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1999 Pup Production of Harp Seals, *Phoca groenlandica*, in the Northwest Atlantic

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Abstract

To determine current pup production of Northwest Atlantic harp seals, aerial surveys of the whelping (pupping) concentrations off southern Labrador and/or eastern Newfoundland (`Front') and in the northern and southern Gulf of St. Lawrence (`Gulf') were conducted during March 1999. A total of 5 concentrations were located, two at the Front, one in the northern Gulf and two closely spaced groups in the southern Gulf (which later joined into one). The northern concentrations were located near traditional areas while the southern Gulf group formed up on suitable ice in the traditional areas but drifted southward towards Prince Edward Island where they coalesced prior to the survey. Photographic surveys were conducted on all concentrations between 14 and 24 March while a visual survey was made of the southern Gulf concentrations on 14 March. Photographic counts were corrected for misidentified pups by comparing multiple readings of photographs made by two or more readers. Survey estimates were also corrected for pups absent from the ice at the time of the survey using the occurrence of distinct age-related developmental stages. Multiple estimates were available for two of the whelping concentrations. Pup production was estimated to be 739,100 (SE=96,300) at the Front, 82,600 (SE=22,500) in the northern Gulf and 176,200 (SE=25,400) in the southern Gulf (Magdalen Island) for a total of 997,900 (SE=102,100).

Résumé

Afin de déterminer la production actuelle de jeunes phoques du Groenland de l'Atlantique Nord-Ouest, on a réalisé des dénombrements aériens de concentrations de naissances, au sud du Labrador et / ou à l'est de Terre-Neuve (la région « front ») et dans le nord et le sud du golfe Saint-Laurent (le « golfe ») en mars 1999. Au total, on a localisé cinq concentrations, deux dans la région « front », une dans le nord du golfe, et deux groupes rapprochés dans le sud du golfe (qui plus tard se sont unis). Les concentrations du nord étaient situées près des aires traditionnelles ; les groupes du sud du golfe, qui se trouvaient d'abord sur la glace des aires traditionnelles, se sont ensuite déplacés vers le sud en direction de l'Île-du-Prince-Édouard et se sont unis avant le dénombrement. Des dénombrements par photographie aérienne ont été réalisés pour toutes les concentrations entre les 14 et 24 mars, et un dénombrement visuel a été effectué pour les concentrations du sud du golfe le 14 mars. On a corrigé des erreurs d'identification de petits dans les dénombrements photographiques en comparant les lectures multiples des photographies faites par deux ou plusieurs lecteurs. Les résultats de dénombrements ont aussi été corrigés de façon à tenir compte des petits absents de la glace au moment du dénombrement en utilisant les stades de développement distincts reliés à l'âge. Des estimations multiples étaient disponibles pour deux des concentrations des naissances. La production de petits a été estimée à 739 100 (erreur-type =96 300) dans la région « front », 82 600 (errur-type=22 500) dans le nord du golfe et 176 200 (erreur-type=25 400) dans le sud du golfe (Îles-de-la-Madeleine), pour un total 997 900 (erreur-type=102 100).

Introduction

Exploited commercially since the 1700s, the harvest of Northwest Atlantic harp seals reached its maximum during the late 1800s with reported catches as high as 526,000 (Sergeant 1991). Harvests declined during the early 1900's due to a combination of two world wars and poor economic conditions, but then increased to 350,000 animals per year by the mid 1950s (Sergeant 1991). These large reported catches continued throughout the 1950s and 60s and by the early 1970s, pup production was thought to have been reduced by 50% from the estimated 600,000 animals born during the early 1950s (Lett and Benjaminsen 1977; Winters 1978). In 1971, the Canadian Government introduced a quota of 200,000 animals to limit the hunt. This quota was reduced to 120,000 animals in 1972, but was later established at 186 000, a level which was lower than the estimates of replacement yield at that time (Anon. 1981). Between 1972 and 1982 catches averaged 172,000 per year (Anon. 1995). However, between 1983 when the European Economic Community instituted a ban on the importation of the whitecoat pelts and 1994, annual catches declined to between 27,000 and 68,000 (Anon. 1995). In 1996, the quota was increased to 250,000 and then increased again to 275,000 in 1997 where it has been maintained since.

Prior to 1990, the annual pup production of this population was estimated using a variety of techniques. These included survival indices, catch at age analyses, sequential population models (Sergeant 1971, 1975; Benjaminsen and Øritsland 1975; Winters 1978; Cooke 1985), aerial photographic surveys (Lavigne *et al*. 1980, 1982), and mark-recapture experiments (Bowen and Sergeant 1983, 1985). Unfortunately, the results of these studies using different techniques were often conflicting with estimates ranging from approximately 250,000 (Lavigne *et al*. 1980, 1982) to 450,000-534,000 (Bowen and Sergeant 1983, 1985) for the 1975-1983 period. In a review of the various estimates, the Royal Commission on Seals and Sealing in Canada (Anon. 1986) concluded that pup production in 1978 was in the order of 300,000-350,000.

In 1990, pup production was estimated using a combination of photographic and visual aerial surveys (Stenson *et al*. 1993). An estimated 467,200 (SE=31,200) pups were born at the Front, 106,300 (SE=23,000) in the southern Gulf (Magdalen Islands area) and 4,373 (SE=1,264) in the northern Gulf (Mecatina) for a total of 577,900 (SE=38,800). Surveys were flown again in 1994 resulting in pup production estimates of 446,700 (SE=57,200) at the Front, 57,600 (SE=13,700) in the northern Gulf and 198,600 (SE=24,200) in the southern Gulf for a total of 702,900 (SE=63,600). These estimates indicated that pup production had likely increased from the early 1980's to the 1990’s.

The objective of this study was to estimate the 1999 pup production of harp seals in the Northwest Atlantic using visual and photographic aerial surveys. The techniques used were similar to those used in 1990 and 1994 and therefore, provide comparable estimates that can be used to determine if pup production has increased in recent years.

Materials and Methods

Identification of Whelping Areas

Whelping concentrations (`patches') were located using fixed-wing and helicopter reconnaissance surveys of areas historically used by harp seals. At the Front and in the northern Gulf of St. Lawrence, fixed-wing reconnaissance flights were conducted almost daily from 5 - 21 March (Fig. 1). Repeated systematic east-west transects, spaced 18.5 km apart, were flown at an altitude of 230m from the coastal edge of the ice pack to the seaward edge between 49^0 36'N and 54^0 55'N at the Front and between the Strait of Belle Isle (~50^0 50'N) and 49^0 50'N in the northern Gulf. Due to the ice drift and a range of pupping dates (early - mid March), most areas were surveyed repeatedly to minimize the chance of missing whelping concentrations. Satellite and VHF radio transmitters were deployed in major whelping concentrations to facilitate relocation and monitor ice movements.

