International Council for the Exploration of the Sea ICES CM2005/R:06
Annual Science Conference
September 20 – 24, 2005
Aberdeen, Scotland

Estimating Abundance of Seals in a Drifting Environment: 2005:

Pup Production of Harp Seals, *Pagophilus groenlandicus*,

in the Northwest Atlantic

G.B. Stenson[1], M.O. Hammill[2], J. Lawson[1]
J.F. Gosselin[2] and T. Haug[3]

[1]Department of Fisheries & Oceans,
Science Branch, P.O. Box 5667
St. John's, Newfoundland, Canada A1C 5X1

[2]Department of Fisheries & Oceans,
Science Branch P.O. Box 1000
Mont Joli, Quebec, Canada G5H 3R4

[3] Institute of Marine Research Tromsø,
Forskningsparken, N-9291
Tromsø, Norway

ABSTRACT

Photographic and visual aerial surveys to determine current pup production of northwest Atlantic harp seals were conducted off Newfoundland and Labrador (the "Front"), and in the Gulf of St. Lawrence during March 2004. Surveys of four whelping concentrations were conducted between 5 and 18 March resulting in estimated pup production of 640,800 (SE=46,900, CV=7.3%) at the Front, 89,600 (SE=22,500, CV=25.4%) in the northern Gulf, and 261,000 (SE=25,700, CV=9.8%) in the southern Gulf (Magdalen Island), for a total of 991,400 (SE=58,200, CV=5.9%). Surveys were corrected for the temporal distribution of births and the mis-identification of pups by readers. Comparison with previous estimates indicates that pup production has not changed since 1999, likely due to the increased hunting of young animals which began in the mid 1990s.

Key words: harp seal, *Pagophilus groenlandicus*, pup production, survey, abundance, birth distribution, northwest Atlantic

INTRODUCTION

Harp seals, *Pagophilus groenlandicus*, are the most abundant pinniped in the northwest Atlantic. Population size in harp seals is estimated using a model that incorporates information on pup production, removals from the population, and variations in age-specific reproductive rates (Healey and Stenson 2000). Prior to 1990, annual pup production was estimated using a variety of methods (Sergeant 1975; Benjaminsen and Øritsland 1975; Winters 1978; Cooke 1985; Lavigne *et al.* 1982; Bowen and Sergeant 1983). A review of the different estimates concluded that pup production in 1978 was in the order of 300,000-350,000 (Anon. 1986). Since 1990, aerial surveys have been flown to determine pup production of northwest Atlantic harp seals at 4 to 5 year intervals. These surveys have resulted in estimates of 577,900 (SE=38,800, CV=6.7%; Stenson *et al*. 1993), 708,400 (SE=67,200, CV=9.5%; Stenson *et al*. 2002), and 997,900 (SE=102,100, CV=10.2%; Stenson *et al*. 2003) in 1990, 1994, and 1999, respectively.

Northwest Atlantic harp seals are hunted throughout their range for commercial and subsistence needs. The commercial harvest of harp seals in Canadian waters began in the 1700s. In 1971, the Canadian Government introduced the first quotas to limit the hunt. Throughout the mid to late 1970s, catches in Greenland and Canada ranged from 156,000 – 191,000 (Stenson *et al*. 2000). Although Greenland catches increased, overall catches fell to 50,000 to 60,000 animals in the mid 1980s due to a decline in Canadian catches as a result of the ban on the importation of whitecoat pelts into the European Economic Community. In 1996, Canadian catches increased significantly due to a renewed interest in seal pelts. Since then, reported catches in Greenland and Canada have remained over 350,000 animals (Stenson *et al*. 2000) making this the largest marine mammal harvest in the world (Stenson *et al*. 2003).

Healey and Stenson (2000) estimated that the northwest Atlantic harp seal population increased in abundance from the early 1970s through to the mid 1990s. In the late 1990s however, the population stabilized, primarily due to increased catches in Canada and Greenland. In contrast, pup production continued to increase up to 1999 (Stenson *et al*. 2003). Because harvests in the past decade were primarily young of the year (Stenson *et al*. 2000), the impact of these catches on pup production was unlikely to be detected until after 2001 when these year classes begin to mature (Stenson *et al*. 2003).

In Canada, the current commercial harvest is regulated under a three year management plan (Anon. 2003) which ends in 2005. Under this plan, the Canadian Total Allowable Catch (TAC) was 975,000 over three years, with an annual TAC of up to 350,000 in any two years. Here we estimate the number of harp seal pups born in 2004. This information will allow us to determine the impact of recent harvests on pup production. It also forms part of the scientific advice process that will be input to the development of a new multi-year management plan.

METHODS

Identification of Whelping Areas

Whelping concentrations ("patches") off the southern Labrador-northeast coast of Newfoundland (Front) and in the Gulf of St. Lawrence (Gulf) were located using fixed-wing and helicopter reconnaissance surveys of areas historically used by harp seals. Within these areas, reconnaissance flights covered all the grey-white (thickness 15-30 cm) to medium first-year (thickness 70-120 cm) ice with water leads, suitable for harp seal whelping. At the Front and in the northern Gulf, fixed-wing reconnaissance flights were conducted almost daily from 5 to 20 March 2004 (Fig. 1). Repeated systematic east-west transects, spaced 18.5 km apart, were flown at an altitude of 230 m from the coastal edge of the ice pack to the seaward edge between 49^0 30'N and 54^0 40'N at the Front and between the Strait of Belle Isle (~50^0 50'N) and 49^0N in the northern Gulf.

In the southern Gulf, reconnaissance surveys of areas traditionally used by harp seals were flown 28 February to 21 March (Fig. 1). There was no ice present around the Magdalen Islands, so repeated flights were made along Prince Edward Island's north and west shores. Surveys were also carried out westward towards New Brunswick and to the east along the Cape Breton Coast. The northern edge of each transect was determined by the availability of suitable ice. Commercial helicopters involved in seal tourism around the Magdalen Islands also provided information on the location of whelping seals.

All areas were surveyed repeatedly to minimize the chance of missing whelping (pupping) concentrations. Once whelping seals were located, VHF and/or satellite transmitters were deployed onto the ice within each concentration to monitor their movements as the pack ice drifted during the survey period.

Estimates of Abundance

<u>Visual Surveys</u>

Visual aerial surveys were flown, using one helicopter in the Gulf and two helicopters at the Front, at an altitude of 45.7 m. Two observers seated in the rear counted all pups within a pre-defined visual area on each side of the aircraft. In the Gulf, the total strip width was 60 m while at the Front it was 40 m. Correct altitude and transect spacing were maintained using a radar altimeter and GPS navigation systems. Surveys in the southern Gulf were conducted on March 5 and 10 while surveys at the Front were carried out on March 15 and 18. No visual surveys took place in the northern Gulf.

<u>Photographic Surveys</u>

Fixed-wing aerial photographic surveys were flown using two twin-engined aircraft (Piper Aztec) each equipped with a 23 × 23 cm format metric mapping camera (Zeiss RMK/A) with a motion compensation mechanism and shooting Kodak Double-X (2405, ISO A4000) aerographic black-and-white film. The cameras were fitted with a 150 mm Sonnar lens, and surveys were conducted at an altitude of 184.5 m. The images covered an area of 274.3 × 274.3 m per photo. The surveys were designed to provide over 90% coverage along a transect line with no photographic frame overlap. Due to changes in wind conditions, percentage of photographic coverage was estimated and considered in the estimation of pup counts for each line. When photographs overlapped slightly along some transects, pups in the area overlapping with the previous frame were excluded from the frame count prior to the analysis.

Cameras were turned on before seals were encountered on a transect line and turned off if no seals were observed for an extended period along a transect line or open water was encountered. An observer with a forward view ensured that the cameras were turned on before seals or suitable ice were encountered again. Most of the transects ended when land was encountered or suitable ice was no longer available. Some transects ended earlier if seals had not been encountered for an extended period and no seals were present on adjacent transects. However, in these cases, flights were continued for at least 8 km to ensure no more seals were present further along the transect line. Correct altitude and transect spacing was maintained using barometric altimeters and GPS navigation systems aboard the aircraft.

Photographs were examined by six readers following an initial training period. On each photograph the position of each pup was recorded on a clear acetate overlay (Front), or was electronically geo-referenced and recorded (southern Gulf). After all photographs were examined, each reader re-read a series of the photographs in sequence. Readings of photographs continued until the counts from the first and second readings differed by less than 5%. If pup counts differed by more than 5%, the counts from the first reading were replaced by those from the second reading.

To correct for reader errors, a series of 50 randomly-selected frames from each concentration was examined by all readers and compared to determine a "best estimate" of the number of pups present. The original pup counts (t) were regressed on the "best estimate" (y) to determine a correction factor for each survey and reader. If the intercept was not significantly different from zero, the regression was repeated assuming no intercept. The corrected counts for each photograph were summed to obtain the corrected count for each transect (x_j).

The measurement error associated with variation about the regression (V_{photo}) was estimated for each photograph using:

$$V_{photo\ j} = \sum_{z=1}^{Z} (V_{intercep} + (V_{slope} \times t_{jz}^{2}))$$

where:
t=the uncorrected number of pups on photo z of transect j;
j=transect number; and
Z=the number of photos on the transect.

Survey Analysis

Both visual and photographic surveys were based on a systematic sampling design with a single random start and transects of variable length as sampling units. Pup production was estimated using the methods outlined in Stenson *et al*. (1993, 2002, 2003) and are briefly described here. The number of pups for the i^{th} survey was estimated by:

$$N_i = k_i \sum_{j=1}^{J_i} x_i$$

where:
J_i=the number of transects in the i^{th} survey;
k_i=weighting factor for the i^{th} survey determined by dividing the transect interval by the transect width; and
x_j=the number of pups on the j^{th} transect.

