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Aerial Survey Estimates of Pup Production of Harp Seals (*Phoca groenlandica*) in the Gulf of St. Lawrence and off Newfoundland during March 1990

by

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Abstract

Pup production of harp seals (*Phoca groenlandica*) in the Northwest Atlantic has not been assessed since the early 1980's even though there has been a large reduction in the numbers of animals taken in the commercial harvest since that time. Aerial photographic and visual surveys were conducted in March 1990 to estimate pup production in the Front and Gulf of St. Lawrence whelping concentrations. Data obtained on the proportion of pups in identifiable age-dependent developmental stages were used to correct the estimates for pups which may not have been present at the time of the survey. Three whelping concentrations were located at the Front while two were located in the Gulf. At the Front, total pup production in the concentrations, based on visual surveys, was estimated to be 467,200 harp seal pups (SE=31,200). The total pup production for both concentrations and scattered pups estimated from aerial photographic survey was 536,400 pups (SE = 115,300), although this was not considered to be as reliable as the visual estimate due to the assumptions involved in combining surveys. Pup production in the Gulf (Magdalen Islands and Mecatina patches) was estimated to be 110,600 (SE=23,000). Thus, total pup production in the Northwest Atlantic, based on visual estimates at the Front and photographic estimates in the Gulf, is 577,900 (SE = 38,800).

Résumé

Il n'y a pas eu d'évaluation de la population de phoques du Groenland (*Phoca groenlandica*) nouveaux-nés dans l'Atlantique nord-ouest depuis le début des années 1980, malgré une forte réduction du nombre d'animaux capturés dans la chasse commerciale depuis lors. On a procédé à un recensement par photographies aériennes et à des observations visuelles en mars 1990 pour estimer la production de nouveaux-nés dans les concentrations de reproducteurs du Front et du Golfe du Saint-Laurent. On a utilisé les données sur la proportion de nouveaux-nés à des stades de croissance selon l'âge reconnaissables pour inclure dans les estimations les jeunes phoques qui pouvaient être absents au moment de l'observation. On a dénombré trois concentrations de reproducteurs sur le Front et deux dans le Golfe du Saint-Laurent. En se fondant sur des observations visuelles, on a estimé à 467 200 (E-T=31 200) le nombre de nouveaux-nés se trouvant dans les concentrations du Front. En y ajoutant le nombre de nouveaux-nés disséminés, calculé d'après le recensement par photographies aériennes, on obtient un total de 536 400 (E-T=115 300) nouveaux-nés sur le Front. Cette évaluation n'est toutefois pas considérée aussi fiable que celle obtenue par estimation visuelle en raison des hypothèses associées à la combinaison des deux méthodes. Quant au nombre de nouveaux-nés du Golfe (concentrations des Îles-de-la-Madeleine et de Mecatina), on l'a estimé a 110 600 (E-T=23 000), ce qui porte la production totale de nouveaux-nés dans l'Atlantique nord-ouest à 577 900 (E-T=38 800), selon des estimations visuelles sur le Front et des photographies aériennes dans le Golfe.

Introduction

Harp seals (*Phoca groenlandica*) give birth to a single whitecoat pup on pack ice during late February and March. Three breeding populations are recognized, the Jan Mayen, White Sea and Northwest Atlantic populations. Northwest Atlantic harp seals whelp on pack ice off the eastern coasts of Labrador and Newfoundland, known as the 'Front' herd, in the central Gulf of St. Lawrence near the Magdalen Islands ('Gulf' herd) and sometimes in the northern Gulf near La Tabatiere (the Mecatina patch) (Sergeant 1976). Relationships among the various breeding herds in the Northwest Atlantic are unknown. Historically, the ratio of pup production in the Gulf and Front herds has been considered to be in the order of 1:2 (Sergeant 1976). However, the consistency of this ratio may vary among years (Winters 1978).

Beginning in the 19th century and lasting until the early 1980's the harp seal was subject to a commercial hunt. Between 1950 and 1970 this hunt may have reduced the Northwest Atlantic harp seal population to 50% of the 3 million 1+ seals estimated in 1952. (Lett and Benjaminsen 1977, Winters 1978). In 1971 the Canadian government established harvest quotas and throughout the 1970's and early 1980's considerable effort was expended to obtain information on the dynamics and size of the Northwest Atlantic population of harp seals (Allen 1975, Benjaminsen and Oritsland 1975, Lavigne et al. 1979, 1980, Sergeant 1971, Bowen and Sergeant 1983, Roff and Bowen 1983, 1986, Myers and Bowen 1989). Considerable controversy surrounded these efforts and in 1983 the European Economic Community banned the importation of pelts from whitecoat harp seal pups for a period of 5 years, effectively destroying the market for seal pelts. This ban was extended in 1988. In the late 1980's Canada banned the large vessel hunt, ending the commercial whitecoat hunt. Harp seals are still hunted by land-based sealers in both the Gulf and Front areas from November through June, and in Arctic waters during the summer.

In the late 1970's and early 1980's pup production was estimated using age composition data (Sergeant 1975, Benjaminsen and Oritsland 1975, Winters 1978, Cooke et al. 1985), aerial surveys (Lavigne et al. 1980, 1982) and mark-recapture experiments (Bowen and Sergeant 1983, 1985). The results were often conflicting with estimates ranging from 251,000 (1975/77, Lavigne et al 1980, 1982) to 450,000 - 534,000 (1977-1983, Bowen and Sergeant 1983, 1985). The Royal Commission on Seals and Sealing in Canada (Anon 1986) concluded that pup production in 1978 was 300,000 - 350,000.

In 1990, the Harris Commission recommended that the possible role of harp seals in the collapse of the north Atlantic cod stocks should be investigated. The

fisrt requirement of such a study is an updated population assessment. This paper reports the results of visual and photographic surveys conducted during March 1990 to estimate pup production of harp seals in the Northwest Atlantic.

Materials and Methods

Reconnaissance Survey

Whelping concentrations were located using fixed-wing and/or helicopter reconnaissance surveys of the areas historically used by whelping harp seals. In the Gulf of St. Lawrence, the whelping patch traditionally forms to the northwest of the Magdalen Islands. Consequently, early searches were concentrated in this area. From 22 February through 20 March reconnaissance flights were flown using a Bell 206 helicopter. Between 6 and 10 March systematic transects were also flown in the same general area using a Piper Navajo aircraft. These flights extended to the north and east until unsuitable ice conditions were encountered.

Reconnaissance flights at the Front were carried out between 5 and 25 March using a Piper Navajo aircraft, equipped with a LORAN C navigation system. Based on maps of historical whelping distributions and the distribution of the medium first year ice type as indicated by ice charts (Atmospheric Environment Service), the area between Cape Harrison to just north of the Funk Islands (50^0-$54^0$42'N, 51^0-56^0W) was examined. Ice found in the southern portion of the survey area was not considered suitable for seals. Systematic east-west transects, spaced 18.5 km apart, were made from the inner edge of the ice pack to the outer edge at an altitude of 230 m. Two observers, one per side, examined all suitable ice. This design was expected to have a high probability of locating whelping patches which are generally >9 km in width (Bowen pers. comm.). To account for ice drift and the possibility of delayed pupping, some areas were surveyed more than once. A satellite-linked transmitter was deployed to ensure re-location of the patch and to monitor its movements. Daily positions were obtained using System Argos. Radio transmitters (range approximately 10-30 km) were also placed by on-ice personnel to facilitate relocation.

A similar survey design was used to search the area of the northern Gulf of St. Lawrence from 50^0-$51^0$40' N. The purpose of this survey was to locate any harp seals whelping in the Mecatina area.

Photographic surveys

Aerial photographic surveys were conducted at both the Front and in the Gulf using a Piper Navajo airplane. Photographs were obtained using a 228.6 x 228.6 mm (9" x 9") format metric mapping camera (Zeiss RMK/A) equipped with a 150 mm Sonnar lens and Kodak Double-X (2405) aerographic black and white film.

All surveys were flown at an altitude of 305 m and maintained using a radar altimeter. Accurate navigation was maintained using a Loran C navigation system. Strip width for individual frames was 455.5 m and image size of a 80 cm pup was 0.4 mm. Photograph intervals were set so that there would be no overlap of consecutive frames.