In the southern Gulf, reconnaissance surveys of areas traditionally used by harp seals were flown 26 February to 15 March using helicopter and fixed wing aircraft (Fig. 2). Repeated helicopter flights were made to the area northwest and west of the Magdalen Islands to locate concentrations of animals near the islands. Surveys farther to the west, towards Gaspe and New Brunswick, and to the east along the Cape Breton Coast were completed using fixed wing aircraft. 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. Two VHF radio transmitters were deployed to facilitate relocation and monitor ice movements.

Estimates of Abundance

Visual surveys

The number of pups present within the Gulf whelping concentration was estimated by conducting visual strip transect surveys (see Stenson *et al.* 1993) on 14 March. A helicopter flying at an altitude of 46 m flew a series of north-south lines that were spaced 4 minutes of longitude apart and had been laid out prior to the flight. Two observers seated in the rear counted all pups within a strip of 35 m on either side of the aircraft. Due to poor weather and the absence of a vessel for support, visual surveys were not flown at the Front or in the northern Gulf.

Photographic Surveys

Fixed-wing aerial photographic surveys were flown using two planes equipped with 23 x 23 cm format metric mapping cameras (Zeiss RMK/A) with a motion compensation mechanism and 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 183 m. The images covered an area of 274.3 X 274.3 m per photo. The amount of overlap between photos within a transects varied with approximately 10% overlap along some transects, while along others non-overlapping frames resulted in coverage varying between 55 - 80%. The 9-13% overlap that occurred between consecutive frames was removed prior to the analysis.

The cameras were turned on before seals were encountered on a transect line. Cameras were turned off if no seals were observed for an extended period along a transect line. An observer with a forward view ensured that the cameras were turned on before seals 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 seals were present further along the transect line. Correct altitude and transect spacing was maintained using barometric altimeters and GPS navigation systems.

One aircraft was also equipped with a Hassleblad 70mm format camera with a quartz lens and a UV filter. This camera system was designed to obtain photographs in the ultra-violet spectrum in order to test the accuracy of pup identifications on the photographs. However, due to mechanical problems no usable photographs were obtained.

The survey in the southern Gulf was flown on 14 March. Two planes flew a series of north-south lines that were spaced 3 minutes of longitude apart and had been mapped prior to the flight to ensure complete coverage of the herd in a single day.

Surveys in the Front and northern Gulf were conducted between 15 and 24 March. A northern (‘Cartwright’) whelping concentration was surveyed on 16 and 22 March while the southern (‘Mary’s Harbour’) concentration was surveyed on 21 and 24 March. Seals giving birth in the northern Gulf (‘Mecatina’) were survey on 15 and 21 March. The Cartwright and Mary’s Harbour 24 March surveys were carried out using two planes while a single plane was used for the remaining surveys. Transect spacing for all surveys were chosen to ensure that the entire patch could be covered in a single day. If sufficient fuel was available, additional transects were flown between previously flown transects. Ice drift was monitored by satellite transmitters to ensure that transects remained independent.

Photographic counts

Photographs were read using the methods described in Stenson *et al.* (1995). Positive prints were examined by six readers, three in Newfoundland and three in the Gulf. Each frame was examined using an illuminated hand-lens (7-8X mag.) or a rail-mounted low magnification binocular microscope. To standardize the readers prior to the actual readings, each examined a common series of photographs and compared identified seals. Once the cues used to identify seals were consistent among readers, all photos were read

once. For each photograph, the number and position of all pups were recorded on a clear acetate overlay.

After all photographs were read, each reader reread a series of their photographs in sequence to determine if identification of seals had improved over the course of the readings. Readings of photos continued until, the counts from the first and second reading differed by less than 5%. In the initial series of photos where counts differed by more than 5%, the counts from the second reading were used to replace those made during the first reading. Generally, counts from the initial and second readings were consistent within the first 120 photos.

To correct for misidentified pups, a series of randomly selected frames from each patch, were examined by all readers. All resulting acetates were then overlaid, and were re-examined by two experienced readers to determine a `best estimate' of the number of pups present. Any pup that could not be positively identified was not included. The original counts (*x*) were regressed on the 'best estimate' (*y*) to determine a correction factor for each survey and reader. Initial calculations indicated that the intercept parameter of the liner regression was not significantly different from 0 for five of the six readers. Therefore, the regressions were recalculated using the form $y = ax$ where *y* is the corrected count and *x* is the original count. Individual photo counts were then corrected using the appropriate regression for each reader (Table 1). The measurement error associated with variation about the regression (V_{photo}) was estimated for each photo using:

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

where:
j = transect number;
Z = the number of photos on the transect.

The variance associated with the reading corrections was summed over transects to estimate the total measurement-error for the survey and added to the sampling variance.

Survey analysis

Both visual and photographic surveys were based on a systematic sampling design with a single random start and a sampling unit of a transect of variable length. The data were analyzed using the methods outlined in Hammill *et al*. (1992) and Stenson *et al*. (1993, 1997) and summarized here.

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

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

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

This assumes that the distribution and density of pups on the unobserved portions were similar to those in the observed. The additional component of error that arises from this assumption was judged to be small and is included in the between-transect variability.

The estimates of error variance were based on serial difference between transects (Cochran 1977 p. 225; Kingsley *et al*. 1985) and calculated as

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

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

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

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

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

The total population was estimated as: $\hat{N} = \sum_{i=1}^{I} N_i$

and its error variance: $\hat{V} = \sum_{i=1}^{I} (V_{lines\ i} + V_{photo\ i})$

where I is the number of surveys.

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

$$\hat{N} = ((N_1 \times V_2) + (N_2 \times V_1)) / (V_1 + V_2)$$

and its error variance :

$$\hat{V} = (V_1 \times V_2) / (V_1 + V_2)$$

Correcting for the Temporal Distribution of Births

To correct the estimates of abundance for pups that had left the ice or were not yet born at the time of the survey (Bowen *et al*. 1987; Myers and Bowen 1989; Stenson *et al*. 1993, 1997), it was necessary to estimate the distribution of births over the pupping season. This was done using information on proportion of pups in each of 7 distinct age-dependent stages (Stewart and Lavigne 1980) in each concentration and the duration of each stage. Prior to the survey, classifications of pup stages were standardized among observers to ensure consistency. To determine the proportion of pups in each stage on a given day, a series of random samples of pups were obtained from each concentrations. Random points were chosen along transverse flight lines flown across the long axis of the patch. At each location observers classified the first 20-30 pups encountered. Occasionally an entire concentration at the Front could not be covered in a single day due to poor weather or the dispersed nature of the concentration. In these instances a series of random transects were flown over the patch and pups classified from a helicopter hovering just above the animal. Repeated classifications were obtained from each concentration several days apart. The methods used to model the stage transitions are given in Myers and Bowen (1989) and Stenson *et al*. (1993).