For photographic surveys where frames did not overlap:

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

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

The estimates of sampling variance, based on serial differences between transects (Kingsley *et al*. 1985), were calculated as:

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

If transect spacing changed within the survey area, each area of homogeneous transect spacing was treated as a separate survey with the estimated number of pups given by:

$$N_i = k_i \left[x_{i1}/2 + \sum_{j=2}^{J_i - 1} x_{ij} + x_{iJ_i}/2 \right]$$

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.

The variance estimate was given by:

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

The variance associated with the mis-identification corrections ($Vphoto_j$) was summed over transects and multiplied by the weighting factor (k_i) to estimate the total measurement error for the survey, and added to the sampling variance (Vs_i) to obtain the variance of a given survey (V_i):

$$V_i = Vs_i + k_i \sum_{j=1}^{J_i} V_{photo_j}$$

Estimates from two surveys of the same area were combined using:

$$N_i = ((N_1 \times V_2) + (N_2 \times V_1)) / (V_1 + V_2)$$

and its error variance by:

$$V_i = (V_1 \times V_2) / (V_1 + V_2)$$

Estimates of the number of pups in each concentration can be corrected for pups born after the survey was flown by:

$$N_i = N_{uncor} / P_i$$

where:
N_{uncor}= the estimate uncorrected estimate for the birthing ogive survey *i*; and
P_i=the proportion estimated to have been born prior to survey *i*.

The estimates of N_{uncor} and P_i are independent and therefore the error variance of the quotient is given by (Mood *et al.* 1974):

$$V_i = N_{uncor}^2 \times V_p / P_i^4 + V_n / P_i^2$$

where:
V_p=the variance in the proportion estimated to have been present prior to survey *i*;
V_n=the variance in the uncorrected estimate for survey *I*.

The total population was estimated as $\hat{N} = \sum_{i=1}^{I} N_i$ and its error variance $\hat{V} = \sum_{i=1}^{I} V_i$ where *I* is the number of surveys.

Temporal Distribution of Births

To correct the estimates of abundance for pups that were not yet born at the time of the survey, it was necessary to estimate the temporal distribution of births over the pupping season. The proportion of pups in each of six age-dependent morphometric and pelage specific stages was determined repeatedly throughout the whelping period using visual assessments (Stenson *et al*. 1993, 2002, 2003). A series of random, low-level (<10 m altitude) helicopter surveys were flown over each whelping concentration during which pups were classified as Newborn, Yellow, Thin Whitecoat, Fat Whitecoat, Raggedy-jacket, or Beater (Stewart and Lavigne 1980). Due to the extremely short duration and subsequently small number of pups observed in the Newborn and Yellow stages these two categories were combined into a single group called Newborn. The change in proportion of Newborn, Thin Whitecoat and Fat-Whitecoat pups over time was used to estimate the distribution of births. Stage durations for Newborns (μ=2.40 d, SE=0.048, *n*=106), Thin Whitecoats (μ=4.42 d, SE=0.138, *n*=26), and Fat Whitecoats (μ=11.39 d, SE= 0.186, *n*=80) were obtained from Kovacs and Lavigne (1985).

The distribution of births was determined based on the assumption that the timing of births followed a normal distribution. The approach is described in detail by Stenson *et al.* (2003), and the algorithm we implemented using SAS IML (code can be obtained at: http://www.mat.ulaval.ca/pages/scs/gd/macro_sas.html.).

RESULTS

Identification of Whelping Areas

Mild winter conditions limited the amount of ice suitable for harp seals in the southern Gulf to the north shore of Prince Edward Island and Northumberland Strait. Reconnaissance flights in the Gulf located harp seals off the north shore of Prince Edward Island.

Three whelping concentrations were located at the Front. The first was located off Cartwright, Labrador (53^{0} 32'N 55^{0} 36'W) on March 6. The second was found off the coast of southern Labrador (52^{0} 17'N 55^{0} 25'W) near Belle Isle. A third group was located in the northern Gulf of St. Lawrence at 50^{0} 30'N 58^{0} 10'W. Strong winds resulted in considerable ice movement during the study period. However, the movements of the concentrations were monitored through the use of nine VHF and two satellite transmitters deployed on the ice within the seals.

Photographic and Visual Surveys of Pup Production

Reader Corrections

Correction factors were developed for all readers. The regressions of the "best estimates" on the individual reader counts were significant. In the southern Gulf, the fit to the regressions was very poor and the corrections were quite large, with slopes ranging from 1.22 to 4.0 (Table 1). Corrections were much smaller for the three people reading photographs from the Front and northern Gulf (Table1).

Southern Gulf

In the southern Gulf, the herd was delimited and practice visual and photographic flights were conducted on 4 March. Visual surveys were flown on 5 and 10 March (Tables 2, 3). Overall, more pups were counted on the visual surveys than on the photographic surveys in spite of the much smaller strip width (visual=60 m, photographic=274.3 m). A total of 3,331 pups were counted on the 21 transects flown on 5 March (Fig. 2) and 2,224 pups were counted on the 18 transects flown on 10 March (Fig. 3). Visual estimates from the two surveys were 281,254 (SE=36,252) and 236,809 (SE=36,370) pups for 5 and 10 March, respectively.

A photographic survey was flown on 5 March. For the photographic survey, a total of 1,439 pups and 11,486 adults were counted on 1,130 photographs taken along the 18 transects (Tables 4 and 5, Fig. 4). After applying the reader correction to the photographic counts for mis-identifed pups, this total increases to 4,467 animals. Extrapolating along, and between, transects, results in an estimate of 113,570 (SE=6,397) pups and 263,671 (SE=48,735) adults.

Front

Following several practice runs, a visual survey of the Belle Isle concentration was flown on March 15 (Table 6, Fig. 5). A total of 31 east-west transects were flown with transect spacing of either 1.85 km (transects 10-20) or 3.7 km (transects 1-10, 20-21). A total of 4,083 pups were counted resulting in an estimated pup production of 316,234 (SE=47, 479).

A photographic survey of the Belle Isle concentration was carried out on March 15 (Fig. 6). This survey covered the area to north of Cape Bauld and into the Strait of Belle Isle. However, the entire concentration could not be covered in a single day and, after correcting for ice drift, the area south east of Cape Bauld was surveyed on March 16. Combining these two surveys, 14,505 pups were counted on 3,927 photographs taken along 31 transects (Table 7). Correcting for mis-identified pups resulted in a total of 14,023 pups and a total estimated pup production of 252,149 (SE=31,893).

Combining the visual and photographic estimates resulted in a combined estimated pup production in the Belle Isle concentration of 272,074 (SE=26,474).

A visual survey of the northern (Cartwright) concentration was carried out on March 18 (Fig. 7). By this time the northern harp seal concentration had drifted south to the area previously occupied by the southern concentration three days earlier. A total of 3,986 pups were counted on 29 transects flown 3.7 km apart (Table 8). Pup production in this group was estimated to be 368,705 (SE=38,754).

A photographic survey of the Cartwright concentration was attempted on March 18 (Table 9). However, matching the transect lines flown to those obtained during the visual surveys and the locations of the VHF transmitters indicated that significant portions of the concentration were not included in the photographic survey.

<u>Northern Gulf</u>

A photographic survey of the northern Gulf (Mecatina) whelping concentration was successfully completed on 17 March (Fig 8). The survey consisted of 15 east –west transects spaced at 5.6 km (transects 1-4), 1.85 km (transects 4-9) or3.7km (transects 9-15) apart (Table 10). A total of 5,998 pups were identified on 1,341 photographs. Correcting for mis-identified seals resulted in a corrected count of 6,083 pups. The resulting estimate of pup production for this concentration was 89,617 (SE=22,815).

Modelling the Temporal Distribution of Births

Estimates of the proportion of pups in each of the developmental stages were obtained from the southern Gulf and Front whelping patches, but stage surveys were not conducted over animals born in the northern Gulf (Table 11). In the southern Gulf, six stage surveys were completed over the single patch of animals located. At the Front, five stage surveys were completed for each of the two patches located.

Modelling the temporal distribution of births indicated that a small correction for pups that were born after the survey period should be applied to the results of the 5 March survey in the southern Gulf (Table 12). An estimated 0.987 (SE=0.015) of the pups were present on the ice at the time of the survey. By 10 March, when the second survey was carried out, all of the pups had been born. Similarly, all pupping had been completed by the time the surveys were carried out at the Front (Table 12).

No data were available to determine the timing of births in the northern Gulf. However, timing of pupping in this area appears to be similar to that of the Front (Stenson, pers. obs). Considering that all pupping had occurred in the other areas prior to 17 March when the survey was carried out, it is unlikely that any correction for late pupping would be required.

Estimating Total 2004 Pup Production

Adjusting the 5 March survey estimate in the southern Gulf to take into account births that had occurred after the survey resulted in a visual estimate of 284,959 (SE=36,252), and a photographic estimate 124,409, harp seal pups (SE=6,878, CV=6%)

(Table 13). However, due to concerns over the photographic estimates (see below) it was not used to determine pup production in the southern Gulf. Combining the 5 March visual survey with the 10 March estimate (236,809, SE= 36,370) resulted in a pup production estimate of 260,962 (SE=25, 676) in this concentration.

Based upon surveys of the Belle Isle (272,074, SE=26,474) and Cartwright (368,705, SE=38,754) concentrations, pup production at the Front was estimated to be 640,779 (SE=46,933). Combining these estimates with those of the northern (89,617, SE=22,815) and southern Gulf result in an estimate of total harp seal pup production in the northwest Atlantic (rounded to the nearest hundred) in 2004 of 991,400 (SE=58,200, CV=5.9%) (Table 13).