In order to correct the survey results for pups misidentified by the reader (see below), imagery was also obtained using a Vinten 70mm aerial reconnaissance camera fitted with a 76.2 mm quartz lens, a Wratten 18A ultra-violet filter and Kodak Tri-X (2403) black and white aerographic film. Negative size was 57 X 57 mm and at the flying altitude used, strip width was 228.6 m. Image size of a 80 cm pup was 0.2 mm. This system obtained imagery in the ultra-violet wavelengths (300-400 nm) which previous studies have shown will increase the visibility of white-coated pups (Lavigne and Oritsland 1974, Lavigne 1976, Reynolds and Lavigne 1981, Ni et al. 1988).

In the Gulf, photographic surveys were conducted on 8, 9 and 10 March. To ensure that the entire patch was surveyed on each day, an initial pattern of north-south transects were flown from one end of the patch to the other. The remaining flight time was used to fly a set of infill transects in areas where the north-south extent of the patch was large or variable or both.

Aerial photographic surveys carried out at the Front were stratified to include two strata: 1) whelping concentrations (high density), and 2) scattered pups outside whelping patches (low density). Systematic photographic surveys of four whelping patches were carried out. Each patch was surveyed once. All transects were flown in an east-west direction and with the exception of the Main patch, each survey was completed within a single day. Surveys were conducted on 14, 15, 16 and 19 March.

To estimate the number of females giving birth outside of the whelping patchs, photographs were taken during a series of systematic east-west transects flown between 54° N and 50° 20' N on 13, 19, 20, 23, 25, 26, and 28 March. Transects were

spaced 37 km apart and the photographic sequence began when the ice was considered heavy enough to support seals and terminated when the ice was considered to be too thin.

Visual Surveys

To determine the proper conditions for conducting a visual survey for harp seals, a series of trials were conducted at various combinations of altitudes and strip widths. Initially, flights were made at an altitude of 90 m with a strip width of 120 m on either side of the aircraft. It was determined that detection was too difficult under these conditions and eventually, a flying altitude of 46 m and a 30 m strip was chosen to ensure that pups were not missed in areas of high concentrations.

Visual surveys of the Main, South and Belle Isle Patches were conducted at the Front using a MMB105 helicopter equipped with a Loran C navigation system. Observers, seated in the left and right rear seats, counted all pups seen within the strip width. Observers calibrated their strips by placing reference marks on the window using a known distance on the ice. Accessory marks placed at the level of the horizon and in line with the edge of the helicopter floats were used to maintain a constant head position. Following the survey, actual strip widths were determined by testing the strip widths used against a known distance on an airport runway. Each observer recorded pups located within the defined strip using a laptop computer. Prior to the actual surveys each observer underwent trial surveys until they felt comfortable with the techniques and computer programs used. A recorder was also present on all surveys to ensure that transect lines were flown correctly and to record additional information.

For the South and Belle Isle patches the first transect was flown along one edge of the patch. Because of its large size, two helicopters were used to survey the Main patch. The approximate centre of the patch was estimated based on trial flights made the day before. Each helicopter began at the centre and flew parallel transects towards opposite ends of the patch. Each transect was terminated approximately 5 km after the last seal was observed. The survey ended when no seals were seen on transect or were observed outside of the survey area.

Classification of developmental stages

All pups observed were classified into 1 of 7 age-dependent pelage and morphometric stages (newborn, yellow coat, thin white coat, fat white coat, grey coat, ragged-jacket, and beater) as described by Stewart and Lavigne (1980). Prior to the survey, personnel from both the Front and Gulf areas standardized stage determinations to ensure observer consistency.

The proportion of pups in each stage was used to model the distribution of births throughout time as described by Bowen et al. (1987) and Myers and Bowen (1989). The model was run using a wide variety of assumptions. The start date, the functional form of the birthing distributions, the length of time the last stage is visible, and the proportion of the last stage visible were varied. The results of the correction for the birthing distribution were used to correct the survey results for pups not yet born or pups in the water at the time of the survey. The confidence limits for the parameters of the birthing distribution were calculated by plotting the log-likelihood for pairs of parameter values. The approximate 95% confidence region is the set of parameter values where the difference in the log-likelihood is greater than approximately 4 from the maximum. The confidence region of the proportion of the total pup production that is visible on the day of the survey was obtained by determining the maximum and minimum proportion of pups visible witin the 95% confidence region for the parameters of the birthing distribution.

In the Gulf, pup staging was conducted repeatedly between 22 February and 19 March. On each day locations were randomly chosen in an effort to obtain information from different regions within the herd. At each location, the helicopter landed near a group of seals and 2-3 observers walked a transect 100 m long from the helicopter, staging all pups lying within 10 m of the line.

To stage pups within each patch at the Front transverse flight lines, based on previous estimates of the patch dimensions, were flown and 10-15 random points chosen. The number of stops made was limited to ensure that the entire patch was covered on each day. At each point 2 groups, moving in opposite directions, classified all of the pups encountered within 10 minutes.

Photo readings

Imagery from the Gulf was examined by a single experienced reader. Negatives were examined under magnification using a Wild-Leitz dissecting microscope mounted on a Richard's light table. Frames were covered by an acetate sheet and the position of both pups and adults were marked on these sheets. Each frame was examined twice. Acetate sheets from the two independent readings were then combined to confirm the identifications of marked seals.

For the Front imagery, positive prints were examined by two readers. One reader had extensive experience identifying seals on photographs while the second had no previous experience. The latter read the imagery obtained from the whelping concentrations while the former read the imagery from the low density stratum. The position and number of all adults and pups in each frame was recorded on a clear acetate laid over each print. Each frame was examined once with the use of a luminated hand-lens (7-8X magnification). An acetate with a 72 cell square grid was laid over the Zeiss prints to improve the ease and accuracy of counting.

Before beginning counting, the inexperienced reader underwent a training period which involved reading a wide variety of photos. Counts were checked by the experienced reader and identified seals compared. This was continued until the counts were similar. Once the actual reading was started, her counts were periodically checked by the experienced reader. After all of the film was read, the experienced reader reread the photos in the same order until the counts were consistent with original counts. The inexperienced reader reread all prints.

Correction for missidentified pups

In order to correct counts for missidentified pups, overlapping Zeiss and Vinten photographs were selected from both strata at the Front and identical areas present on each film identified. All photos were examined by a reader with extensive experience identifying seals on both black and white and ultra-violet imagery. Each photo was read independently and the individual seals counted on either film type were compared to determine if any pups were missed or misidentified. The count was considered to be the best estimate of actual number of seals present and included animals counted on either film, both films, or discovered during the rereading.

Conversion from recorded to corrected ('matched') counts, denoted by x_i and y_i

respectively, was by linear regression of x_i on y_i for the matched frames, ie $x_i = a + by_i$. Separate regressions were constructed for each of the three readers based on images most similar to the actual photos read. The regressions for the two experienced readers (1 Front, Gulf) were based on sample sizes of 1110 and 296 Vinten (UV) frames, respectively, obtained from both high and low density strata. The regression for the less experienced reader was based on 391 Vinten prints from the high density stratum.

The 'matched' counts were regressed on the original counts since the objective was to convert the original counts to true values. Individual photo counts were corrected by means of the appropriate regression. The regression was not constrained to pass through the origin and negative estimates of true counts were replaced by zero.

The estimated corrected transect total are subject to error due to the variation about the regression, referred to as the 'measurement error' (in contrast to the sampling error stemming from the transects being a systematic sample). It was felt that the heterogeneity and non-normality (discrete counts) in the data was such as to make conventional regression theory not reliable for estimating the measurement error. Accordingly, bootstrap estimates were obtained for the variance of each estimated transect total. Two hundred bootstrap samples were generated for each of the Front transects and 400 for the Gulf transects, which should be adequate for estimating standard errors (Efron 1981). As a check, the means of the bootstrap samples were also computed, and differed negligibly from the estimated totals.

For each patch, or collection of transect lines, the sampling variance was calculated as described below. The measurement-error variance of the transects were then added to form the total measurement-error for the patch, and this, in turn was added to the sampling variance.