Results

Identification of whelping areas

Front

Two whelping concentrations were located off the coast of southern Labrador on 4 March 1999 (Fig. 3). The first occurred on the pack ice east of Cartwright (~ 54^0 25'N 56^0 W to 53^0 50' N 53^0 55'W) while the second was located east of Mary's Harbour (~53^0 18'N 55^0 25'W to 52^0 30'N 53^0 24'W). Satellite and VHF transmitters were deployed in each concentration to monitor movements. Both concentrations remained distinct and onshore winds kept the concentrations together as they drifted in a generally southward direction within the 9+ ice pack.

Northern Gulf

A small whelping concentration was located in the Strait of Belle Isle (~ 51^0 40'N 55^0 45'W) on 7 March. By 10 March, strong winds pushed this ice across the strait and these animals joined a larger group located along the Quebec shoreline. The movements of this group were monitored using VHF transmitters. During the survey period these seals were located on a relatively narrow band of ice that extended along the western (Quebec) shore from approximately 51^0 2'N to 50^0 4'N.

Southern Gulf

In the southern Gulf, two concentrations of whelping seals were situated close together. These were located to the NNW of the Magdalen Islands on 26 February between approximately $47^0$00' N and $47^0$40' N and $62^0$30'W and $63^0$30'W (Fig. 4). Two VHF transmitters were deployed, one in each group. During the first week of March, the patches were pushed north. However, by the second week the patches were pushed southwest by wind and current activity to lie off the northern and northwest coast of Prince Edward Island. By the 13 March the concentrations had joined into one group and were located just inside Northumberland Strait, at the northwest tip of Prince Edward Island and along the north coast of Prince Edward Island.

Photographic Surveys

Reader corrections

Correction factors were developed for all readers from the 50 photos examined. The regressions of the 'true counts' on the individual reader counts were significant for all readers and had R^2 of > 96%. Corrections varied between readers and surveys resulting in slight increases (0-12%) or slight decreases (0-13%) in counts of seals on the photos. In

five of the six regressions the intercept did not differ significantly from 0. Therefore the regression was recalculated with the data constrained to pass through 0 (Table 1). A regression including the intercept was used for Reader 6.

Front

A survey of the northern (Cartwright) was attempted on 16 March. However, due to poor weather the entire concentration was not surveyed. A complete survey of the concentration was carried out on 22 March (Fig 4, Table 2). A total of 14 transects, divided into 2 strata, were flown between 52^0 40'N and 53^0 58'N. One strata had a transect interval of 7.4 km (n=8) while the other had transects spaced 14.8 km (n=6) apart. A total of 15,657 pups were counted on 1,951 photographs (Fig. 5). Correcting for mis-identified pups resulted in a total of 17,815 (SE = 197) seals. Based on these counts a total of 532,400 (SE = 90,600) pups were estimated to have been present in this concentration.

The southern (Mary's Harbour) whelping concentration was surveyed twice, once on 21 March and again on 24 March. The 21 March survey (Fig. 4, Table 3) consisted of 7 transect, spaced 14.8 km apart, between 51^0 38'N and 52^0 10'N. Readers identified 4,022 pups on 857 photos (Fig. 6). Corrections for reader errors resulted in a total count of 4298 (SE = 277) pups. Total pup production was estimated to be 239,300 (SE = 93,000). A second survey of the Mary's Habour concentration was carried out on 24 March (Fig. 7, Table 4). Improved coverage was obtained with 15 transects flown between 51^0 27'N and 52^0 3'N. The transect interval was 7.4 km. A total of 2,240 photos were obtained, containing 6,618 pups. The corrected estimate of 7,487 (SE = 112) pups resulted in a total pup production estimate of 202,200 (SE = 34,600). Averaging the two estimates resulted in an estimated pup production of 206,700 (SE = 32,500) for this concentration.

Northern Gulf

An incomplete survey of the northern Gulf (Mecatina) whelping concentration was attempted on 15 March. A survey of the entire concentration was successfully completed on 21 March (Fig. 4, Table 5). The survey consisted of 3 strata, 6 north –south lines spaced at intervals of 8 min of longitude and 2 sets of east – west lines spaced either 7.4 km (n = 5) or 14.8 km (n = 5) apart. The whelping concentration occupied an area from approximately 51^0 01'N 58^0 25'W to 50^0 4'N 60^0 32'W. A total of 1,714 pups were identified on 579 photographs (Fig 8). Correcting for reader errors resulted in a total of 2,275 (SE = 90) pups. The resulting estimate of pup production for this concentration was 82,600 (SE = 22,500).

Southern Gulf

The southern Gulf whelping concentration (SG1) was surveyed on 14 March. A total of 21 transects were flown. The original design called for transect spacing of 4 minutes.

However, 20 lines were flown with a spacing of 3 minutes and 1 line had a spacing of 1.5 minutes on one side and 5 minutes on the other. The survey was divided into 3 strata with transect intervals of 3 (n=18), 4 (n=1), and 3 (n=2), minutes apart, respectively (Fig. 9; Table 6). A total of 7,375 pups were counted by the readers on the photographs. Correcting each photograph for mis-identified seals increased the counts to 8,631 pups. Taking into account the transect spacing, the total population estimate from the photographic survey for the southern Gulf of St Lawrence was estimated to be 177,300 (SE=32,800).

Visual surveys

A visual survey was also flown in the southern Gulf on 14 March. Sixteen north-south transects were flown spaced 4 minutes apart (Figure 10). A total of 2,418 seals were counted on the transects within the 70 m wide strip. Pup production was estimated as 174,500 (SE=40,200). Estimates from the visual survey and the photographic survey were averaged resulting in an estimated pup production of 176,200 (SE=25,400) animals in the southern Gulf of St Lawrence.

Corrections for the Temporal Distribution of Births

Estimates of the proportion of pups in each developmental stage were obtained from all of the whelping concentrations (Table 7). Given the absence of newborn or yellow pups, the low number of thin whitecoats just prior to the survey period, and the absence of early stages after the surveys were flown, a correction for pups born after the survey period does not appear necessary. The majority of animals present during the survey period were between the fat whitecoat and ragged jacket stages. Since very few animals at these stages enter the water on their own volition (Hammill pers. obs.), no correction was applied for animals in the water.

Estimated Pup Production

Single estimates of pup production were obtained from two (Cartwright and northern Gulf) whelping concentrations while two estimates are available for seals whelping in the Mary's Harbour and southern Gulf areas. Combining the estimates of the four concentrations using the averaged estimates where possible, resulted in an estimate of total pup production in 1999 of 997,900 (SE = 102,200, Table 8).

Discussion

The survey methods used in this survey are very similar to those used during the 1990 and 1994 surveys (Stenson *et al*. 1993, 1995). These surveys used extensive reconnaissance of all areas to locate whelping seals, corrected the resulting estimates for errors in the reading of photographs and used a combination of visual and photographic surveys to

estimate pup production. The 1990 and 1994 surveys were generally flown earlier in the pupping season compared to the 1999 survey and counts in these earlier surveys were corrected for the temporal distribution of births. Owing to poor weather conditions the 1999 survey was flown about 5 days later in the southern Gulf and 2-10 days later off the Front. The survey of the northern Gulf took place at about the same time as in 1994. Considering the later timing of most of the 1999 surveys and the lack of early stage pups during or after the survey period, no correction for the temporal distribution of births was applied to these estimates.