DISCUSSION

The methods used in this survey are very similar to those employed during the 1990, 1994, and 1999 surveys (Stenson *et al*. 1993, 2002, 2003). The basic design involves detecting concentrations of whelping harp seals, estimating the number of pups present on the ice, and correcting these estimates for any births that may have occurred after the counting surveys have been flown. As in previous studies, the current survey design calls for a combination of visual and photographic surveys with the objective to obtain multiple surveys of all major concentrations. Generally, when both methods are employed to estimate pupping in the same concentration the results are comparable (Stenson *et al.* 2002, 2003). Visual surveys are flown using a helicopter. Although the distance that can be covered using this technique is limited, they are easy to fly, less costly than photographic surveys, and the results can often be obtained within a few days. The photographic surveys are often flown using a fixed wing aircraft, which provides a much greater range, and with photographs a permanent record is obtained. However, photographic surveys are time-consuming to analyse (equivalent to three person years in the current survey), and are more difficult logistically to set up because the seal concentrations are often located 200 km offshore and may drift over 30 km between reconnaissance flights and a photographic flight the following day. Over the series of surveys we have carried out, the contribution of each technique to the total estimate has varied. In many cases concentrations have been surveyed photographically while in others, only visual estimates were available. For some areas, both methods were successful (Stenson *et al.* 1993, 2002, 2003, this study). It is evident that using both survey methods is costly and time consuming. However, due to the unpredictable conditions we encounter during these surveys, it is important to prepare for as many different situations as possible. In some years we are able to carry out visual surveys on the major concentrations. If this occurred regularly, we would be able to reduce costs by restricting the photographic surveys to areas that cannot be reached by the helicopters (e.g. northern Gulf). This is more likely to occur in the southern Gulf than in other areas. At other times, however, combinations of logistics, weather, and ice conditions make visual surveys impossible. In these cases we have to rely on the photographic surveys. Unfortunately we usually cannot predict the conditions until the surveys are underway. For these reasons, we do not feel that it is appropriate to use only a single survey method for northwest Atlantic harp seals. This conclusion was borne out by results of the 2004 survey.

Compared to previous surveys, more extensive reader corrections were applied to the data for the 2004 southern Gulf photographs. As a result of these corrections, the numbers of seals on the photographs almost doubled compared to the raw counts; however, these corrected estimates are still much lower than the 5 and 10 March visual estimates. We believe that the difference between the visual and photographic counts is a product of photograph quality. The photographic images from the 2004 survey were much less clear than the images from previous surveys and all film was returned to the aerial photographic company to be re-processed. However, the imagery from the southern Gulf was still not as clear as that from the Front (D. Wakeham, pers. comm.), and has been returned again to the company. Other evidence also underlines problems with the pup photograph counts. From the photographs, adult counts were much higher than the pup counts. A total of 11,486 adults were counted on the photographs compared to only 1,439 pups, resulting in an adult to raw pup count ratio of 8:1 and an adult to photo-corrected pup count ratio of 2.6:1 (Tables 3, 4). In previous surveys, the adult to pup ratio was closer to 1:1. Surveys flown in 1999 and 1994 had adult to pup ratios of 0.91 and 0.98 respectively (adult counts not available for the 1990 survey). Although the use of adult counts to provide an estimate of pup production is complicated by uncertainties in the proportion of adult males and females hauled out on the ice, the ratio of adults to pups of 8:1 we obtained from the 2004 survey is much higher than previously observed and most likely resulted from pups not being detected on the images. Based on counts of adults from the 2004 photographs, the population would number 263,671 (SE=48,735) animals, which is essentially the same as the 5 March visual survey estimate of 281,254 (SE=36,252) pups, before correcting for births occurring after the survey. We therefore conclude that the 5 March photographic survey pup count is severely biased and should be discarded.

Due to strong northeasterly winds during mid March, ice drift along the southern Labrador coast was extensive in 2004. As a result, the northern (Cartwright) seal concentration moved south to the area around Belle Isle before it could be surveyed. This was the same area where the southern (Belle Isle) concentration had been surveyed three days earlier. Fortunately the two whelping concentrations were well-defined with VHF and satellite transmitters and, as a result, we were able to ensure that seals were not counted twice.

We were unable to complete the photographic survey of the Belle Isle concentration in a single day. Seals were observed to the north and east of the tip of Newfoundland (Cape Bauld, Fig. 6) during the visual surveys but were not included in the photographic lines. To account for these seals, the area to the southeast was surveyed the following day. To ensure that there was no overlap with the previous photographs, we allowed for more ice drift between the two days than we estimated based on the movement of ice-based transmitters. This was considered to be the most conservative approach. If drift was less than we estimated, some pups may have been missed and the combined photographic estimate for these two days would be negatively biased.

Similarly, if the seals photographed on 16 March were not included in the visual surveys on 15 March, it would mean that the estimates are biased downward slightly.

In previous surveys we have corrected survey estimates for births that have occurred after the survey flights. If the distribution of harp seal births over the pupping season is assumed to follow a normal distribution, the parameters of this distribution can be estimated relatively easily from the frequencies of three age-dependent stages. The resulting estimates of the proportion of pups present on the ice at the time of a survey tend to be higher, and hence more conservative than using more complex methods that also make assumptions about the starting date for pupping (Myers and Bowen 1989, Stenson *et al.* 2003). We used a similar approach in 2004, but correction factors were very small since most of the pupping had occurred prior to our surveys being flown.

The age of the pups present at the time of the surveys in 2004 also suggests that very few, if any, had left the ice before the surveys were carried out. Stenson *et al*. (1993) assumed that significant numbers of pups may have gone into the water once they reach Stage 6 ('Raggedy-jacket'), but that younger pups remained present on the ice. Staging data (Table 11) indicates that very few pups had reached this stage by the time of the surveys in 2004.

In 2004, the distribution of whelping animals was similar to the historical pattern, with two large groups at the Front corresponding to the traditional "north" and "south" concentrations. A small group was observed in the northern Gulf of St. Lawrence and another larger whelping concentration in the southern Gulf near the Magdalen Islands (Sergeant 1991, Stenson *et al*. 1993). This contrasts with the situation in 1994, when numerous dispersed whelping concentrations were observed at the Front (Stenson *et al.* 2002).

Winters (1978) estimated that the proportion of the total annual pup production which occurred in the Gulf varied greatly (13-51%). Aerial survey results indicate that the proportion born in the Gulf does vary, but that the number of pups born there may be less than the 1/3 assumed traditionally (Sergeant 1991). There is also considerable variation in the numbers of pups that are born in the northern Gulf. In 1990, 19% of total pup production was born in the Gulf with very few (<4,500) being born in the northern Gulf (Stenson *et al*. 1993). In contrast, this proportion increased to 36% in 1994, including 8.2% of the total pup production occurring in the northern Gulf (Stenson *et al*. 2002). In 1999 the proportion of pups born in the northern Gulf remained the same, but the proportion in the southern Gulf was lower (17.6%) resulting in 26% of total pup production occurring in the Gulf. The distribution of pupping in 2004 was very similar to that seen in 1994 with 26% of the pupping occurring in the southern Gulf and 9% in the northern for a total of 35%. These shifts may reflect changes in ice conditions, the drifting of pups into the northern Gulf through the Strait of Belle Isle, or shifts in prey abundance resulting in differences in the number of animals moving into the Gulf (Sergeant 1991).

Evaluating harp seal abundance is a large, complex logistic and financial undertaking. Given current interest in harvesting of this resource and the relatively high market value for pelts, it is important to determine if the current design and monitoring programme are effective in detecting population change. Four aerial surveys have been completed since 1990 using the current design. Coefficients of variation for these surveys have ranged from 5.9% to 10.2%, with a mean of 8.1%. Assuming that population change is exponential, accepting the chances of Type 1 error (concluding there is a change, when there is none) to be 0.05 (one chance in twenty), and an interval of four years between surveys, then the probability of detecting an overall change in the population (power) of 25% within a five year interval (i.e. one survey) in either direction, would be only 0.35 (Gerrodette 1987). Increasing the chance of a Type 1 error to 0.1, increases the power to detect a 25% change between successive surveys to 0.53 after five years, and 0.8 after nine years (i.e. 2 surveys). However, given the current high harvest levels, the main concern would be that the population is declining. In that case a one-tailed test would be more suitable. The power to detect a change in the population would be 0.53, and 0.74 assuming alpha levels of 0.05 and 0.1, respectively. Thus it should be possible to detect large changes in pup production (≥25%) within one survey (5 years) using the current survey approach. However, this assumes that the confidence in the survey estimate is not reduced. In order to minimize unexpected changes in the population, or uncertainties associated with the possibility of a questionable survey, a varied suite of monitoring techniques and a conservative approach to setting harvest levels are recommended.

The results of this survey indicate that the increase in pup production observed throughout the 1990s has likely stopped. In 1990, pup production was estimated to be 577,900 (SE=38,800, Stenson *et al*. 1993). This increased to 997,900 (SE=102,100) pups in 1999 (Stenson et al. 2003), which is nearly the same as we observed in 2004. During the same period, catches from this population increased substantially, from an average of 115,000 between 1990-1995 to 350,000 between 1996-1999 (Stenson *et al*. 2000). However, the vast majority (60-80%) of these catches have been young of the year (Stenson *et al*. 2000) that would not have matured until approximately age five (Sjare *et al*. 1996). The impact of these large catches on pup production are now being observed in the population.

ACKNOWLEDGEMENTS

We thank W. Penney, D. McKinnon, D. Wakeham, P. Carter, K. Nilssen, L. Lindblom, P. Abgrall, O. Svetocheva, and V. Svetochev, for help in field. H. MacRae , G. Mathews, and R. Duff of the Canadian Coast Guard kept us on line and at the correct altitude while the captain and crew of the *CCGS Ann Harvey* provided us with a safe haven. We also wish to thank the crew of the reconnaissance aircraft and the pilots and cameramen of the aerial photographic aircraft. We are especially grateful to D. Wakeham, D. McKinnon, D. Kavanagh, P. Carter, J. Guerin, and S. Turgeon for reading the photos. Support for this work was provided under the Atlantic Seal Research Program Department of Fisheries and Oceans Strategic Research Fund.

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Table 1. Regression statistics (total number of photographs read, intercept, slope and adjusted r^2) used to correct for misidentified pups on aerial survey photographs. Each reader read 50 photographs to provide data to develop the regression. In the Gulf, the regression was fitted to the square root of the counts for reader 3.