Analysis of survey results

The surveys were based on a systematic sampling design with, in effect, a single random start. The sampling unit was a transect of variable real length. The estimates of error variance were based on serial difference between transects (Cochran 1977, Kingsley and Smith 1981, Kingsley and Hammill 1991).

Groups of adjacent transects were defined based on homogeneous transect spacing. For each group a weighting factor k_i was calculated as

$$k_i = S_i / W_i \tag{1}$$

where:
S_i = transect spacing (km) for the i^{th} group;
W_i = transect width (km) for the i^{th} group.

The number of pups present were summed over transects (x_j). For photographic surveys where coverage was not continuous

$$x_j = \frac{\sum_{z=1}^{f_j} t_{jz} \times l_j}{f_j \times p_j} \tag{2}$$

where:
f_j = the number of photographs on transect line j ;
t_{jz} = the number of seals in the z^{th} interval on the j^{th} transect ;
l_j = the total transect length ;
p_j = the frame length ;

The estimated numbers of pups for the i^{th} survey is given by

$$\hat{N}_i = k_i \sum_{j=1}^{J_i} x_j \tag{3}$$

where:
J_i = the number of transects in the i^{th} survey ;

and variance calculated as

$$V_i = \frac{k_i \times (k_i - 1) \times J_i}{2(J_i - 1)} \sum_{j=1}^{J_i - 1} (x_j - x_{j+1})^2 \tag{4}$$

During the visual survey of the South Patch, the photographic surveys of the Main patch at the Front and in the Gulf, transect spacing changed within the survey area. For these areas, each area of homogeneous transect spacing was treated as a separate survey with the estimated number of pups given by

$$\hat{N}_i = k_i \left[x_{i1}/2 + \sum_{j=2}^{J_i - 1} x_{ij} + x_{iJ_i}/2 \right] \tag{5}$$

where:
J_i = the number of transects in the i^{th} group ;
x_{ij} = the number of pups counted on the j^{th} transect in the i^{th} group.
and the end transects are the limits of the survey area.

Rewriting the variance estimate given in Equation 4 results in

$$V_i = \frac{k_i \times (k_i - 1)}{2} \sum_{j=1}^{J_i - 1} (x_j - x_{j+1})^2 \tag{6}$$

The combined estimate for total population and its error variance for the entire population are obtained by

$$\hat{N} = \sum_{i=1}^{I} N_i \tag{7}$$

$$\hat{V} = \sum_{i=1}^{I} V_i \tag{8}$$

where I is the number of groups of transects.

Results

Gulf

Reconnaissance

Helicopter reconnaissance surveys in the Gulf located several groups of seals consisting of 50 to 100 animals 74 km NNW of Cap-aux Meules on 22 February. By 25 February, these groups had combined into the main Gulf patch and was located 65 km NNW of Cap aux Meules. During the survey period the patch continued to drift eastward and pass to the north of the Magdalen Islands. A small patch of 50 adults with a few pups was spotted 23 February at 47°59N, 62°04W. By 25 February this patch had dispersed and the ice broken up. Additional reconnaissance were conducted to the north and to the east of the known location of the whelping patch, but no other concentrations of seals were seen (Fig. 1). No whelping harp

seals were found during subsequent flights nor during hooded seal research flights southward to Prince Edward Island and eastward to Cape Breton Island.

Correction for misidentified pups

A regression line relating actual readings to 'matched' counts was developed for the reader of the Gulf imagery. This regression was based on imagery obtained at the Front as camera malfunctions during the Gulf surveys resulted in extremely poor quality UV imagery. All counts were corrected as

$$x_i = 0.1481 + 1.495y_i \tag{9}$$

Photographic Surveys

Complete coverage of the patch was obtained on 8 March, but no imagery was obtained on 9 or 10 March due to camera malfunctions. On 8 March, a total of 26 transects were flown with the patch divided into four strata (Table 1). Spacing between the individual transects was 14.8 km, 7.4 km, 3.7 km and 7.4 km respectively. Total photographic coverage of 4.3% was obtained. Pup production, uncorrected for the distribution of births, was 103,075 with a standard error of 22,942.

Developmental stage classifications

Staging of pups began with the discovery of the small group of pups on 22 February, and continued almost daily until 19 March (Table 2). Pupping continued until 13 March. An examination of the distribution of births throughout the patch indicated that older pups were associated with the eastern edge of the patch, with the mean age declining westward.

Front and Mecatina

Reconnaissance

The first harp seal whelping concentration at the Front (Main) was located on 5 March at 54° 07'N and 54° 49'W. Two addition concentrations were located on 10 March (South) and 13 March (Belle Isle) at 53° 19'N 54° 52'W and 51° 52'N 53°22'W, respectively. The area between the Grey Islands (51°N) and Cape Harrison (54° 42'N) was searched on a number of occasions but no additional whelping concentrations were found (Fig. 2). The area south of the Grey Islands to 49°50'N was searched on 14 March, but the ice was unsuitable for seals.

A Fisheries and Oceans surveillance aircraft sighted a large group of seals on 15 March at 47° 40'N 48° 20'W. A reconnaissance flight by experienced personnel flew over the patch on 20 March. The vast majority of the seals were identified as immature harps. A few old harps were observed and only 2 pups. Only a single afterbirth was seen.

On 12 March reconnaissance flights were made over the northern Gulf of St. Lawrence (Fig. 2). A group of whelping seals, the Mecatina patch, was located at 50° 09'N 58°55'W.

Correction for misidentified pups

The regression lines developed to correct for misidentified pups were very different for the two readers. The reader with extensive previous experience identified most of the pups present resulting in a regression line of

$$x_i = -0.063 + 1.068 y_i \tag{10}$$

The inexperienced reader incorrectly identified ice and water features as pups resulting in an overall inflated count. The resultant regression line was

$$x_i = -0.097 + 0.678 y_i \tag{11}$$

Photographic surveys

A photographic survey of the Mecatina patch was conducted on 14 March, consisting of six (6) transects flown at 1.85 km intervals (Table 3). A total of 1289 pups were counted on 88 photos. The total coverage was approximately 19.4%. After correcting for counting error, pup production was estimated to be 4,373 (SE = 1,264).

Because of high winds (> 75 km/hr) breaking up the patch, the Main patch could not be surveyed in one day. The patch had been spread over an extremely large area from approximately 53° to 53°40'N and 54° 16' to 52° 41'W. The northern part of the Main patch was surveyed on 15 March while the southern area was completed on 16 March (Table 4). The amount of drift which occurred between the two survey days was estimated from the location of a satellite transmitter placed on the ice in the Belle Isle patch which was further south (51° 10'N, 53° 05'W). A total of 15 transects were flown. Transect spacing varied resulting in two strata with a transect interval of 14.8 km separated by a stratum with transects 7.4 km apart. A total of 395 frames were counted providing 1.8% coverage. The resulting pup production estimate was 370,258 (SE=45,250).

This estimate, however, is negatively biased. On 16 March a small group of seals was found outside of the survey area. This group, identified by the presence of dye on the ice and a short-range transmitter, was part of the Main patch during the visual survey on 12 March. The number of pups in this group could not be estimated but was thought to be relatively small, perhaps in the low hundreds.

The South patch was also surveyed on 16 March using three transects spaced 7.4 km apart (Table 5). The 93 Zeiss photographs covered 2.4% of the area. Pup production was estimated to be 114,167. Because the north-south extent of this patch was small in comparison to the transect spacing, extreme heterogeneity among transects resulted in a large standard error of 83,807.

Five (5) transects, spaced 3.7 km apart, were flown over the Belle Isle patch on 19 March (Table 6). A total of 96 frames was read. Coverage was estimated to be 4.6% and the estimate pup production was 6,162 (SE=1,404).

Photographic transects of the low density stratum were flown on 6 separate days between 13 and 28 March. Because of the extreme mixing and breaking up of the patches due to storms and high winds, the location of the patches could not be identified on the photographs taken. As a result, an estimate of pup production

based on these photographs includes both seals born in the concentrations and those which may have been born outside the patches.

Based on the flight lines and estimates of drift obtained from the satellite-linked beacon located in the Belle Isle patch, many of these lines overlapped. However, by matching lines and the relative locations of the beacon, transects flown on 13, 19, 20 and 25 March can be combined to give complete coverage of the entire survey area (Fig. 3). Combining these surveys, an independent, although rough, estimate of total pup production at the Front of 536,375 (SE=115,297) was obtained (Table 7).