Surveying later in the nursing period raises the concern that pups may be lost either by going into the water or due to dispersion of the ice pack itself. In the past few years, efforts have been made to estimate the proportion of pups of different stages that may go into the water by requesting research personnel to record the occurrence of pups in the water. The most common stages present during the survey period, fat whitecoats and greys, are seldom observed in the water and if they do enter the water they appear to remain for only a short time (Stenson and Hammill, unpublished data). Such animals have been observed on the photographs and unless they spend a considerable time diving (which has not been observed) pup production is unlikely to have been underestimated significantly due to animals leaving the ice.

An ultra-violet camera system was used during the 1990 survey to increase the visibility of white-coated pups by providing a dark pup image against a white background (Lavigne 1976). This was necessary due to the small images obtained during the 1990 survey, which was flown at an altitude of 305 m (vs. 183 m in this survey) with a camera using a similar lens (150 mm). At this altitude the images were 40% smaller than those obtained during the 1994 and 1999 surveys. Given the difficulties encountered using the ultra-violet system in 1990 such as increased interpretation problems of the imagery due to false positives (see Stenson *et al*. 1993), and the larger image sizes obtained during the 1994 survey, the ultra-violet system was not used in the 1994 survey. This was unlikely to have biased the 1994 results since i) no differences were observed in the number of pups counted on test images obtained using an ultra-violet and simultaneous images obtained using a black and white camera system with the lens size/altitude combinations flown during the 1994 survey (Ni *et al*. 1988), and ii) the use of a motion compensation mechanism on the camera and fine grain film ensured that high quality images were obtained. However, in response to suggestions that the use of ultra-violet images be used again, a second camera equipped with an ultra-violet filter was mounted in one of the photographic aircraft during this survey. Unfortunately, none of the imagery turned out because of mechanical difficulties encountered during the survey. In spite of the failure in the ultra-violet imagery, we do not believe that the 1999 survey results are significantly biased for the reasons outlined above for the 1994 survey. Furthermore, in the southern Gulf it was possible to complete a visual aerial survey at the same time as the photographic survey was flown over similar lines. The estimates from the two surveys were similar suggesting that a significant number of pups were not missed when examining the photographic imagery. Due to the large distances involved, visual surveys

at the Front require the use of ship-based helicopters. Although arrangements were made for the use of helicopters based on a Canadian Coast Guard icebreaker, a labour dispute resulted in this component of the survey being cancelled.

Correction factors were developed for each reader/survey combination individually. In the past (e.g. Stenson *et al*. 1995) a single regression was estimated for each of the readers and applied to all of the photographs they read. By applying individual corrections for each survey we were able to account for potential difference in survey conditions. Generally, the corrections required for each reader were relatively small, particularly for an experience reader such as Reader 1. The corrections required for different surveys by the same individual varied slightly but tended to be in the same direction and of similar magnitude. Three of the readers (Readers 3, 5, 6) were inexperienced prior to this survey. However, they were able to spend sufficient time training prior to beginning their counts and in rereading their photos once they had finished, to ensure that their counts were as accurate as possible. The error associated with the regressions to correct for the number of seals on the photographs contributed only about 0.1% to the total survey variance.

The use of multiple surveys allowed us to improve the precision of the pup production estimates for two concentrations. Both of the photographic estimates of the Mary's Harbour concentration and the visual and photographic estimates obtained in the southern gulf were very close. Given that the two surveys in the southern gulf had similar transect lines the closeness of the estimates is not unexpected. However, it does indicate that both visual and photographic surveys are capable of providing reasonable estimates of harp seals. Unfortunately, only a single estimate was available for the Cartwright concentration. This was the largest concentration and the estimate had a large variance associated with it. A second survey of this concentration would likely have improved the precision of the estimate considerably. However, even with the large variance associated with this survey, the overall standard error was only 10% of the estimate. This is similar to that observed in 1994 when the standard error was approximately 9% of the survey estimate.

Unlike 1994 when a numerous dispersed whelping concentrations were found, the whelping concentrations observed in 1999 were similar to the historical pattern. At the Front, whelping has been reported to occur mainly in a few large groups (Curran and Lett 1977; Sergeant 1991; Stenson *et al*. 1993). In 1999, two large groups were observed, corresponding to the traditional 'north' and 'south' concentrations. Although the northern Gulf concentration appeared to form in the southern portion of the Strait of Belle Isle, it was located in its traditional position near Mecatina (Sergeant 1991) by the time of the survey. This group may have been augmented by seals that traditionally whelp near Belle Isle which may explain the large number of pups seen. In the southern Gulf, light ice conditions had forced the survey to be cancelled in 1998 in the hopes that normal conditions would be encountered in 1999. Although, conditions were still light compared to historical patterns, they were much better than 1998 and the extremely light ice years observed in the Gulf in 1960, 1965, 1969, 1981 (Sergeant 1991) and 2000. In 1999, the

whelping patch was located near the end of February in its traditional position to the north, northwest of the Magdalen Islands. Two groups of seals, separated by about 5 miles, were found, but with the drift of the ice these groups coalesced into a single patch near Prince Edward Island by early March. Overall, the ice remained stable and conditions were good for working on the ice. Therefore, we do not believe that pup mortality differed much from normal years.

A change in the proportions of pups in the different areas was observed again in 1999. The southern Gulf is traditionally assumed to account for approximately one-third of total pup production (Sergeant 1991) although Winters (1978) estimated that the proportion of the total annual pup production which occurred in the Gulf varied greatly (13% -51%). The similar design of the survey carried out in 1990 and 1994 allow us to compare how pup production in the different areas varies. In 1990, the southern Gulf accounted for approximately 18% (106,000 SE=23,000) of the total pup production, while the northern Gulf contributed less than 1% (4,400 SE=1,300) of the total pup production of 577,900 (SE= 38,800) (Stenson *et al.* 1993). In 1994, a greater proportion of pups were born in the Gulf with 26% (200,000 SE=24,200) and 7.5% (57,600 SE=13,700) of the total pup production of 702,900 (SE=63,600) born in southern and northern Gulf, respectively (Stenson *et al*. 1995). In fact pup production at the Front was lower in 1994 (446,700 SE=57,200) than in 1990 (467,000 SE=31,000; Stenson *et al*. 1993, 1995). In 1999 however, the proportion of pups born at the Front (739,100 SE=96,300) increased significantly to approximately 74% of the total production of 996,900 (102,100). In contrast, the total number of pups estimated born in the southern Gulf was slightly lower in 1999 (176,200 SE=25,400) than in 1994. This shift may reflect the lighter ice conditions encountered or shifts in prey abundance prior to whelping resulting in fewer animals moving into the southern Gulf (Sergeant 1991). Harvest quotas are assigned to the different areas based on historical hunting patterns and assumed distributions of births. This new information on the relative distribution of whelping animals should be considered when assigning quotas for the different areas.