Patch	**Date**	**Reader**	**Photographs read**	**Intercept (SE)**	**Slope (SE)**	**r^2**
S. Gulf	5	1	575	2.90 (1.059)	1.22 (0.129)	0.65
		2	266	3.59 (1.236)	1.25 (0.170)	0.53
		3	289	-	4.09 (0.228)	0.86
Belle Isle	15	4	2,043	-	1.042 (0.008)	0.998
		5	247	-	0.984 (0.012)	0.992
	16	4	1,520	-	1.024 (0.010)	0.995
Mecatina	17	4	319	-	1.084 (0.008)	0.998
		5	1,549	-	0.859 (0.013)	0.988
Cartwright	18	4	1,056	-	1.084 (0.008)	0.997
		5	281	-	0.947 (0.014)	0.990
		6	920	-	1.184 (0.035)	0.956

Table 2. Number of pups counted on north-south transects obtained during visual surveys of the southern Gulf on 5 March 2004. Transects were spaced 4 minutes of longitude apart. Total strip width was 60m.

Transect	Start Latitude (deg/min)	End Latitude (deg/min)	Longitude (deg/min)	Seals counted	Estimated number of pups
1	46 57	47 14	63 44	0	0.0
2	47 13	46 54	63 40	30	2,525.0
3	46 54	47 13	63 36	96	8,079.5
4	47 12	47 10	63 32	209	17,574.7
5	47 00	47 11	63 28	199	16,736.8
6	47 11	46 48	63 24	64	5,393.8
7	46 48	46 58	63 20	0	0.0
8	46 57	46 47	63 16	32	2,702.9
9	46 47	46 56	63 12	53	4,477.1
10	46 55	46 45	63 08	211	17,835.7
11	46 44	46 59	63 04	222	18,754.5
12	46 58	46 43	63 00	468	39,552.6
13	46 44	47 00	62 56	424	35,810.0
14	47 00	46 41	62 52	272	30,855.1
15	46 42	47 10	62 48	307	25,932.4
16	47 00	46 38	62 44	211	17,840.1
17	46 38	47 10	62 40	444	37,529.6
18	46 58	46 43	62 36	79	6,676.6
19	46 40	46 57	62 32	8	676.5
20	46 57	46 42	62 28	1	84.5
21	46 43	46 55	62 24	1	84.5
Total				**3,331**	**289,122**

Table 3. Number of pups counted on north-south transects obtained during visual surveys of the southern Gulf on 10 March 2004. Transects were spaced 5 minutes of longitude apart. Total strip width was 60m.

Transect	Start Latitude (deg/min)	End Latitude (deg/min)	Longitude (deg/min)	Seals counted	Estimated pups
1	46 41	46 55	62 30	1	105.7
2	46 56	46 39	62 36	16	1,691.7
3	46 40	46 56	62 40	311	32,879.7
4	46 56	46 44	62 47	145	15,319.5
5	46 45	47 10	62 51	128	13,511.5
6	47 00	46 43	62 55	227	23,970.1
7	46 45	47 10	63 00	287	30,296.9
8	47 10	46 46	63 05	338	35,671.8
9	46 48	46 58	63 10	215	22,696.0
10	46 57	46 47	63 15	244	25,759.3
11	46 50	47 12	63 20	16	1,684.8
12	47 10	46 40	63 25	0	0.0
13	46 56	47 14	63 30	88	9,253.1
14	47 14	46 59	63 35	152	15,976.2
15	47 00	47 10	63 40	34	3,575.4
16	47 10	46 59	63 45	42	4,417.6
17	47 00	47 11	63 51	0	0.0
18	47 11	47 00	63 55	0	0.0
Total				**2,244**	**236,809.4**

Table 4. Number of pups counted on north-south transects obtained during a photograph survey of the southern Gulf on 5 March 2004. Transects were spaced 5 minutes of longitude apart.

Transect	Start Latitude (deg/min)	End Latitude (deg/min)	Longitude (deg/min)	No. Photos	Pups counted	Corrected counts	Photo variance
62 25	46 54	46 55	62 25	6	0	17.4	7.6
62 30	46 45	46 50	62 30	28	0	81.2	35.3
62 35	46 43	47 02	62 35	115	8	343.1	146.3
62 40	46 45	46 58	62 40	78	163	425.0	146.2
62 45	46 42	47 03	62 45	106	126	408.0	224.4
62 50	46 47	46 59	62 50	74	64	345.8	177.7
62 55	46 45	47 10	62 55	149	195	287.1	169.2
63 00	46 48	47 04	63 00	101	175	506.3	179.1
63 05	46 46	47 02	63 05	101	184	517.3	203
63 10	46 50	47 00	63 10	68	153	383.8	137.8
63 15	46 47	46 55	63 15	51	20	172.2	68.8
63 20	46 56	47 03	63 20	42	0	0	0
63 25	47 03	47 15	63 25	64	6	19.7	5.2
63 30	47 03	47 11	63 30	48	198	420.2	228.2
63 35	46 59	47 11	63 35	75	112	409.5	254.1
63 40	47 02	47 06	63 40	24	35	130.0	61.0
Total				**1,130**	**1,439**	**4,467**	

Table 5. Number of adults counted on north-south transects obtained during a photographic survey of the southern Gulf on 5 March 2004. Transects were spaced 5 minutes of longitude apart.

Transect	Start Latitude (deg/min)	End Latitude (deg/min)	Longitude (deg/min)	No. Photos	Adults counted	Estimated adults
62 25	46 54	46 55	62 25	6	0	0.0
62 30	46 45	46 50	62 30	28	42	1,035.0
62 35	46 43	47 02	62 35	115	172	4,238.7
62 40	46 45	46 58	62 40	78	1,686	41,549.5
62 45	46 42	47 03	62 45	106	520	12,814.8
62 50	46 47	46 59	62 50	74	792	19,517.9
62 55	46 45	47 10	62 55	149	775	19,099.0
63 00	46 48	47 04	63 00	101	1,611	39,701.2
63 05	46 46	47 02	63 05	101	1,492	36,768.6
63 10	46 50	47 00	63 10	68	1,635	40,292.6
63 15	46 47	46 55	63 15	51	243	5,988.4
63 20	46 56	47 03	63 20	42	2	49.3
63 25	47 03	47 15	63 25	64	49	1,207.5
63 30	47 03	47 11	63 30	48	1,279	31,519.4
63 35	46 59	47 11	63 35	75	1,053	25,949.9
63 40	47 02	47 06	63 40	24	135	3,326.9
Total				**1,130**	**11,486**	**283,058.9**

Table 6. Number of pups counted on east-west transects obtained during visual surveys of the Belle Isle concentration on 15 March 2004. Transects 10 and 20 are corrected for changes in transect spacing. Sighting strip widths were 40m.

Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	Seals counted	Estimated pups
1	52 12	55 28	55 15	0	0.00
2	52 10	55 26	55 17	41	3,792.50
3	52 08	55 33	55 17	50	4,625.00
4	52 06	55 32	55 15	77	7,122.50
5	52 04	55 31	55 11	62	5,735.00
6	52 02	55 34	55 08	8	740.00
7	52 00	55 34	55 06	42	3,885.00
8	51 58	55 38	55 06	62	5,735.00
9	51 56	55 38	55 04	116	10,730.00
10	51 54	55 46	55 05	55	3,815.63
11	51 53	55 50	55 04	94	4,347.50
12	51 52	55 49	55 05	347	16,048.75
13	51 51	55 51	55 04	42	1,942.50
14	51 50	56 00	55 03	19	878.75
15	51 49	56 00	55 00	34	1,572.50
16	51 48	55 59	54 58	16	740.00
17	51 47	56 03	54 58	97	4,486.25
18	51 46	56 07	54 59	129	5,966.25
19	51 45	56 04	55 00	398	18,407.50
20	51 44	56 07	55 02	250	17,343.75
21	51 42	56 06	54 45	430	39,775.00
22	51 40	56 14	54 40	67	6,197.50
23	51 38	56 15	55 20	321	29,692.50
24	51 36	56 21	55 59	379	35,057.50
25	51 34	56 30	56 03	200	18,500.00
26	51 32	56 35	56 11	246	22,755.00
27	51 30	56 39	56 14	370	34,225.00
28	51 28	56 35	56 21	125	11,562.50
29	51 26	56 40	56 26	6	555.00
30	51 24	56 49	56 37	0	0.00
31	51 22	56 48	56 39	0	0.00
Total				**4,083**	**316,234.38**

Table 7. Number of pups counted on east-west transects obtained during a photographic survey of the Belle Isle concentration (Front) on 15 and 16 March 2004.

Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	No. Photos	Pups counted	Corrected counts	Photo variance
March 15							
1	51 24	56 51	56 39	55	23	23.96	0.002
2	51 26	56 40	56 27	58	107	111.45	0.035
3	51 28	56 32	56 21	47	667	694.75	2.407
4	51 30	56 40	56 14	116	557	580.17	0.917
5	51 32	56 36	56 9	117	1,650	1,718.64	6.091
6	51 34	56 30	56 4	119	1,212	1,262.42	4.056
7	51 36	56 23	56 0	103	1,664	1,733.05	7.033
8.1	51 40	56 8	55 33	156	460	452.67	1.923
8.2	51 40	55 22	55 11	51	13	12.79	0.003
9	51 44	56 5	55 36	130	1,254	1,306.17	2.151
10	51 46	55 47	55 37	45	238	247.90	0.219
11.1	51 48	55 58	55 34	113	26	27.08	0.002
11.2	51 48	55 17	55 10	33	36	37.50	0.016
12	51 52	55 56	55 13	193	135	140.62	0.029
13.1	51 56	55 49	55 24	122	245	255.19	0.474
13.2	51 56	55 19	55 4	68	817	850.99	3.135
14.1	52 00	55 45	55 18	121	102	106.24	0.040
14.2	52 00	55 16	55 5	56	53	55.20	0.019
15	52 04	55 38	55 13	117	448	466.64	0.386
15	52 04	55 38	55 13	117	448	466.64	0.386
16	52 06	55 39	55 16	106	379	394.77	0.688
17	52 08	55 37	55 15	98	279	290.61	0.445
18	52 10	55 36	55 17	87	174	181.24	0.376
19	52 12	55 35	55 15	87	91	94.79	0.067
20	52 14	55 35	55 15	92	29	30.21	0.012
March 16							
1.1	50 46	55 19	55 05	61	21	21.51	0.004
1.2	50 46	54 55	54 37	73	40	40.97	0.011
2	50 50	54 30	55 19	201	120	122.92	0.060
3	50 54	55 18	54 34	180	293	300.12	0.792
4	50 58	55 14	54 37	152	106	108.58	0.111
5	51 00	55 23	54 43	164	461	472.21	0.599
6.1	51 02	55 09	54 43	103	247	253.00	0.285
6.2	51 02	54 35	54 33	8	5	5.12	0.001
7	51 04	55 29	54 55	123	414	424.06	0.606
8	51 06	55 30	54 56	135	414	424.06	0.693
9.1	51 08	55 28	55 21	30	20	20.49	0.027
9.2	51 08	55 09	54 50	81	444	454.79	0.505
10	51 10	55 31	54 55	146	515	527.52	0.730
11.1	51 12	55 22	55 17	24	20	20.49	0.015
11.2	51 12	55 05	54 55	39	278	284.76	0.635
Total				**3,927**	**14,505**	**15,022.28**	**35.993**

Table 8. Number of pups counted on north-south transects obtained during visual surveys of the Cartwright concentration on 18 March 2004. Sighting strip widths were 40m.

Transect	**Latitude (deg/min)**	**Start Longitude (deg/min)**	**End Longitude (deg/min)**	**Seals counted**	**Estimated pups**
1	52 24	55 31	54 56	12	1,110.0
2	52 22	55 30	54 57	68	6,290.0
3	52 20	55 21	54 52	108	9,990.0
4	52 18	55 29	54 54	170	15,725.0
5	52 16	55 28	54 57	109	10,082.5
6	52 14	55 28	55 00	121	11,192.5
7	52 12	55 26	54 51	100	9,250.0
8	52 10	55 25	54 59	32	2,960.0
9	52 08	55 24	54 54	99	9,157.5
10	52 06	55 23	54 55	66	6,105.0
11	52 04	55 36	54 44	156	14,430.0
12	52 02	55 29	54 45	196	18,130.0
13	52 00	55 41	54 42	182	16,835.0
14	51 58	55 45	54 44	172	15,910.0
15	51 56	55 41	54 43	106	9,805.0
16	51 54	55 50	54 44	83	7,677.5
17	51 52	55 50	54 44	51	4,717.5
18	51 50	55 49	54 53	38	3,515.0
19	51 48	55 48	54 53	164	15,170.0
20	51 46	55 58	54 58	349	32,282.5
21	51 44	55 57	54 59	82	7,585.0
22	51 42	56 10	54 57	252	23,310.0
23	51 40	55 24	54 51	55	5,087.5
24	51 38	55 24	54 54	50	4,625.0
25	51 36	55 19	54 57	171	15,817.5
26	51 34	55 14	54 55	272	25,160.0
27	51 32	55 15	54 51	302	27,935.0
28	51 30	55 16	54 49	353	32,652.5
29	51 28	55 07	54 49	67	6,197.5
Total				**3,986**	**368,705.0**

Table 9. Number of pups counted on east-west transects obtained during an incomplete photographic survey of the Cartwright concentration (Front) on 18 March 2004.

Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	No. Photos	Pups counted	Corrected counts	Photo variance
1	51 44	55 27	54 55	131	1,192	1,196.64	3.118
2.1	51 46	55 47	55 37	41	178	210.79	2.528
2.2	51 46	55 25	55 11	56	932	935.63	1.776
3	51 48	55 42	54 51	185	1,350	1,355.25	3.502
4.1	51 50	55 24	55 01	98	552	554.15	2.345
4.2	51 50	54 53	54 37	44	2	2.01	0.000
5.1	51 52	55 19	55 05	58	187	187.73	0.273
5.2	51 52	54 44	54 36	33	2	2.01	0.000
6.1	51 54	55 31	55 27	17	72	68.17	0.151
6.2	51 54	55 18	54 32	183	114	107.93	0.410
6.3	51 54	54 30	54 24	24	0	0.00	0.000
7.1	51 56	55 17	54 26	201	97	97.38	0.021
7.2	51 56	55 35	55 26	36	58	58.23	0.019
8.1	52 00	55 16	55 09	30	238	238.93	0.565
8.2	52 00	55 06	54 59	29	2	2.01	0.000
9	52 04	55 23	55 01	91	557	559.17	1.431
10	52 8	55 21	55 14	33	241	241.94	0.521
11.1	52 12	55 26	55 22	18	223	264.07	5.878
11.2	52 12	55 19	55 11	33	1	1.00	0.000
Total				**1,341**	**5,998**	**6,083**	**22.538**

Table 10. Number of pups counted on east-west transects obtained during a photographic survey of the northern Gulf concentration on 17 March 2004.

Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	No. Photos	Pups counted	Corrected counts	Photo variance
1.1	49 36	59 29	59 12	74	687	608.65	2.323
1.2	49 36	59 10	59 0	42	51	45.18	0.070
1.3	49 36	58 57	58 47	43	184	163.02	0.414
1.4	49 36	58 42	58 33	38	99	87.71	0.095
1.5	49 36	58 30	58 16	58	355	314.51	1.123
1.6	49 36	58 10	58 09	6	6	5.32	0.002
2.1	49 39	58 13	58 10	11	20	17.72	0.019
2.2	49 39	59 30	59 18	304	898	795.59	4.625
3.1	49 42	59 24	59 07	73	132	116.95	0.194
3.2	49 42	59 04	58 55	39	23	20.38	0.036
3.3	49 42	58 37	58 16	90	113	100.11	0.078
3.4	49 42	58 12	58 05	28	2	1.77	0.000
4	49 45	59 27	58 10	319	519	562.70	0.341
5	49 46	59 14	59 02	52	1,785	1,581.43	43.034
6	49 47	59 19	59 00	82	2,015	1,785.20	30.477
7.1	49 48	59 19	59 19	3	0	0.00	0.000
7.2	49 48	59 18	59 00	78	980	868.23	8.439
8.1	49 49	59 14	59 04	41	593	525.37	5.105
8.2	49 49	58 59	58 59	3	0	0.00	0.000
9	49 50	59 15	58 58	74	164	145.30	0.399
10.1	49 52	59 12	59 03	46	17	15.06	0.006
10.2	49 52	58 53	58 44	38	0	0.00	0.000
11.1	49 54	59 12	59 06	26	0	0.00	0.000
11.2	49 54	58 53	58 52	2	0	0.00	0.000
12	49 56	59 01	58 57	15	0	0.00	0.000
13	49 58	59 6	58 52	58	5	4.43	0.001
14	50 00	59 11	58 39	148	20	17.72	0.013
15	50 02	58 54	58 35	77	4	3.54	0.002
Total				**1,868**	**8,672**	**7,785.88**	**96.798**

Table 11. Numbers of harp seal pups in individual age dependent stages in the southern Gulf of St. Lawrence and off Newfoundland during March 2004. Only the first three stages were used to determine the temporal distribution of births.

Date	Newborn	Thin-white	Fat-white	Grey	Raggedy-Jacket	Beater	Total
Gulf							
March 1	141	597	34	0	0	0	772
2	73	956	88	0	0	0	1,117
8	42	756	862	66	0	0	1,726
11	0	32	1,028	23	29	0	1,112
15	0	15	518	2082	177	4	2,796
19	0	0	423	64	469	78	1,034
Front: Belle Isle							
March 9	311	3,708	167	0	0	0	4,186
10	257	467	2	0	0	0	726
16	1	114	2,418	182	4	0	2,722
19	0	27	1,222	138	5	0	1,392
22	0	1	99	1200	109	5	1,414
Front: Cartwright							
March 10	565	1,041	0	0	0	0	1,606
12	87	2,775	33	0	0	0	2,895
17	3	252	2,426	139	0	1	2,821
19	0	22	1,246	68	0	0	1,336
22	0	17	1,259	410	11	0	1,697

Table 12. Estimate of proportions of Northwest Atlantic harp seal pups on the ice at the time of the surveys. No data were available to determine the birthing ogive for the northern Gulf concentration.

Area	Date	Estimate	Std Err
Cartwright	18	1.0	<.001
Belle Isle	15	1.0	<.001
S. Gulf	5	0.987	0.015
	10	1	<.001

Table 13. Estimated pup production and standard errors of northwest Atlantic harp seals during March 2004. The southern Gulf March 5 survey was corrected for the birthing ogive. All estimates are rounded to the nearest hundred pups.