Visual surveys

Three whelping patches were surveyed using visual techniques. On 12 March the Main patch was surveyed using two helicopters flying a total of 50 transects spaced 1.85 km apart (Table 8). Survey coverage was 2.3%. The results of one observer surveying the northern half were discarded due to difficulties maintaining the correct strip width. This resulted in a total survey strip width of 30 m. Checking strip widths following the survey indicated that the combined survey width for the two observers for the southern half of the patch was 65 m. The estimate of harp seal pups in the Main patch, uncorrected for the distribution of births, was 293,338 (SE = 19,460) and mean density was 394.0 pups/km^2 (SD=300.6).

The South patch was surveyed on 19 March. Because of its orientation, north-south transects were flown. The first 3 transects were spaced 2.2 km apart while remaining transects were spaced 3.3 km apart (Table 9). The combined survey area was 60 m per transect for a total coverage of 1.8%. The estimate of harp seal pups present was 114,685 (SE = 16,999).

Thirteen east-west transects, spaced 0.925 km apart, were flown over the Belle Isle patch (Table 10). Survey coverage was estimated to be 7.0%. Mean density of the South and Belle Isle patches were 524.0 pups/km^2 (SD=340.5) and 114.7 pups/km^2 (SD=117.7) respectively. The total estimate for the Belle Isle patch was 7,793 pups (SE = 1,438).

Developmental stage classifications

Because of the geographical separation of the whelping patches, developmental stage determinations of pups in the Main and South patches occurred early in the survey period while those in the Belle Isle patch were not done until later. Developmental stages of pups in the Main patch were estimated on 7, 10, and 15 March. Stage determinations of pups in the South patch were made on 11 and 17 March while pups in the Belle Isle patch were not staged until 19 and 26 March (Table 11).

Correction for temporal distribution of births

We fit the beta, Weibul, and log-logistic functions to the birthing distributions. The beta and Weibul provided similar fits (in terms of the maximum log-likelihood) while the log-logistic provided a much poorer fit. The results for the Weibul distribution are provided.

The stage classification in the Gulf population was extensive (Table 2). Based on the proportion of pups in each developmental stage, 97% of the pups were present during the survey, resulting in a corrected pup production of 106,300 (SE=23,000), rounded to the nearest 100 (Table 13). The model fit was good, and there appears to be little error in the survey caused by pups not being born at the time of the survey, or pups that had left the area.

No corrections could be made for the small Mecatina patch because of the lack of staging data. However, if the timing of pupping is similar to the main Gulf patch, this correction should be only a few percent.

Stage classifications at the Front were not as extensive as in the Gulf. Initially, we used the transition rates between stages as described in Myers and Bowen (1989) but they clearly did not fit the data. The duration between the pup stages were much longer than previously seen.

Unfortunatley, stage durations were not determined directly in 1990. However, they could be estimated from available data by using the assumption that the relative durations were the same between stages. A common factor can then be used to multiply all the stage durations. Two approaches were tried. First, we attempted to estimate this factor directly from the survey data, i.e. we added another parameter

to the likelihood. Second, this factor was estimated based on resightings of a known group of pups.

When another parameter was added to model to account for a long stage duration the fit of the model improved significantly, and was consistent with the data. It was found that if we assumed that the Myers and Bowen (1989) stage durations are 70% of those in 1990 then we obtained the best improvement.

We also resighted a small sample of known pups in 1990. On March 7 a radio transmitter was deployed on an ice pan, and the stages of pups on the ice pan recorded. One newborn, 10 yellow, and 15 thin white pups were counted. The transmitter was retrieved on March 16 and the pup stages again recorded: 1 newborn, 16 thin white, and 12 fat white pups. If all thin white pups were just one day old (the minimum age estimated previously) on March 7 and the stage durations used by Myers and Bowen (1989) are applicable to this population, then almost 50% of them should have been grey by March 16. Again, if we assumed that the Myers and Bowen (1989) stage durations are 70% of those in 1990, we n obtain a reasonable fit. Based on these two independent lines of evidence we uses the modified stage durations for the Front estimates.

The visual survey of the Main patch at the Front (March 12) resulted in an uncorrected estimate 292,338 (SE=19,460). An estimated 91% (S.E.= 2.5%) of the pups were present at the time of the survey. Correcting for pups not present resulted in a total estimate of 321,200 (SE=23,000), rounded to the nearest 100.

For the main Front patch the photographic survey (March 15/16) provided an uncorrected estimate of 370,258 (SE=45,250). Over 99% of the pups are estimated to be on the ice at this date, so no correction to this estimate was made.

In the South patch at the Front, the photographic survey (March 16) resulted in an uncorrected estimate of 114,167 (SE=83,807). We estimate that 83% (SE=3%) of the pups were present on that day, resulting in a corrected estimate of 137,600 (SE=101,100), rounded to the nearest 100. The uncorrected estimate provided by the visual survey on the same day was 114,685 (SE=16,999). Using the same correction factor (83% SE=3%) resulted in an estimate of 138,200 (SE=21,100), rounded to the nearest 100.

No corrections were made on the small Belle Island patch because of limited sampling. However, the March 19 survey estimates of 7,793 (SE=1,438) for visual and 6,162 (SE=1,404) for photo survey likely needs only a small correction because

they occurred later when nearly all pups should have been born.

The estimate of pups born in the whelping concentrations at the Front based on the visual surveys is 467,200 (SE=31,200). Based on the photographic surveys of the high density strata, 514,000 (SE=110,800) were estimated to have been born in the whelping patches. Because of the wide variety of assumptions necessary in obtaining the photographic estimate, the visual estimate is considered to be more reliable. Combining the visual survey estimates for the Front and the photographic surveys in the Gulf results in an estimated total pup production of 577,900 (SE=38,800).

Discussion

Although intuitively simple, there are several problems associated with aerial survey techniques. Pup production estimates based on such surveys may be biased if whelping concentrations are missed, the estimates are not corrected for pups born after the survey or which have left the ice, errors in counting pups on the photographs, or pups born outside of the concentrations are not surveyed (Myers and Bowen 1989). The survey design used in this study attempted to reduce the possible sources of bias by using a combination of visual and photographic techniques, extensive reconnaissance, coverage of areas outside of the whelping concentrations, and determining the temporal distribution of births.

The largest likely source of error is the failure to detect all of the whelping concentrations (Myers and Bowen 1989). To minimize this extensive reconnaissance was carried out. It is unlikely that any major patches were missed at the Front. Although the flight lines were spaced 18.5 km apart and, therefore, patches smaller than this could have been missed, multiple flights over the area as the ice drifted southward reduced this possibility. During a survey of harp seals in 1983, a whelping patch was found to the south of the main patches in the region of the Funk Islands (Wakeham, DFO, St. John's, pers. comm.). In 1990 ice in this area was considered unsuitable for seals. Futher, reports from local sealers indicated that no seals were found in the area until late April (W. Penney, DFO, St. John's, pers. comm.) suggesting that they did not whelp south of the Belle Isle patch. Pups were seen among a group of immature seals located east of the survey area but the low numbers seen (n=2) and lack of afterbirth suggest that they would not add significantly to the estimate.

In the Gulf, historical data indicates that a single large patch usually forms to

the northwest of the Magdalen Islands. As the season progresses this patch drifts to the east. Occasionally the patch divides into 2 or more smaller groups, which may continue out of the Gulf or pass down the west side and around the southern end of the Magdalen Islands. Reconnaissance surveys of the historical whelping areas located only a single patch in 1990. Although no extensive surveys were conducted to the west and southwest of the Magdalen Islands we believe that it is unlikely that whelping occurred in these areas, particularly given the ice and wind conditions encountered. The normal pattern of ice drift in these areas would likely bring animals close to the Magdalen Islands. No such groups were seen even though reconnaissance around the islands continued until late in the season. In addition, random flights to the south carried out during hooded seal research in late March failed to locate any harp seals.