The increase in pup production observed since the 1970s and 1980s appears to have continued. The 1999 estimate (996,900 SE=102,100) is significantly higher ($p=0.016$, $t=2.45$, $df=82.7$, Satterthwaite, 1946) than the estimate obtained in 1994 (702,900 SE=63,600, Stenson *et al.* 1995). Using the point estimates for 1994 and 1999 indicated that pup production has increased at a rate of 7% per annum over this time period. Catches from this population have increased substantially, particularly since 1996 (Anon 1999; Stenson *et al*. 1999, 2000). However, the vast majority (60-80%) of these catches have been young of the year (Stenson *et al*. 1999, 2000) that would not have matured until approximately age 5 (Sjare *et al.* 1996, 2000). Therefore, the impact of these large catches on pup production will not be known until the 1996 year class matures in 2001.

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Table 1. Regression statistics used to correct for misidentified pups on photographs. The number of photographs used to determine the regression (N), adjust r^2 and total number of photographs read are indicated.

Concentration	Day	Reader	N	Photos Read	Intercept (SE)	Slope (SE)	r^2
Cartwright	22 Mar	1	70	1,951	-	1.036 (0.007)	.997
Mary's Harbour	21 Mar	1	50	366	-	1.009 (0.006)	.998
		3	50	491	-	0.944 (0.014)	.989
	24 Mar	1	54	1,568	-	0.998 (0.010)	.995
		2	54	344	-	0.999 (0.013)	.992
		3	54	328	-	1.047 (0.016)	.987
N. Gulf	21 Mar	3	50	579	-	0.986 (0.009)	.996
S. Gulf	14 Mar	4	50	1037	-	1.122 (0.018)	.987
		5	50	342	-	1.118 (0.009)	.997
		6	50	781	4.342 (1.929)	1.094 (0.025)	.975

Table 2. Number of pups counted on east – west transects obtained during a photograph survey of the Cartwright (northern) whelping concentration off Newfoundland on 22 March 1999. Transect intervals for stratum 1 is 7.4 km and 14.8 km for stratum 2.

Stratum	Latitude (deg/min)	Start Longitude	End Longitude	No. Photos	Pups counted	Corrected counts	Photo variance
1	53 58	55 56.0	56 08.5	32	393	203.57	51.64
1	53 54	56 00.0	56 52.3	179	514	833.43	3,168.38
1	53 50	55 32.9	56 46.2	256	1,283	1336.01	8,295.62
1	53 46	55 24.3	56 19.0	212	2,489	3972.33	5,962.94
1	53 42	55 31.9	56 25.1	138	2,948	3054.13	15,881.49
1	53 38	55 27.5	55 54.8	100	4,202	4353.27	1,799.47
1	53 34	55 14.5	55 55.1	104	1,933	2002.59	658.53
1 / 2	53 30	55 02.0	55 42.6	153	116	120.18	434.05
2	53 22	54 59.0	55 41.6	162	374	387.46	765.62
2	53 14	54 42.6	55 41.9	152	259	268.32	464.42
2	53 06	54 48.7	55 27.7	107	148	153.63	112.36
2	52 58	54 46.8	55 43.4	151	475	492.10	1,887.77
2	52 50	54 57.1	55 45.8	123	375	388.50	1,867.53
2	52 42	55 15.5	55 42.0	82	148	153.33	292.23

Table 3. Number of pups counted on east – west transects obtained during a photograph survey of the Mary's Harbour (southern) whelping concentration off Newfoundland on 21 March 1999. Transect interval was 14.8 km.

Latitude (deg/min)	Start Longitude	End Longitude	No. Photos	Pups counted	Corrected counts	Photo variance
51 38	54 58.4	55 33.5	160	232	201.12	1,182
51 46	54 51.6	55 42.0	211	924	892.66	22,196
51 54	54 57.6	55 52.5	168	1054	913.70	21,750
52 02	54 55.9	55 42.6	193	1727	1,733.71	31,319
52 10	55 04.8	55 34.0	125	85	85.33	143

Table 4. Number of pups counted on east – west transects obtained during a photograph survey of the Mary's Harbour (southern) whelping concentration off Newfoundland on 24 March 1999. Transect interval was 7.4 km.

Latitude (deg/min)	Start Longitude	End Longitude	No. Photos	Pups counted	Corrected counts	Photo variance
51 27	54 27.4	55 14.2	71	50	49.90	10.84
51 31	54 55.4	55 24.4	66	110	109.90	270.51
51 35	54 56.9	55 20.0	100	1115	1112.82	1,996.44
51 39	54 49.5	55 33.1	120	118	117.89	138.53
51 43	54 35.0	55 35.0	266	417	416.18	131.68
51 47	54 49.0	55 37.0	197	358	357.30	152.60
51 51	54 48.4	55 56.5	158	310	309.71	1,494.10
51 55	54 49.0	55 53.7	245	750	748.53	434.41
51 59	54 43.0	55 45.8	181	261	260.49	123.99
52 03	54 45.6	55 36.0	194	1149	1146.75	1,440.82
52 07	54 44.2	55 34.7	110	410	429.96	4,181.66
52 11	54 03.0	55 28.0	120	689	687.65	724.56
52 15	54 46.0	55 24.3	151	430	450.93	1,169.17
52 19	54 40.1	55 230	194	423	422.17	329.89
52 23	54 50.0	55 19.7	67	28	29.36	37.97

Table 5. Number of pups counted on individual east-west (a) and north-south (b) transects obtained during a photograph survey of the North Gulf (Mecatina) whelping concentration on 21 March 1999. Transect intervals for stratum 1 is 14.8 km, 7.4 km for stratum 2, and 9.5 km (8 min long) for stratum 3.

a)

Stratum	Latitude (deg/min)	Start Longitude	End Longitude	No. Photos	Pups counted	Corrected counts	Photo variance
1	51 00	58 26.2	58 38.9	30	0	0.00	0.00
1	50 52	58 33.7	58 55.3	53	96	94.63	476.27
1	50 44	58 41.6	58 56.4	39	135	133.08	3,237.32
1	50 36	59 01.7	59 09.7	23	11	10.84	9.60
1 / 2	50 28	59 06.0	59 22.2	44	114	112.38	158.60
2	50 24	59 14.5	59 33.4	59	647	637.79	2,945.38
2	50 20	59 19.3	59 39.1	58	172	169.55	418.12
2	50 16	59 28.2	59 52.8	64	131	129.14	276.04
2	50 12	59 35.9	60 00.8	70	169	166.60	333.22

b)

Stratum	Start Latitude	End Latitude	Longitude	No. Photos	Pups counted	Corrected counts	Photo variance
3	50 05.0	50 09.9	60 32	21	59	58.16	93.01
3	50 04.7	50 10.1	60 24	26	63	62.10	141.31
3	50 04.5	50 11.0	60 16	30	8	7.89	5.60
3	50 04.8	50 09.6	60 08	22	38	37.46	52.32
3	50 04.9	50 10.2	60 00	24	22	21.69	17.86
3	50 06.7	50 10.2	59 52	16	49	48.30	67.02

Table 6. Number of pups counted on north – south transects obtained during a photograph survey of the southern Gulf of St Lawrence) whelping concentration off Prince Edward Island on 14 March 1999.