Area	Date	Method	Estimate	Std Err
Cartwright	18	Visual	368,700	38,800
Belle Isle	15	Visual	316,200	47,500
	15	Photographic	252,100	31,900
	Average		272,100	26,500
N. Gulf	17	Photographic	89,600	22,800
S. Gulf	5	Visual	285,000	36,200
	10	Visual	236,800	36,400
	Average		261,000	25,700
Total			**991,400**	**58,200**

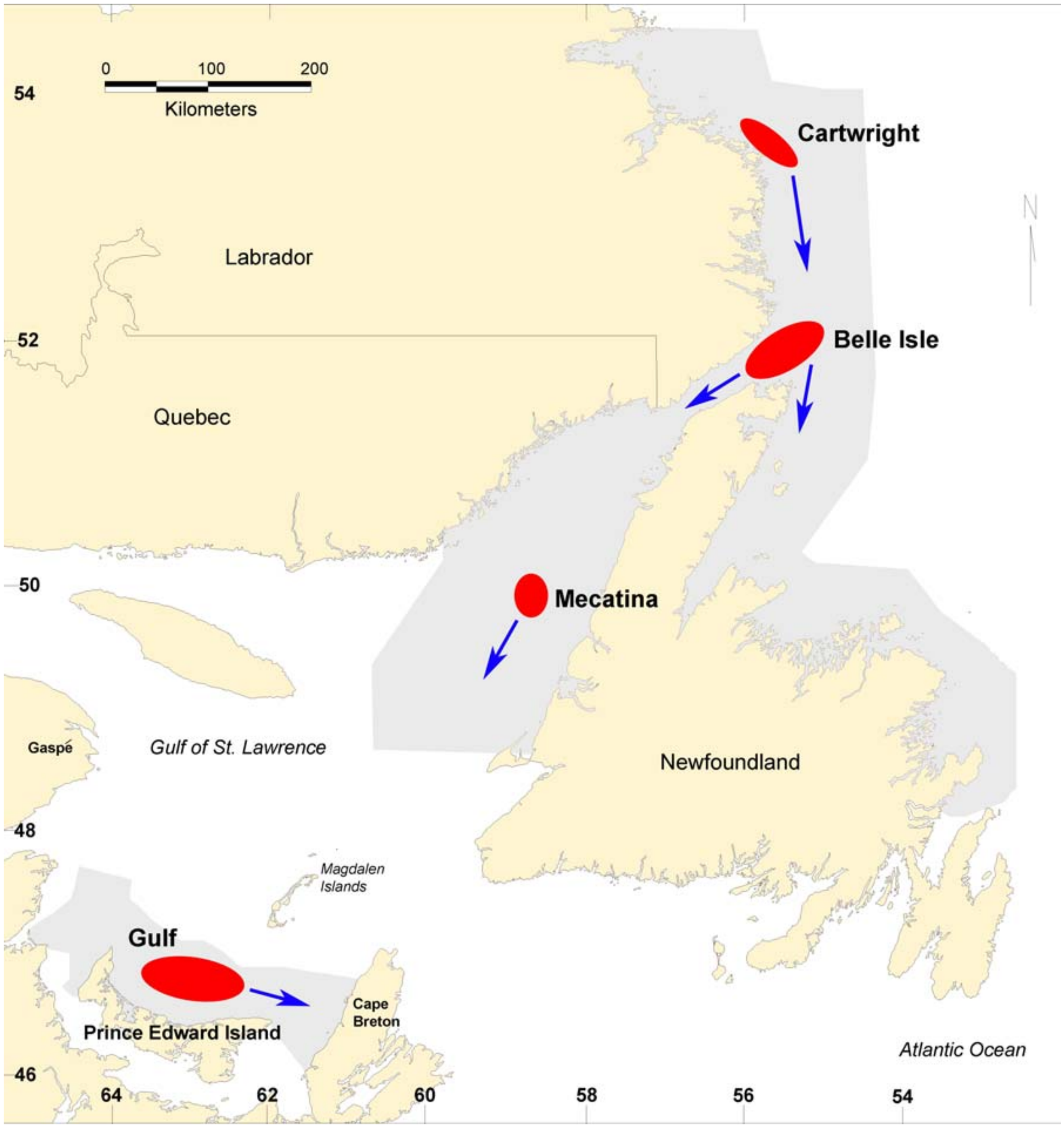

Figure 1. Map of four whelping concentrations located in the Gulf of St. Lawrence and off Newfoundland and Labrador during March 2004. Shading indicates areas covered by reconnaissance surveys and the general direction of drift is indicated by the arrows.

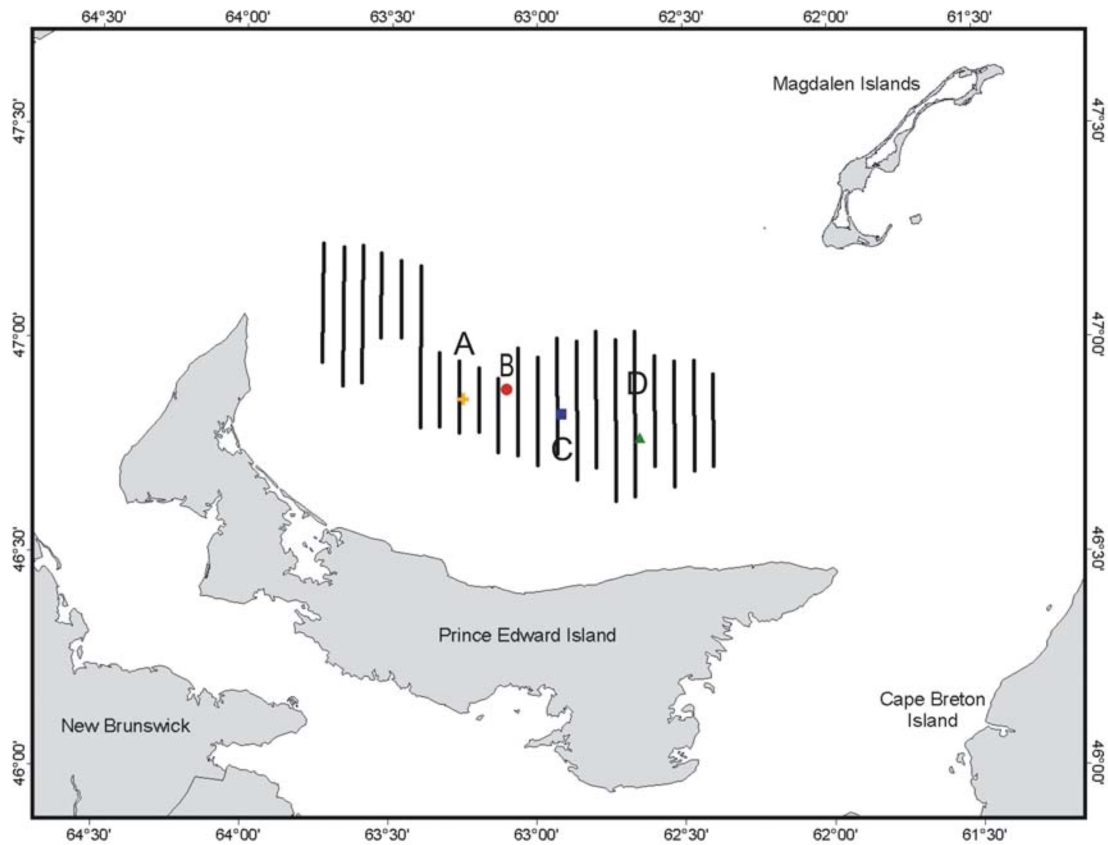

Figure 2. Location of visual survey transects flown to determine harp seal pup production in the southern Gulf of St. Lawrence, on 5 March 2004. Ice-based VHF beacons indicated by the same letters as in Figure 3.

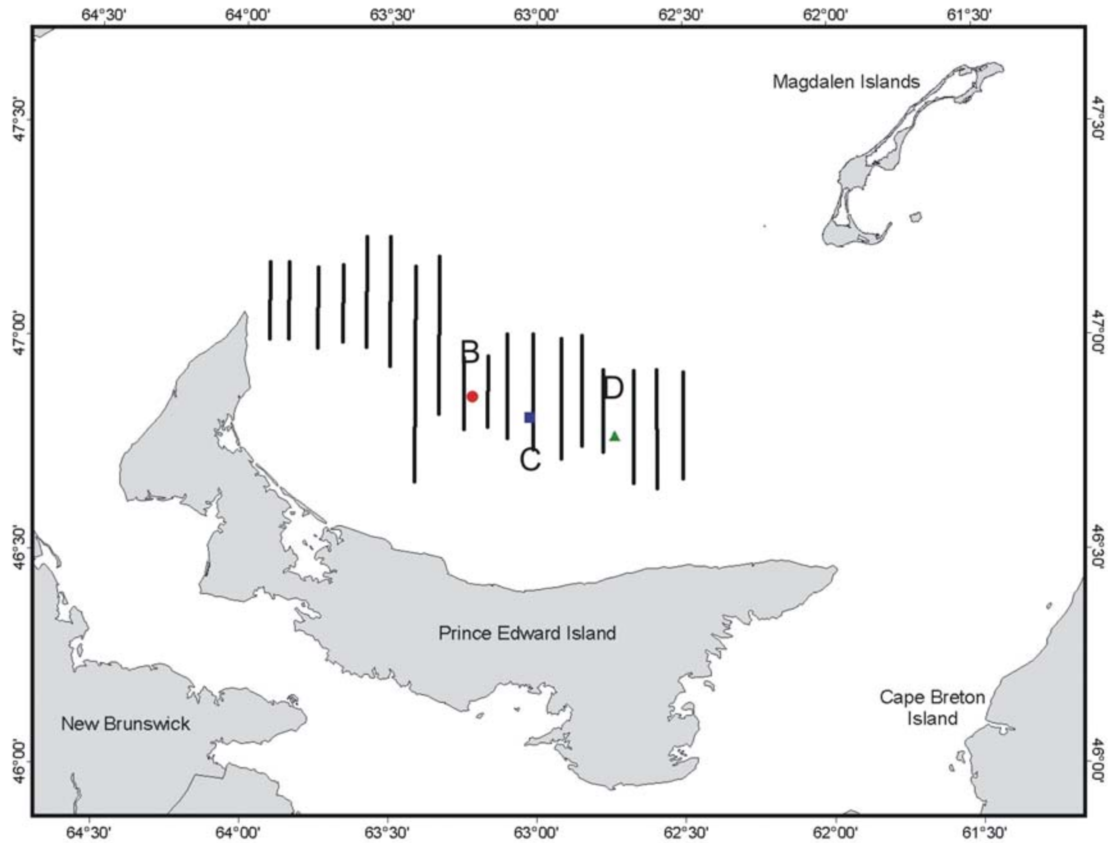

Figure 3. Location of visual survey transects flown to determine harp seal pup production in the southern Gulf of St. Lawrence, on 10 March 2004. Movement of the whelping patch is indicated by comparing locations of individual ice-based VHF beacons (represented by the same letters) in Figures 2 and 3.