Because harp seal births are usually spread over an extended period, it is likely that some pups will be missed on any survey because they had not been born or had left the ice. Bowen et al. (1987) presents a model designed to correct for missing hooded seal pups based on the proportion of pups in discrete age-dependent developmental stages. Myers and Bowen (1989) extend this model to harp seals based on data collected at the Front in 1983. Their findings showed that the optimum survey period for harp seals is relatively long (10-12 days) beginning around 10 March. Surveys outside of this period require corrections for missed pups which may reduce the reliability of the estimate. This 'window' is dependent upon the time of peak pupping which was estimated to occur between 7 and 8 March in 1983. With the exception of one survey, our estimates required little or no correction. Although the visual survey of the Main patch was conducted on 12 March which was within the optimum period in 1983, only an estimated 91% of the births had occurred. The staging data suggests that a large pulse of births had occurred around 12 March resulting in a much later peak pupping date. Peak pupping in the South patch occurred later and also showed large pulses of births.

The large proportion of thin whitecoats and lack of grey coats observed during the staging at the Main patch on the Front, are inconsistent with the Myers and Bowen (1989) data on stage duration. This probably cannot be accounted for by errors in staging (see Stenson and Myers 1988 for a discussion of the impacts). Standardization of observers, including one involved in the earlier study, was done in an attempt to reduce the probability of errors. A second possibility is that there was a change in stage durations from those previously estimated. Stewart (1987) found that attendance of female harps was reduced due to poor weather. In 1990, a number of storms occurred, including two days of strong winds between the day of the Main patch visual survey and the last day of staging in this patch. Since the difference between thin and fat whitecoats is related to weight gain, the relative duration of these two stages is likely influenced by the nursing rate of pups. If nursing

rate also influences the timing of the grey stage, it may account for the differences we observed. Alternatively, it is also possible that the duration of developmental stages are more variable than originally thought. The possibility of changes in stage durations should be examined during future surveys, especially at the Front.

A major error in aerial surveys is caused by the inability of the person to accurately count all of the animals present. The extent of possible bias or errors during the visual surveys will vary with survey altitude, strip width, flying speed, and observer experience (Caughley 1974, Caughley et al. 1976). To reduce the possibility of errors during our surveys, the observers underwent an extensive training period including flying a number of trial surveys prior to the actual surveys. We also lowered the flying altitude and narrowed the strip width to a point where the observers were confident that few pups were being missed. The close agreement in counts between observers on different sides of the helicopter as well as the similarity between visual and photographic estimates suggest that significant numbers of pups were not missed using visual techniques.

During aerial photographic surveys, it is often difficult to identify the animals present. This is particularly important when counting animals such white-coated harp seal pups on white ice. In an experiment to test the influence of camera systems and flying altitude on counts of harp seals, Ni et al. (1988) found that a significant number of pups may be missed on B&W imagery at 300 m. Alternately, small open areas of water or ice may be missidentified as pups. In order to improve the reliability of the counts, all of the readers, including those with previous experience, underwent extensive training prior to beginning their counts.

The presence of two camera systems (B&W and UV) operating simultaneously allowed us to estimate the proportion of pups misidentified during these surveys. Unlike the surrounding ice, harp seal pups absorb radiation in the ultra-violet wavelengths (300-400 nm) thus improving the visibility of the pups on the imagery (Lavigne 1976, Lavigne and Oritsland 1974, Reynolds and Lavigne 1981). By matching frames, two images obtained using different wavelengths could be compared. Although it is possible that pups could be missed on both film, the 'matched' count used for the reader error corrections should be a reasonable estimate of the actual numbers present. The different corrections required for the various readers indicates the importance of examining for individual biases among readers.

In the calibration literature regressing the 'matched' counts on the recorded counts is referred to as the 'inverse approach' (Krutchkoff 1967) with x for a given y estimated as $x = a + by$. It can be argued that, since the 'matched' counts are assumed to be correct, i.e. error free, one should regress y_i on x_i, i.e. $y_i = c + dx_i$

and estimate x for a given y and $(y-c)/d$. This is known as the 'classical approach' (Krutchkoff 1967). Krutchkoff (1967) concludes that the inverse approach has uniformly smaller mean square error than the classical approach. Martinelle (1970), however, states that this applies only for small samples. Both approaches are included in a recent study by Tracey and Srivastava (1990). It would appear that no approach is universally best and the conditions under which one is better than another are relatively complex. The inverse approach was used because it seemed the more logical in the present context.

The data used for the regression contained a high proportion of $(0,0)$ pairs. However the presence of pairs $(X,0)$ and $(0,Y)$, with $X > 0, Y > 0$ indicated that the regression should not be constrained to pass through the origin. All $(0,0)$ pairs were included in the regression to ensure that this 'correction' received the appropriate weight. This gives the possibility of conversion to negative 'true values' when the intercept, a, is estimated as negative. As this is biologically impossible, negative estimates of true counts were replaced by zero.

Pup production in the northwest Atlantic

The best estimate of pup production at the Front was obtained using the visual surveys. Using this technique, an estimate of 467,200 pups (SE=31,200) was derived for the three whelping patches at the Front (Table 12). The estimates are very similar to the photographic estimates for all three whelping concentrations. However, the visual surveys were considered to provide a more reliable estimate than the photographic surveys because of fewer assumptions which had to be made concerning ice drift and reader errors. They were also more precise (Table 12). Their agreement with the photographic estimates for all surveys does suggests that significant numbers of pups were not missed using visual techniques.

The survey of the low density stratum at the Front was designed to determine if a significant number of harp seals are born outside of the whelping concentrations. It has usually been assumed that the vast majority of pups are born within the whelping concentrations but this has not been carefully tested (Myers and Bowen 1989). Unfortunately, we were not able to determine the percentage of pups born outside of the whelping concentrations since the patches were broken up by a series of storms prior to the survey. The estimate of total Front production, including pups born outside of the whelping patches, derived from the low density transects (536,400, SE=115,300), rounded to the nearest 100, is not significantly different from those obtained from the visual (467,200, SE=31,200) and photographic surveys (514,000, SE=110,800) of the patches. This supports the theory that harp seals are

highly social animals with the majority of pups being born within the whelping concentrations and suggests that pup production at the Front in 1990 is in the order of 500,000 seals.

Historically, the ratio between pup production in the Gulf and at the Front has been assumed to be approximately 1:2 (Sergeant 1965). However, Winter (1978) estimated that between 1965 and 1977, the annual proportion of pup production accounted for by the Front varied from 49-87%. One year (1969) was considered to be unusual in that sparse ice formation in the Gulf was thought to have forced a large number of females from the Gulf to the Front (Winter 1978, Sergeant 1970). Even excluding 1969, however, Winters estimates that Front production accounted for 70 - 77 % in 3 of the 12 years which suggests that the ratio of Front to Gulf pups observered in 1990 (81%) is not unreasonable.

In summary, an estimated 577,900 (SE = 38,800) harp seal pups were born in the northwest Atlantic in 1990. This is based on an estimated 467,200 pups (Table 12) from the Front, 106,300 in the Gulf and 4,300 in the Mecatina patch (Table 13).

This study provides the first estimate of pup production in harp seals since the early 1980's. It is difficult to compare these results with earlier estimates, however, due to the different techniques used. Past estimates have been based on age-composition (Sergeant 1971, 1975; Benjaminsen and Oritsland 1975; Winters 1978; Roff and Bowen 1983, 1986, Cooke et al 1985) or mark recapture experiments (Bowen and Sergeant 1983, 1985). Each technique involves assumptions which may bias the estimates to different, and likely unknown, degrees. Prior to 1990, the Gulf and Front have not been surveyed satisfactorily in the same year using aerial survey techniques. If the proportion of pups born in each area varies among years, surveys conducted even in consecutive years cannot be combined for a comparable estimate.

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Table 1: Photographic survey of the Gulf harp seal whelping patch conducted on 8 March 1990.