Stratum	Start Latitude (degrees/ minutes)	Stop Latitude (degrees/ minutes)	Longitude (degrees/ minutes)	Pups counted	Corrected counts	Photo variance	Transect spacing (minutes longitude)
1	46 48.0	46 40.2	63 20.0	0	0	0	3
1	46 49.2	46 55.1	63 23.1	0	0	0	3
1	46 51.0	46 43.3	63 26.1	33	75.17	33.691	3
1	46 45.4	46 55.3	63 29.4	239	330.89	64.673	3
1	46 55.4	46 41.3	63 32.5	42	47.14	9.81	3
1	46 47.5	47 09.2	63 35.6	147	282.36	105.82	3
1	47 07.1	46 40.4	63 39.1	344	480.6	98.298	3
1	46 43.3	47 17.1	63 42.2	1077	1204.19	10.655	3
1	47 14.0	46 45.1	63 45.3	254	289.4	287.77	3
1	46 54.4	47 19.2	63 48.4	771	865.29	1206.41	3
1	47 19.1	46 49.1	63 51.5	565	640.06	612.02	3
1	47 06.4	46 58.3	63 54.6	393	561.65	846.2	3
1	46 56.0	47 08.6	63 58.1	121	171.61	120.48	3
1	47 10.5	47 03.1	64 01.2	16	28.85	6.86	3
1	46 59.4	47 10.1	64 04.4	106	153.04	79.45	3
1	47 10.3	46 59.2	64 07.5	220	377.64	283.23	3
1	46 56.4	47 10.5	64 10.6	1794	2608.44	18.201	3
1 / 2	47 15.1	46 53.4	64 12.1	1339	2520.52	1018.91	3
2 / 3	46 49.0	47 23.1	64 17.2	799	1530.55	476.85	4
3	47 21.1	47 05.5	64 20.3	0	0	0	3
3	46 47.4	47 09.6	64 23.4	0	0	0	3

Table 7. Numbers of harp seal pups in individual age dependent stages in the Gulf of St. Lawrence and off Newfoundland during March 1999.

Date	Patch	Stage						Total
		Newborn/ Yellow	Thin white	Fat white	Grey coat	Ragged jacket	Beater	
Mar 7	Cartwright	40	64	52	0	0	0	156
10		24	176	45	5	0	0	250
14		0	91	133	25	0	0	249
18		0	2	29	308	72	0	411
21		0	3	11	213	108	2	337
23		0	0	0	136	472	102	710
7	Mary's Hb	52	224	15	0	0	0	291
10		67	120	30	0	0	0	217
13		48	251	60	0	0	0	359
18		1	10	146	60	3	0	220
21		0	2	26	345	104	7	484
23		0	0	76	279	167	24	546
7	N. Gulf	31	112	21	0	0	0	164
9		16	53	45	0	0	0	114
10		4	230	54	1	0	0	289
11		4	460	123	12	0	0	599
13		0	20	16	8	0	0	44
15		0	9	74	85	4	0	172
22		0	0	0	67	49	10	126
Feb. 28	S. Gulf	241	249	0	0	0	0	490
Mar 1		40	61	8	0	0	0	109
3		294	65	1	0	0	0	360
4		42	317	73	0	0	0	432
5		3	81	86	0	0	0	170
10		0	80	325	9	0	0	414
12		0	41	211	32	0	0	284
20		0	0	190	324	106	0	620
24		0	0	9	137	222	0	368
26		0	0	2	40	105	0	147

Table 8. Estimated pup production and standard errors of northwest Atlantic harp seals during March 1999.

Area	Date	Method	Estimate	Std Err
Cartwright	22	Photographic	532,400	90,600
Mary's Hb	21	Photographic	239,300	93,100
	24	Photographic	202,200	34,600
	Average		206,700	32,500
N. Gulf	22	Photographic	82,600	22,500
S. Gulf	14	Photographic	177,300	32,800
	14	Visual	174,500	40,200
	Average		176,200	25,400
Total			997,900	102,100