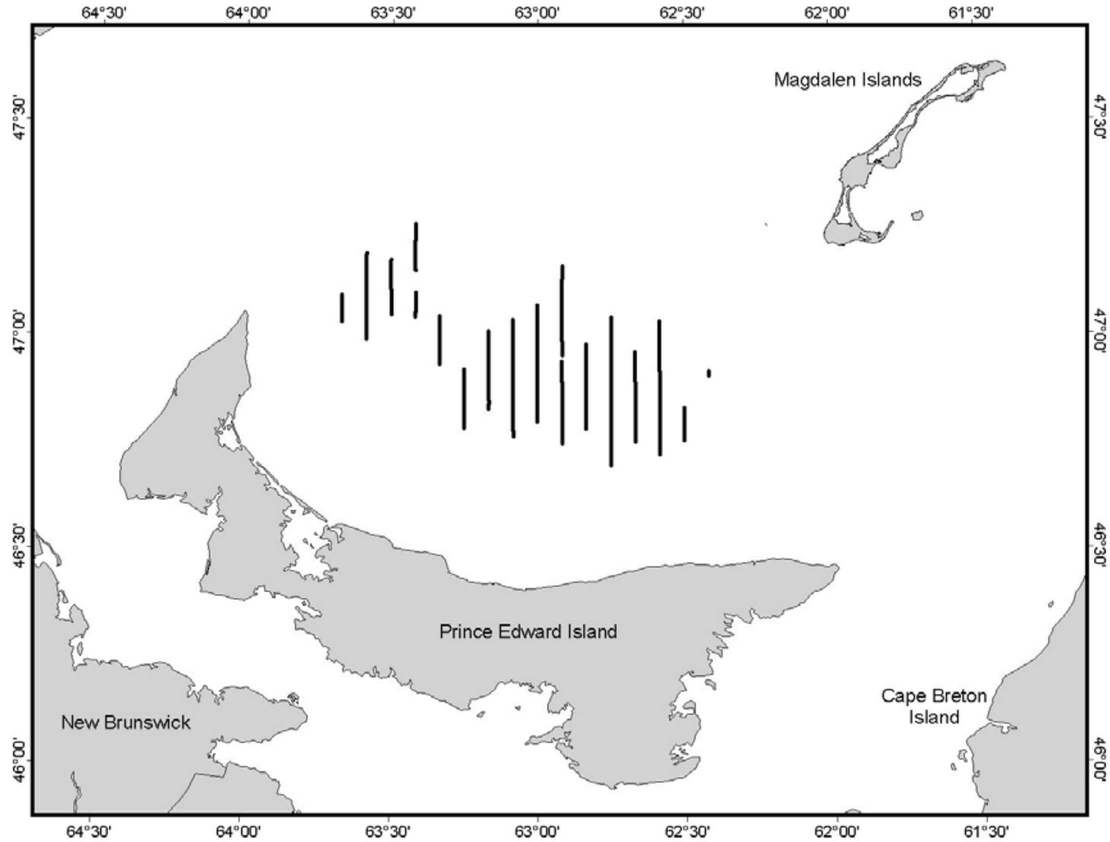

Figure 4. Location of photographic survey transects flown to determine harp seal pup production in the southern Gulf of St. Lawrence, on 5 March 2004.

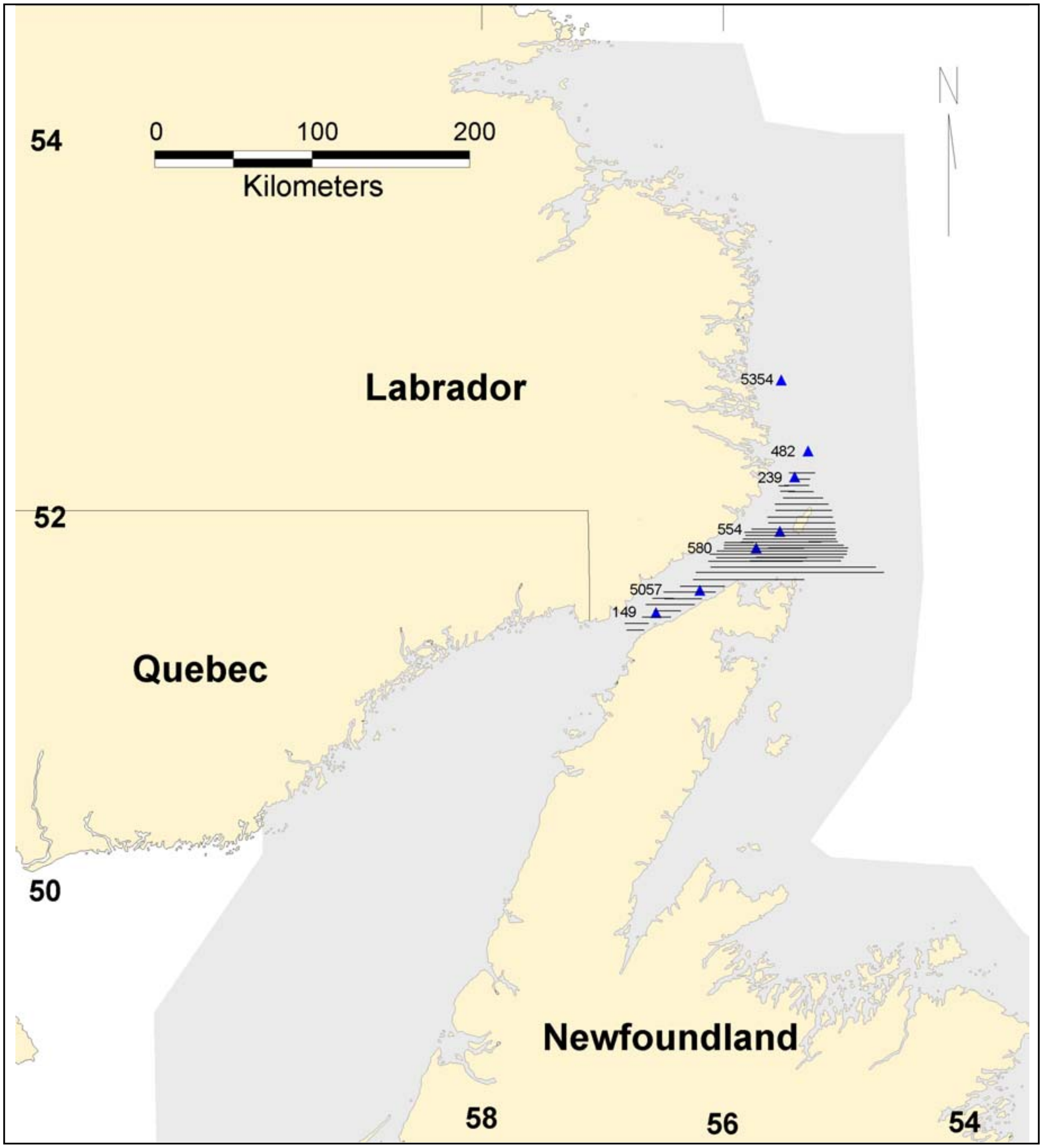

Figure 5. Location of visual survey transects flown to determine harp seal pup production in the southern (Belle Isle) whelping concentration on 15 March 2004. Ice-based transmitter positions are indicated by triangles and individual numbers. Shading indicates areas where reconnaissance surveys were flown.