Transect	Lat(°N)		Long(°W)	# Photos	No. of Pups	
	Begin	End			Count	Corrected
1	47°36′	47°25′	60°20′	15	0	2.22
2	47°35′	47°50′	60°28′	22	0	3.26
3	47°38′	47°31′	60°36′	15	0	2.22
4	47°44′	47°52′	60°44′	11	0	1.63
5	47°40′	47°50′	60°48′	14	0	2.07
6	47°42′	47°52′	60°52′	13	0	1.92
7	47°52′	47°41′	60°56′	13	6	10.90
8	47°43′	47°54′	61°00′	14	66	100.77
9	47°53′	47°41′	61°04′	13	220	330.91
10	47°43′	47°53′	61°08′	19	81	167.31
11	47°36′	47°52′	61°10′	23	218	329.40
12	47°51′	47°39′	61°12′	11	152	228.93
13	47°51′	47°36′	61°14′	21	279	420.33
14	47°36′	47°53′	61°16′	20	631	946.56
15	47°37′	47°48′	61°18′	15	202	304.29
16	47°55′	47°35′	61°20′	20	487	731.22
17	47°50′	47°37′	61°22′	19	22	35.71
18	47°48′	47°57′	61°24′	14	6	11.04
19	47°55′	47°44′	61°28′	19	137	207.68
20	47°46′	47°56′	61°32′	12	37	57.12
21	47°55′	47°46′	61°36′	10	6	10.45
22	47°45′	47°55′	61°40′	13	139	209.79
23	47°52′	47°45′	61°44′	10	0	1.48
24	47°45′	47°53′	61°48′	31	48	76.37
25	47°51′	47°45′	61°52′	19	405	608.45
26	47°40′	47°52′	61°56′	52	22	40.60
		TOTALS		458	3164	4842.63

Table 2: Numbers of harp seal pups in individual age-dependent stages at the Gulf during 1990.

Date	Stage 1	2	3	4	5	6	7	Total
Feb 22	0	2	0	0	0	0	0	2
25	0	0	3	0	0	0	0	3
26	0	14	71	0	0	0	0	85
27	0	0	8	1	0	0	0	9
Mar 1	10	83	471	54	0	0	0	618
2	0	22	166	1	0	0	0	189
4	5	48	407	61	0	0	0	521
6	0	3	15	10	0	0	0	28
8	0	9	58	92	0	0	0	159
10	0	0	18	177	16	0	0	211
11	0	11	118	318	190	8	0	645
19	0	0	0	7	15	7	2	31

Table 3: Photographic survey of the Mecatina patch conducted on 14 March 1990.

Transect	Lat(°N)	Long(°W) Begin	Long(°W) End	# Photos	No. of Pups Count	No. of Pups Corrected
1	50°01′	58°58′	59°05′	16	103	68.39
2	50°02′	59°05′	58°58′	15	156	104.42
3	50°03′	59°05′	58°57′	14	22	14.53
4	50°04′	58°58′	59°05′	15	551	372.16
5	50°05′	58°58′	59°05′	15	297	200.42
6	50°06′	59°05′	58°58′	13	160	107.72
			TOTAL	88	1289	867.64

Table 4: Photographic survey of the Main Front patch conducted on 15/16 March 1990.

Transect	Lat(°N)	Long(°W)		# Photos	No. of Pups	
		Begin	End		Count	Corrected
1	52°24′	53°30′	53°54′	23	625	421.66
2	52°30′	52°41′	53°24′	31	557	375.07
3	52°32′	53°54′	53°30′	17	213	143.36
4	52°40′	53°30′	53°54′	22	464	313.37
5	52°48′	53°54′	53°30′	21	526	355.12
6	52°56′	53°15′	54°00′	49	1067	719.53
7	53°00′	53°30′	53°56′	34	73	47.46
8	53°08′	54°06′	53°30′	35	619	416.92
9	53°16′	54°10′	53°30′	40	459	308.42
10	53°20′	53°34′	54°14′	45	435	292.83
11	53°24′	54°16′	54°00′	15	294	197.89
12	53°28′	54°00′	54°16′	17	521	352.02
13	53°32′	54°16′	54°00′	14	642	433.97
14	53°36′	54°00′	54°16′	19	659	445.11
15	53°40′	54°16′	54°00′	13	1243	841.58
			TOTAL	395	8397	5664.30

Table 5: Photographic survey of the South Front patch conducted on 16 March 1990.

Transect	Lat(°N)	Long(°W)		# Photos	No. of Pups	
		Begin	End		Count	Corrected
1	52°50′	54°46′	54°14′	25	227	151.79
2	52°54′	54°46′	54°14′	32	3536	2394.66
3	52°58′	54°14′	54°46′	16	458	307.26
			TOTAL	93	4221	2853.71

Table 6: Photographic survey of the Belle Isle patch conducted on 19 March 1990.

Transect	Lat(°N)	Long°W		# Photos	No. of Pups	
		Begin	End		Count	Corrected
1	51°12′	52°10′	52°30′	27	54	34.77
2	51°14′	52°30′	52°10′	14	116	77.59
3	51°16′	52°30′	52°10′	14	64	42.33
4	51°18′	52°10′	52°30′	27	90	58.89
5	51°20′	52°30′	52°10′	14	61	40.01
			TOTAL	96	385	253.59

Table 7: Estimates of Front harp seal pup production based on low density strata.

Date	No. of Transects	N	SE
March 13	3	16,897	5,600
March 19/20	7	485,841	113,521
March 25	2	33,637	19,360
TOTAL	12	536,375	115,297

Table 8: Visual survey of harp seal pup production in the Main Front patch on 12 March 1990. Strip width = 30 m for transects 1-22 and 65 m for the remaining transects.

Transect	Lat(°N)	Long(°W)		Distance (km)	No. of Pups
		Begin	End		
1	54°26′	54°09.0′	54°11.4′	2.58	31
2	54°25′	54°09.3′	54°13.7′	4.74	34
3	54°24′	54°10.5′	54°12.3′	1.94	33
4	54°23′	54°11.7′	54°13.4′	1.83	19
5	54°22′	54°06.1′	54°14.8′	9.38	62
6	54°21′	54°08.0′	54°16.1′	8.73	156
7	54°20′	54°07.7′	54°15.4′	8.31	177
8	54°19′	54°05.8′	54°18.4′	13.59	90
9	54°18′	54°07.0′	54°20.0′	14.04	43
10	54°17′	54°07.0′	54°20.5′	14.58	143
11	54°16′	54°07.0′	54°19.0′	12.97	132
12	54°15′	54°07.1′	54°20.1′	14.05	277
13	54°14′	54°07.5′	54°20.8′	14.38	434
14	54°13′	54°08.0′	54°20.0′	12.98	324
15	54°12′	54°09.0′	54°19.1′	10.93	94
16	54°11′	54°08.3′	54°13.0′	5.09	17
17	54°10′	54°08.4′	54°15.5′	7.69	38
18	54°09′	54°08.0′	54°18.7′	11.59	21
19	54°08′	54°06.7′	54°19.8′	14.20	17
20	54°07′	54°07.3′	54°22.4′	16.37	40
21	54°06′	54°06.0′	54°21.0′	16.27	48
22	54°05′	54°06.5′	54°23.0′	17.91	64
23	54°04′	54°05.5′	54°20.0′	15.74	271
24	54°03′	54°04.7′	54°21.6′	18.36	368
25	54°02′	54°04.4′	54°19.1′	15.97	549
26	54°01′	54°03.4′	54°25.7′	24.24	556

Table 8 continued...

Transect	Lat(°N)	Long(°W)		Distance (km)	No. of Pups
		Begin	End		
27	54°00′	54°02.5′	54°30.5′	30.45	450
28	53°59′	54°02.1′	54°25.6′	25.57	601
29	53°58′	54°01.9′	54°20.2′	19.92	369
30	53°57′	54°01.7′	54°03.5′	1.96	82
31	53°56′	54°00.0′	54°03.5′	3.81	145
32	53°55′	53°59.5′	54°01.8′	2.51	158
33	53°54′	53°58.2′	54°01.5′	3.59	248
34	53°53′	53°57.0′	54°00.4′	3.71	197
35	53°52′	53°55.8′	53°59.3′	3.82	209
36	53°51′	53°54.0′	53°58.3′	4.69	156
37	53°50′	53°53.0′	53°58.0′	5.46	224
38	53°49′	53°52.0′	53°56.7′	5.13	151
39	53°48′	53°50.0′	53°55.0′	5.46	104
40	53°47′	53°48.6′	53°52.4′	4.15	80
41	53°46′	53°47.5′	53°52.9′	5.91	95
42	53°45′	53°46.0′	53°51.3′	5.79	56
43	53°44′	53°45.3′	53°49.7′	4.82	70
44	53°43′	53°43.2′	53°48.4′	5.69	73
45	53°42′	53°42.9′	53°47.7′	5.25	48
46	53°41′	53°42.5′	53°44.0′	1.64	20
47	53°40′	53°41.7′	53°43.5′	1.97	30
48	53°39′	53°41.5′	53°42.5′	1.09	6
49	53°38′	53°39.9′	53°43.0′	3.40	3
50	53°37′	53°39.8′	53°41.0′	1.32	6
			TOTAL		7619

Table 9: Visual survey of harp seal pup production in the South Front patch on 16 March 1990. Strip width = 60 m.