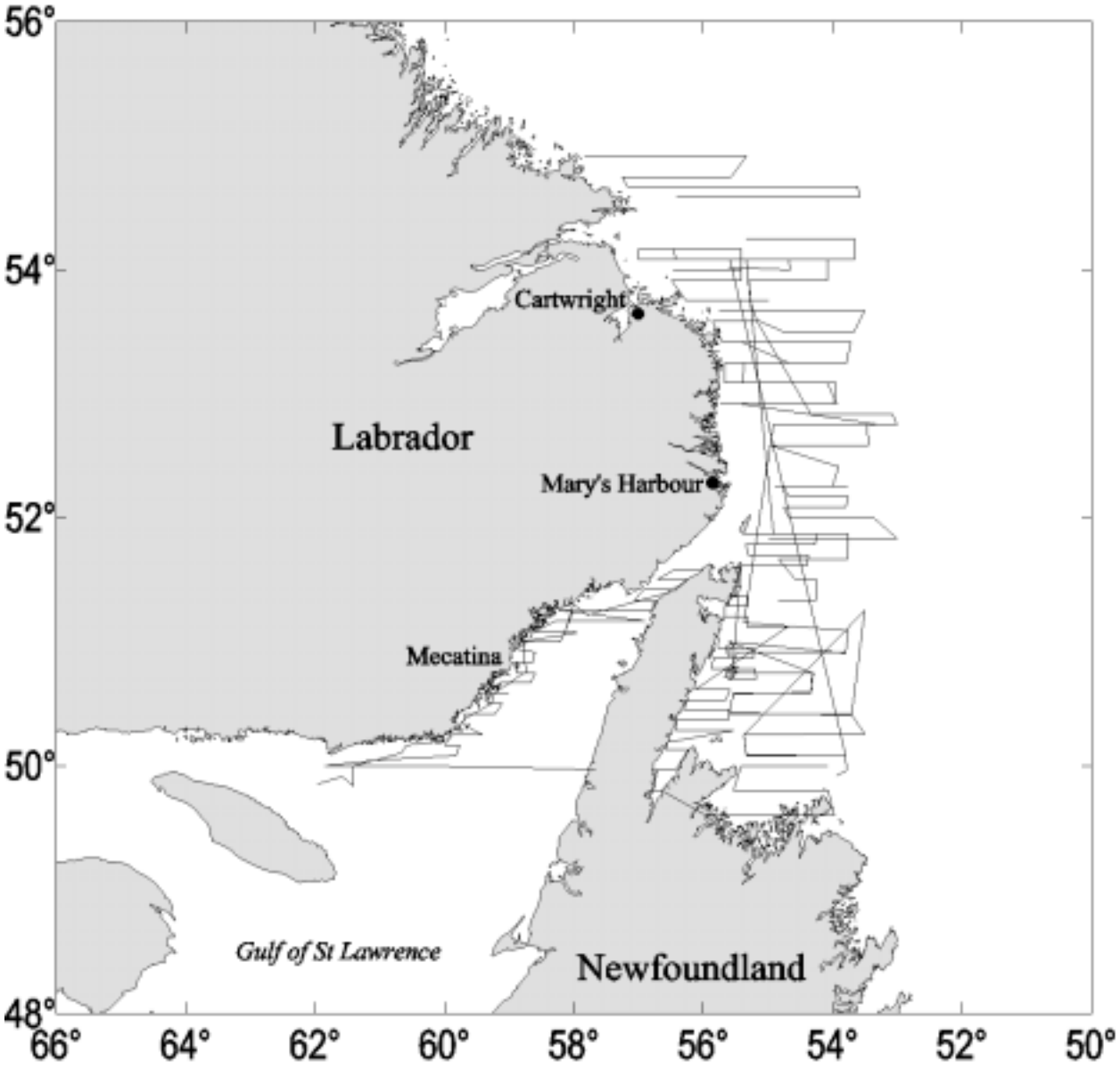

Figure 1. Reconnaissance surveys flown in the northern Gulf and off Newfoundland from 5 – 21 March 1999.

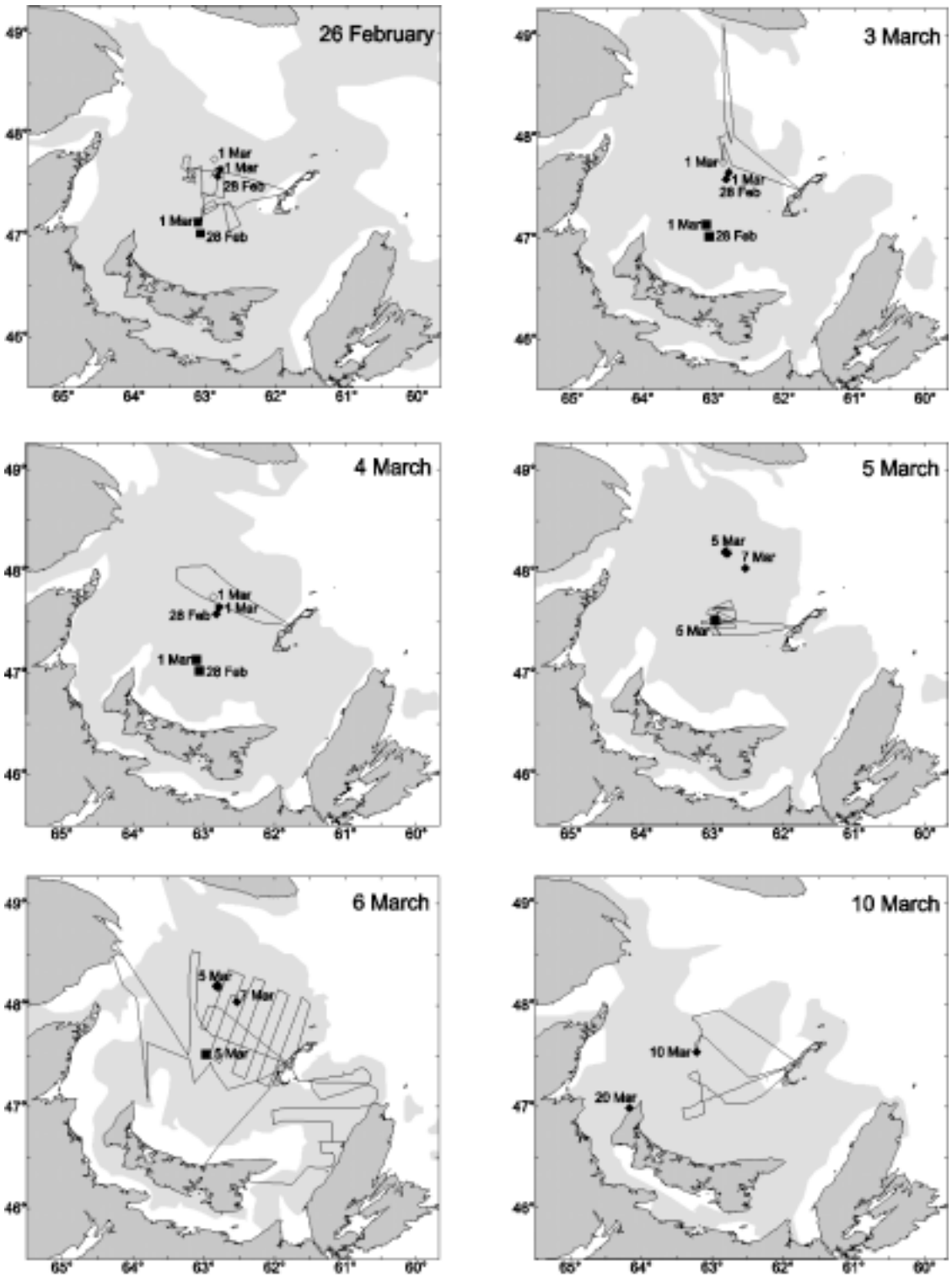

Figure 2 . Reconnaissance flown from 26 February to 15 March 1999. Areas with more than 50% of ice thicker than 15-30 cm are indicated by shade. Ice drift is represented by positions of VHF transmitters on the ice.