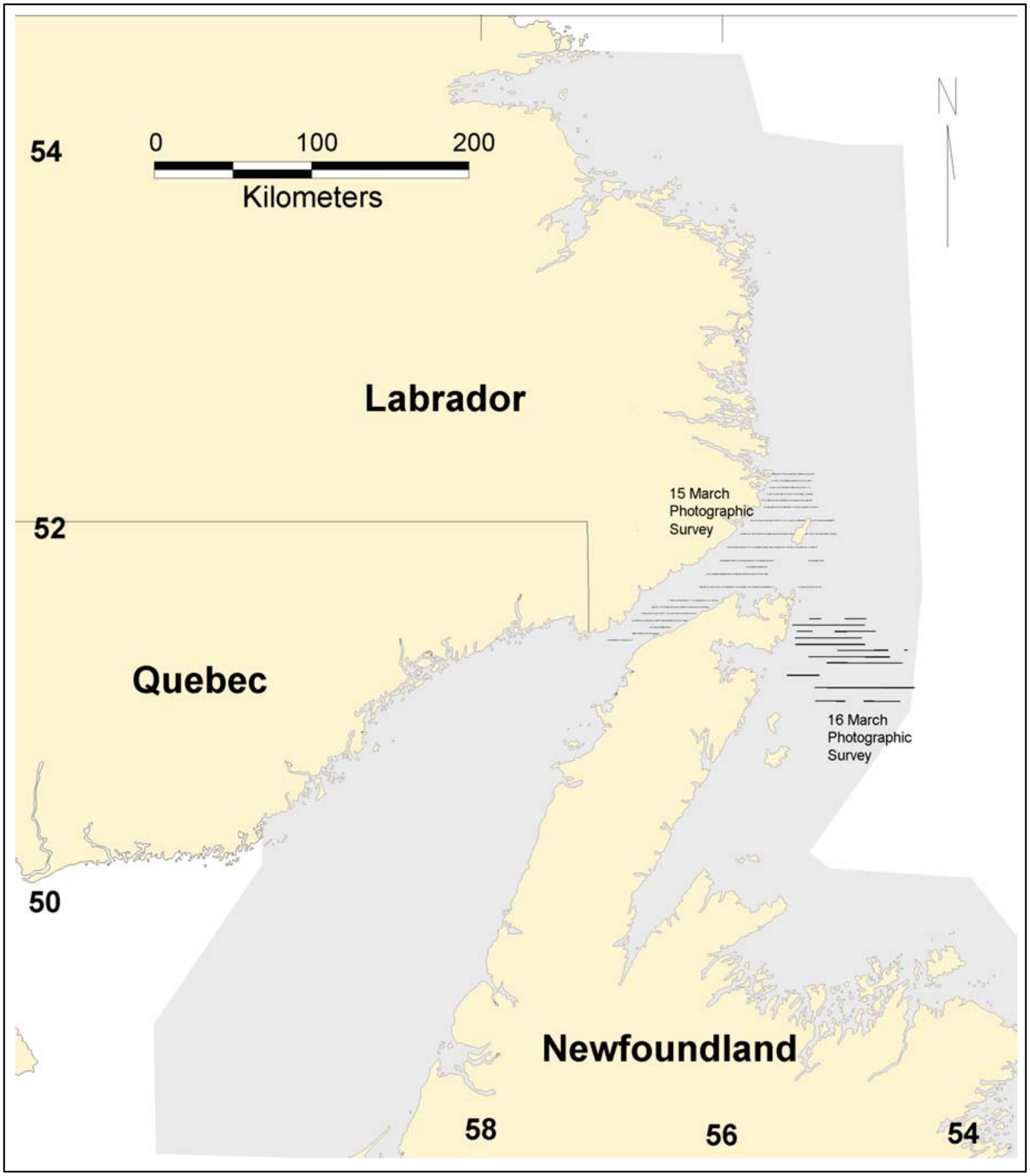

Figure 6. Location of photographic survey transects flown to determine harp seal pup production in the southern (Belle Isle) whelping concentration on 15 and 16 March 2004. Shading indicates areas covered by reconnaissance surveys.

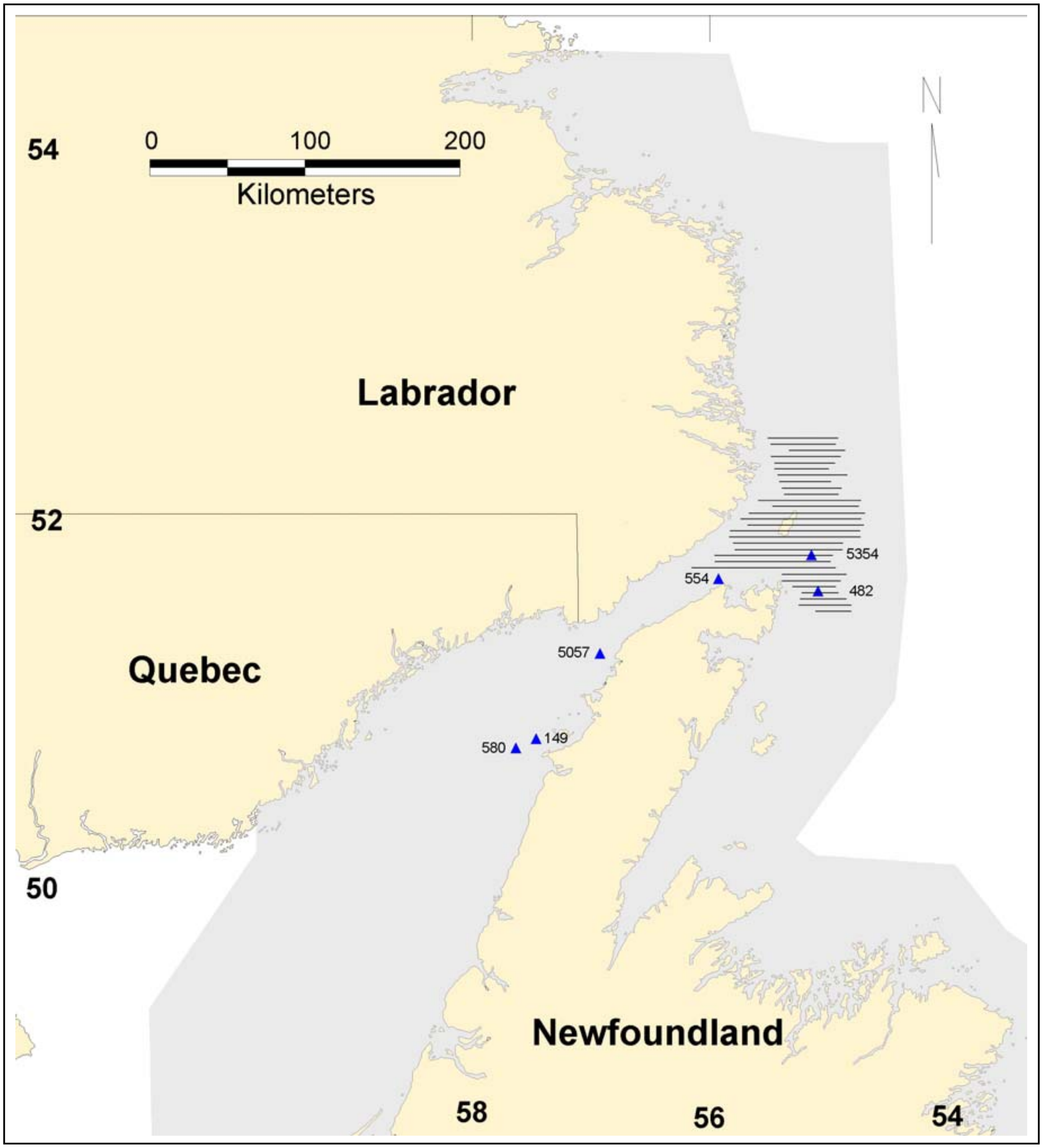

Figure 7. Location of visual survey transects flown to determine harp seal pup production in the northern (Cartwright) whelping concentration on 18 March 2004. Ice-based transmitter positions are indicated by triangles and individual numbers (cf. Figure 5). Shading indicates areas where reconnaissance surveys were flown.

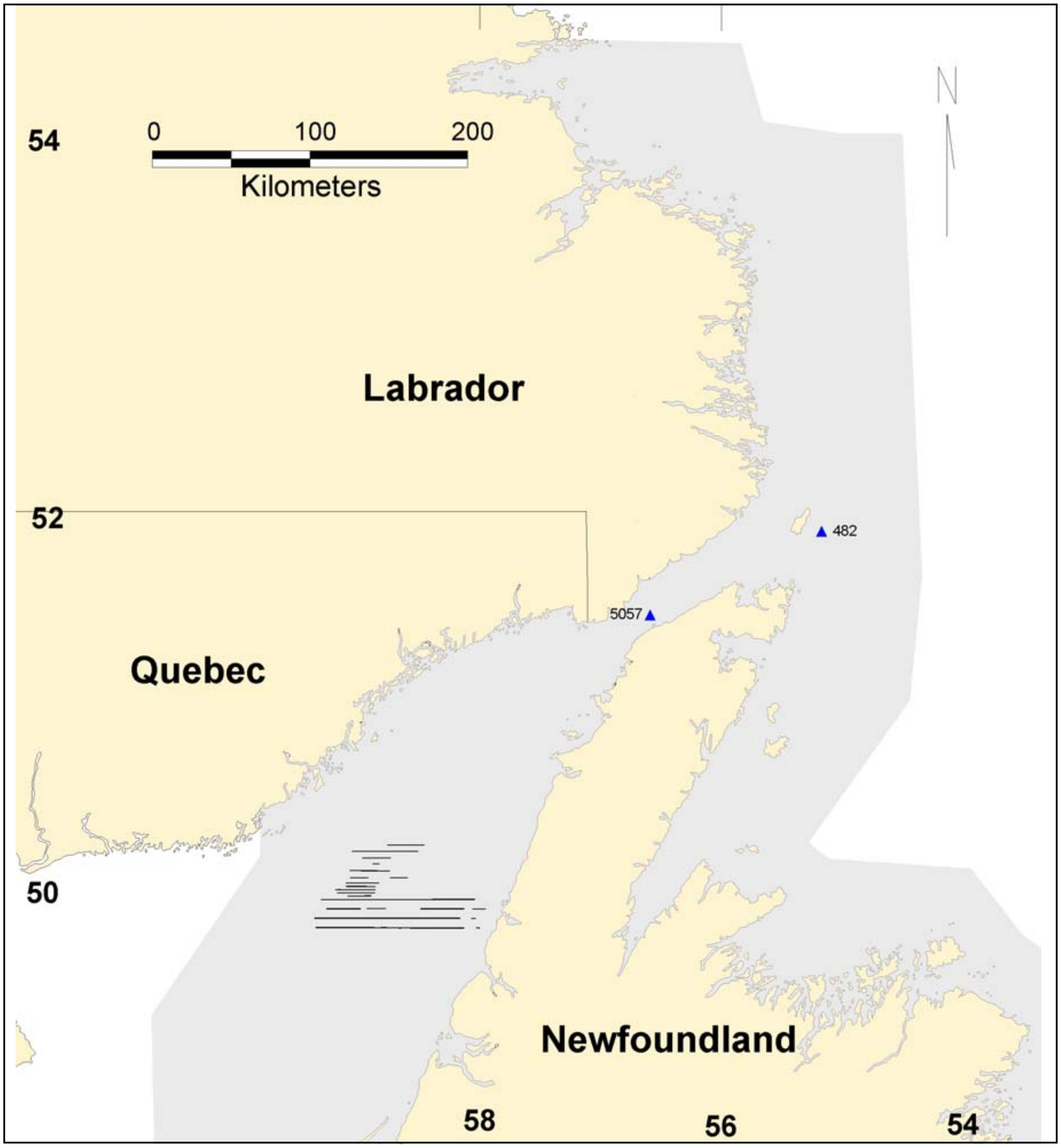

Figure 8. Location of photographic survey transects flown to determine harp seal pup production in the northern Gulf of St. Lawrence (Mecatina) on 17 March 2004. Ice-based transmitter positions are indicated by triangles. Shading indicates areas where reconnaissance surveys were flown.