Transect	Lat(°N)		Long(°W)	Distance (km)	No. of Pups
	Begin	End			
2	53°01.0′	52°53.0′	54°15.0′	14.80	239
3	52°54.8′	52°59.0′	54°17.0′	7.77	377
4	52°57.8′	52°54.0′	54°20.0′	7.03	104
5	52°54.8′	52°56.6′	54°23.0′	3.33	233
6	52°57.4′	52°54.0′	54°26.0′	6.29	294
7	52°53.8′	52°57.4′	54°29.0′	6.66	362
8	52°56.8′	52°52.0′	54°32.0′	8.88	353
9	52°53.0′	52°56.8′	54°35.0′	7.03	207
10	52°55.1′	52°52.7′	54°38.0′	4.44	23
11	52°53.9′	52°55.2′	54°41.0′	2.401	4
			TOTAL		2196

Table 10: Visual survey of harp seal pup production in the Belle Isle patch on 19 March 1990. Strip width = 65 m.

Transect	Lat(°N)	Long(°W)		Distance (km)	No. of Pups
		Begin	End		
1	51°11.0′	52°12.4′	52°13.5′	1.28	5
2	51°11.5′	52°12.5′	52°16.0′	4.06	6
3	51°12.0′	52°11.9′	52°21.0′	10.55	1
4	51°12.5′	52°21.0′	51°17.0′	4.64	6
5	51°13.0′	52°17.9′	52°21.0′	3.59	18
6	51°13.5′	52°19.8′	52°16.5′	3.82	18
7	51°14.0′	52°16.3′	52°19.9′	4.17	103
8	51°14.5′	52°14.0′	52°20.0′	6.95	154
9	51°15.0′	52°14.1′	52°20.1′	6.95	54
10	51°15.5′	52°13.4′	52°18.8′	6.25	48
11	51°16.0′	52°16.3′	52°12.0′	4.98	55
12	51°16.5′	52°11.0′	52°15.6′	5.32	58
13	51°17.0′	52°14.6′	52°09.7′	5.67	21
			TOTAL		547

Table 11: Numbers of harp seal pups in individual age-dependent stages at the Front during 1990.

Date	Patch	Stage							Total
		1	2	3	4	5	6	7	
Mar 7	Main	20	70	249	0	0	0	0	339
8		0	2	19	0	0	0	0	21
9		1	0	29	0	0	0	0	30
10		23	19	428	0	0	0	0	470
15		1	0	489	99	5	0	0	594
16		1	0	37	77	0	0	0	115
12	South	23	42	67	0	0	0	0	132
17		1	11	605	0	0	0	0	617
19	Belle Isle	0	0	388	45	6	0	0	439
26		0	0	0	17	159	8	0	184

Table 12: Comparison of visual and photographic survey estimates of harp seal pup production in the Front patches, March 1990. Estimates corrected for birthing distribution where appropriate and rounded to the nearest 100.

	Visual		Photo	
Patch	N	SE	N	SE
Main	321,200	23,000	370,300	45,300
Southern	138,200	21,100	137,500	101,100
Belle Isle	7,800	1,400	6,200	1,400
TOTAL	467,200	31,200	514,000	110,800

Table 13: Estimated harp seal pup production in the Gulf of St. Lawrence based on Zeiss photographic imagery obtained at 300 m. Estimates corrected for birthing distribution where appropriate and rounded to the nearest 100.

Patch	No. of Pups	SE
Gulf (Magdalen)	106,300	23,000
Mecatina	4,400	1,300
TOTAL	110,700	23,000

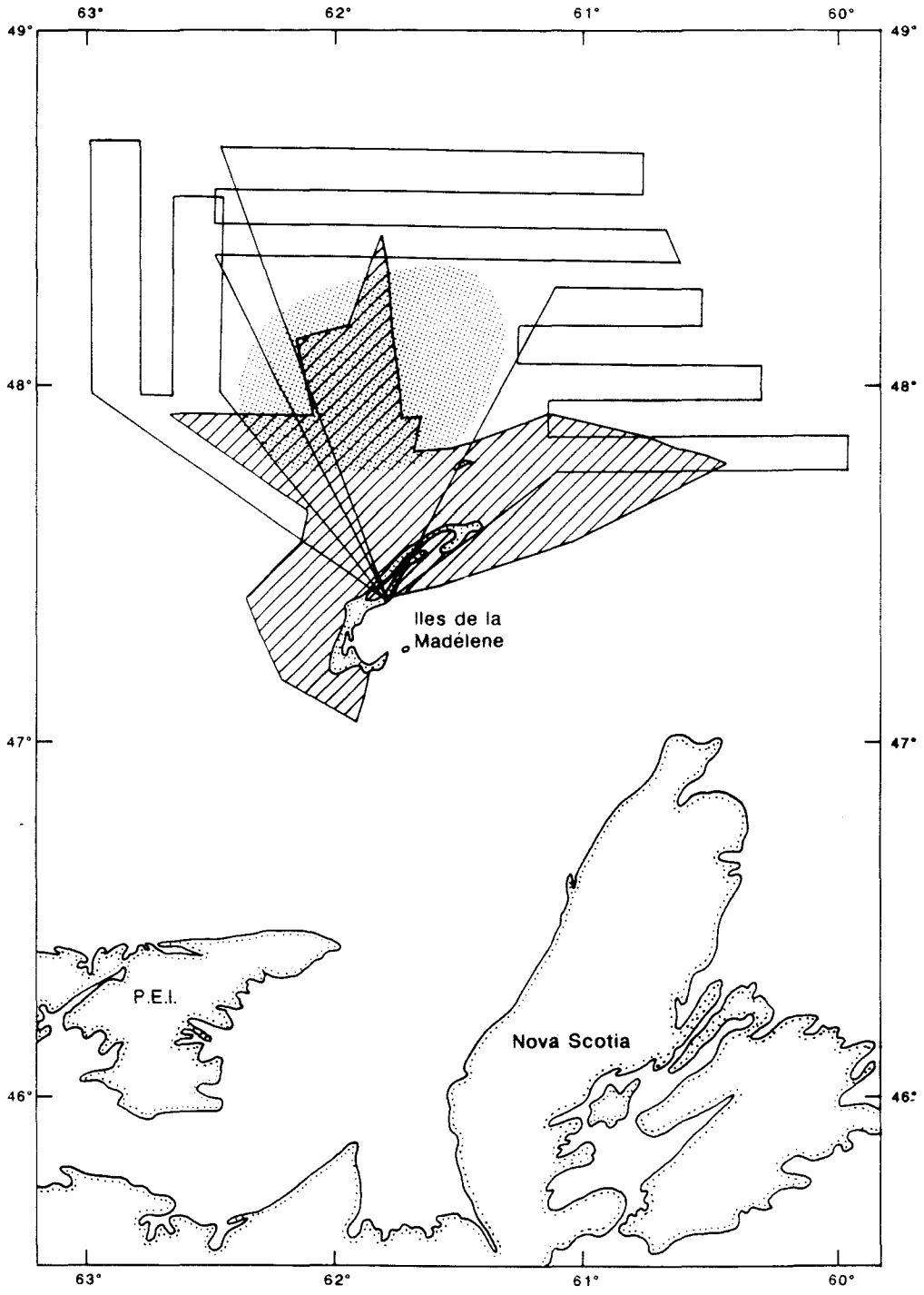

Figure 1: Reconnaissance surveys conducted in the Gulf of St. Lawrence during March 1990. Solid lines indicate flights conducted by fixed-wing aircraft; dashed lines outline the area surveyed by helicopter; hatched areas indicate the position of the harp seal whelping concentration on 8 March.

