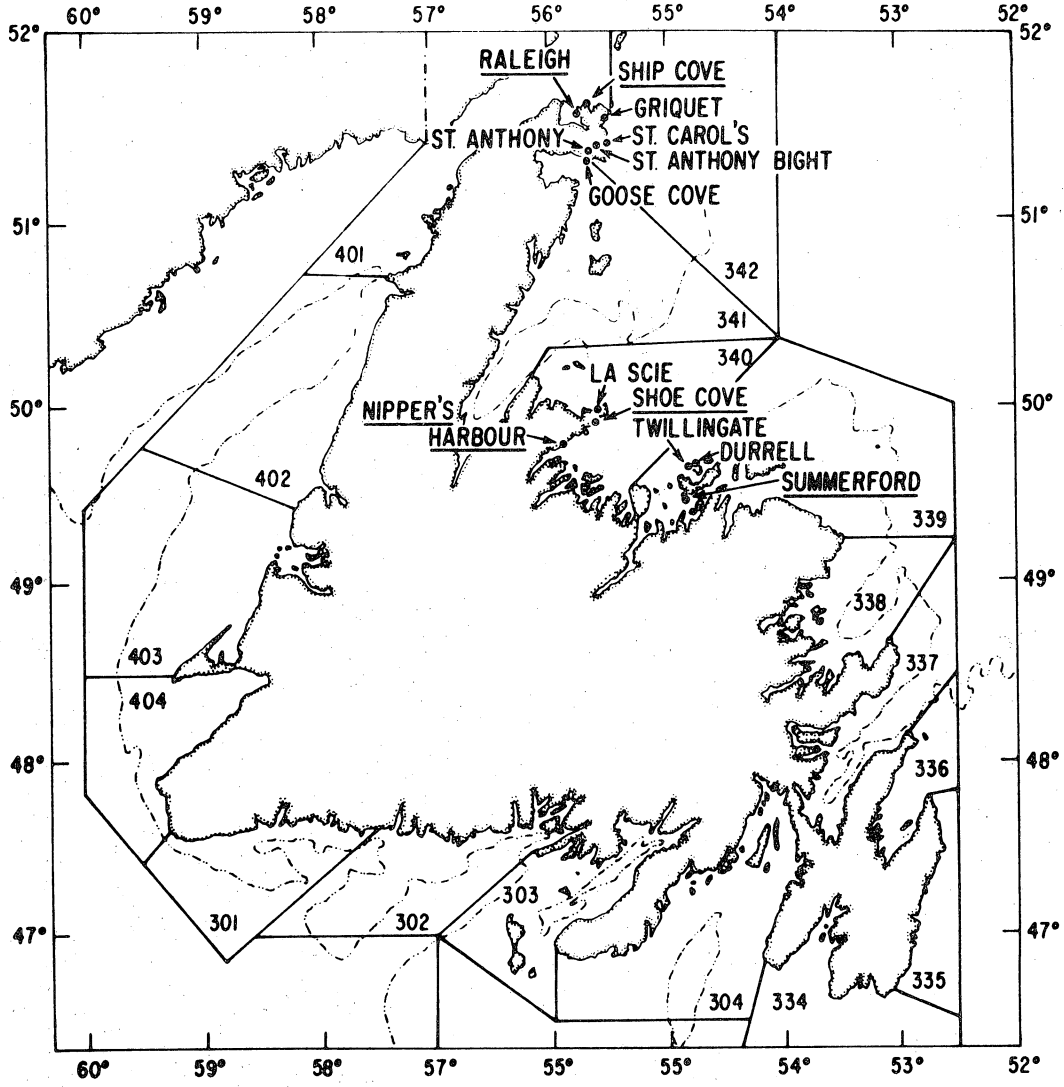

Fig. 2. Location of communities surveyed for incidence of non-reporting of tags. Underscored communities were not completely sampled.