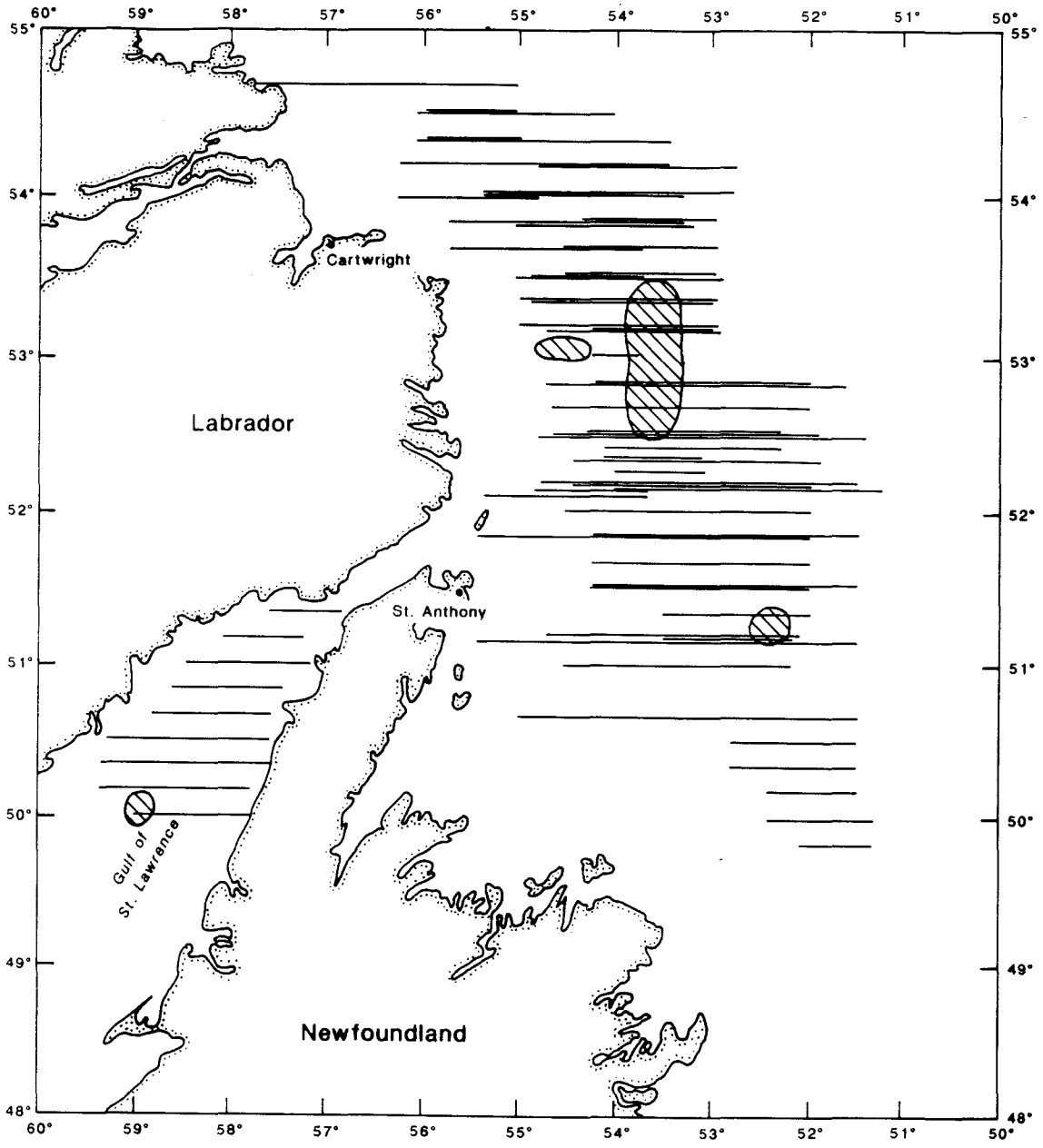

Figure 2: Aerial reconnaissance surveys conducted at the Front and northeastern Gulf of St. Lawrence during March 1990. The hatched lines indicate positions of harp seal whelping patches when first discovered.

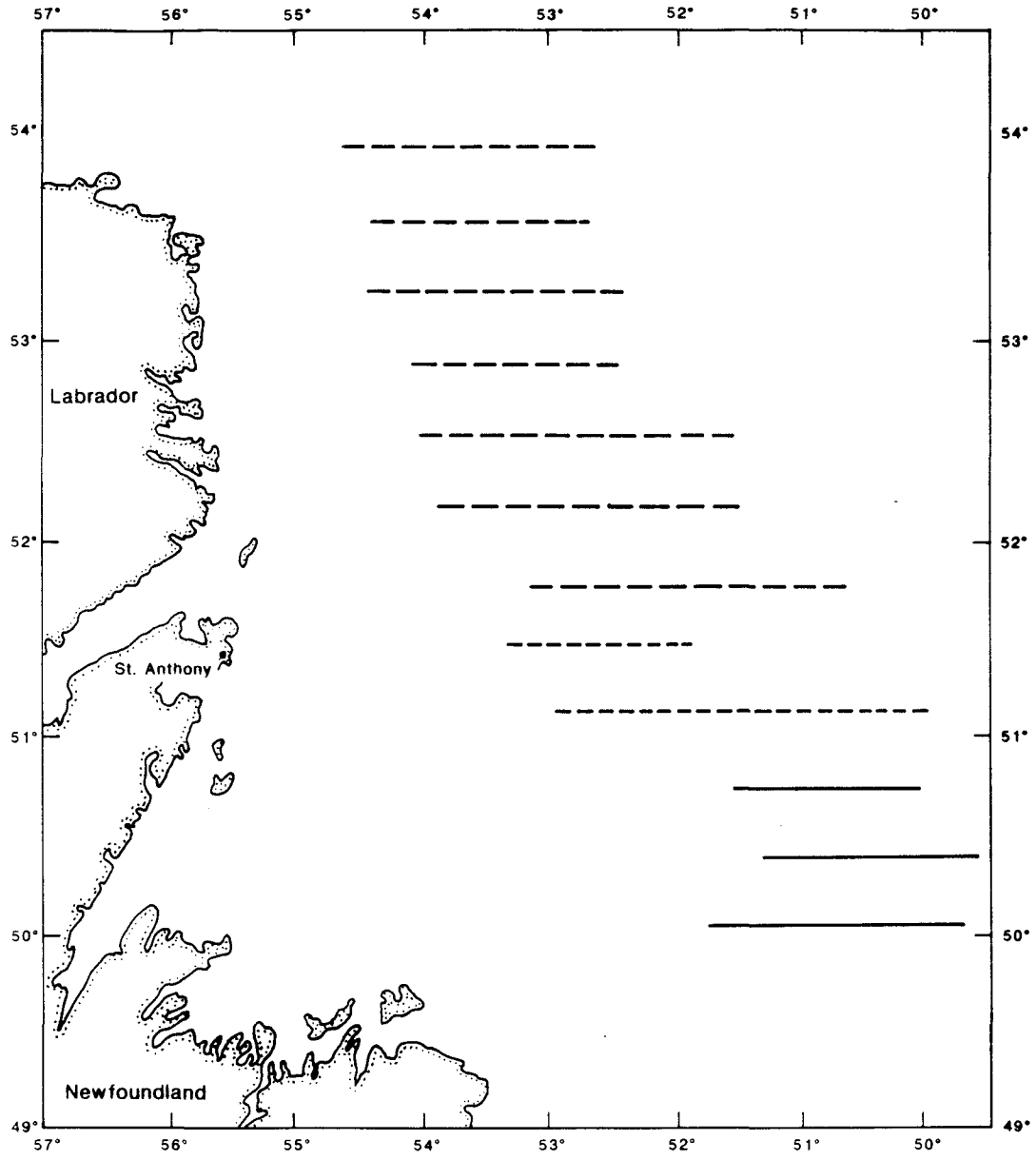

Figure 3: Relative positions of low density photographic transects flown on 13 (solid), 19, 20 (large dash) and 25 (small dash) March providing complete coverage of the survey area as estimated on 25 March, 1990. Transect lines shown are based on drift of a satellite-linked transmitter located in the southern region of the survey area.