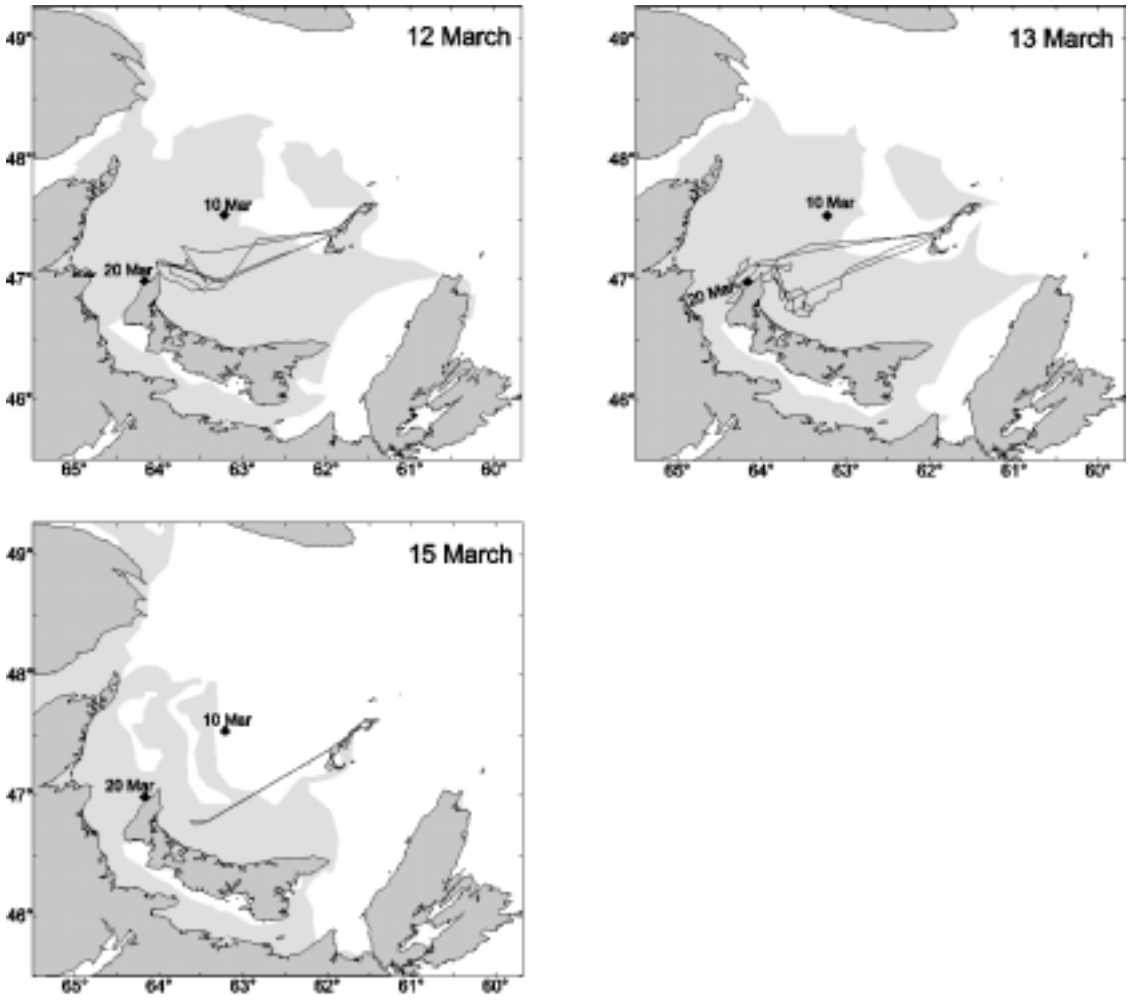

Figure 2 (con'd). Reconnaissance flown from 26 February to 15 March 1999. Areas with more than 50% of ice thicker than 15-30 cm are indicated by shade. Ice drift is represented by positions of VHF transmitters on the ice.

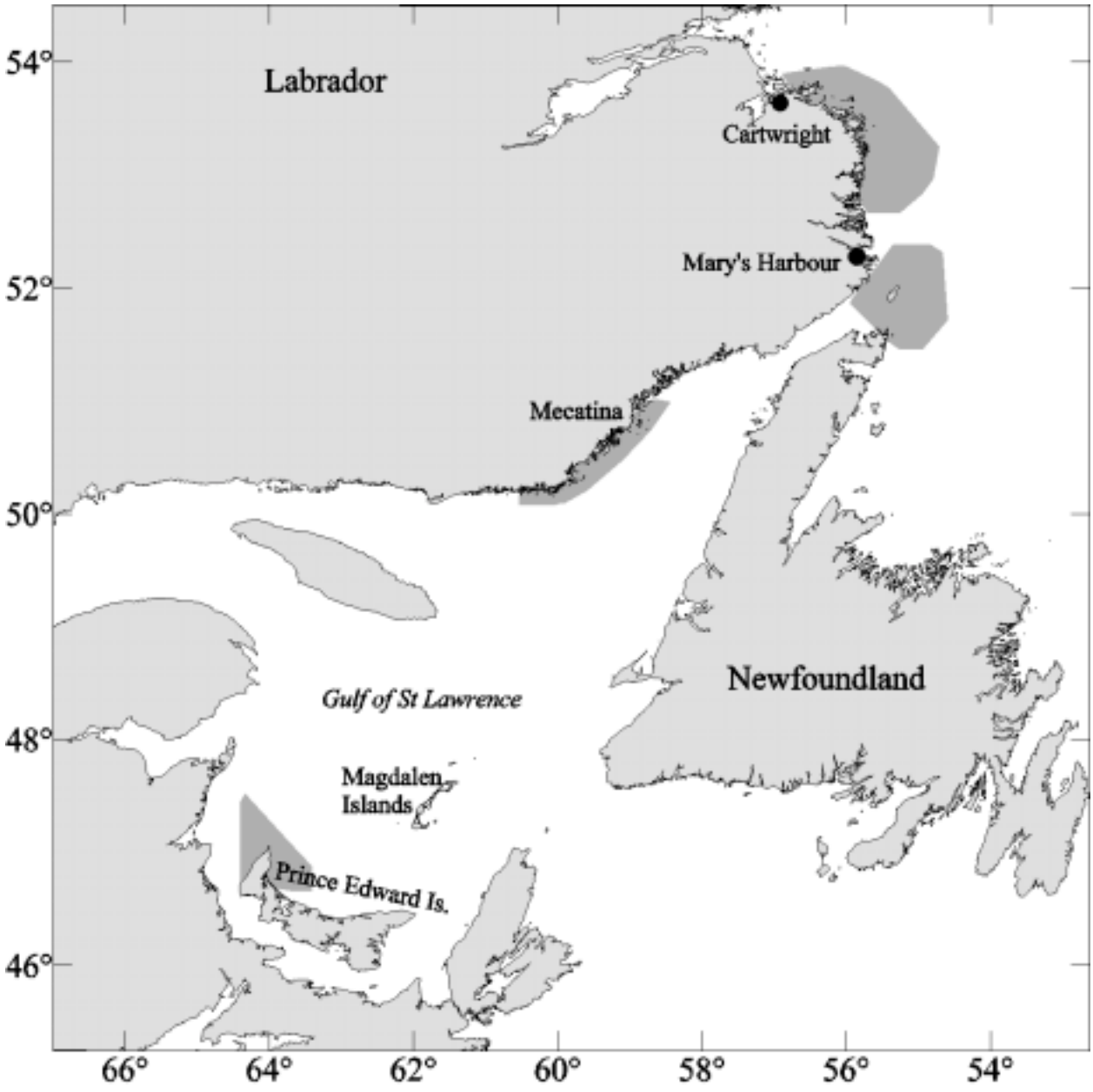

Figure 3. Positions of the 4 patches of harp seal surveyed in the Northwest Atlantic in March 1999.

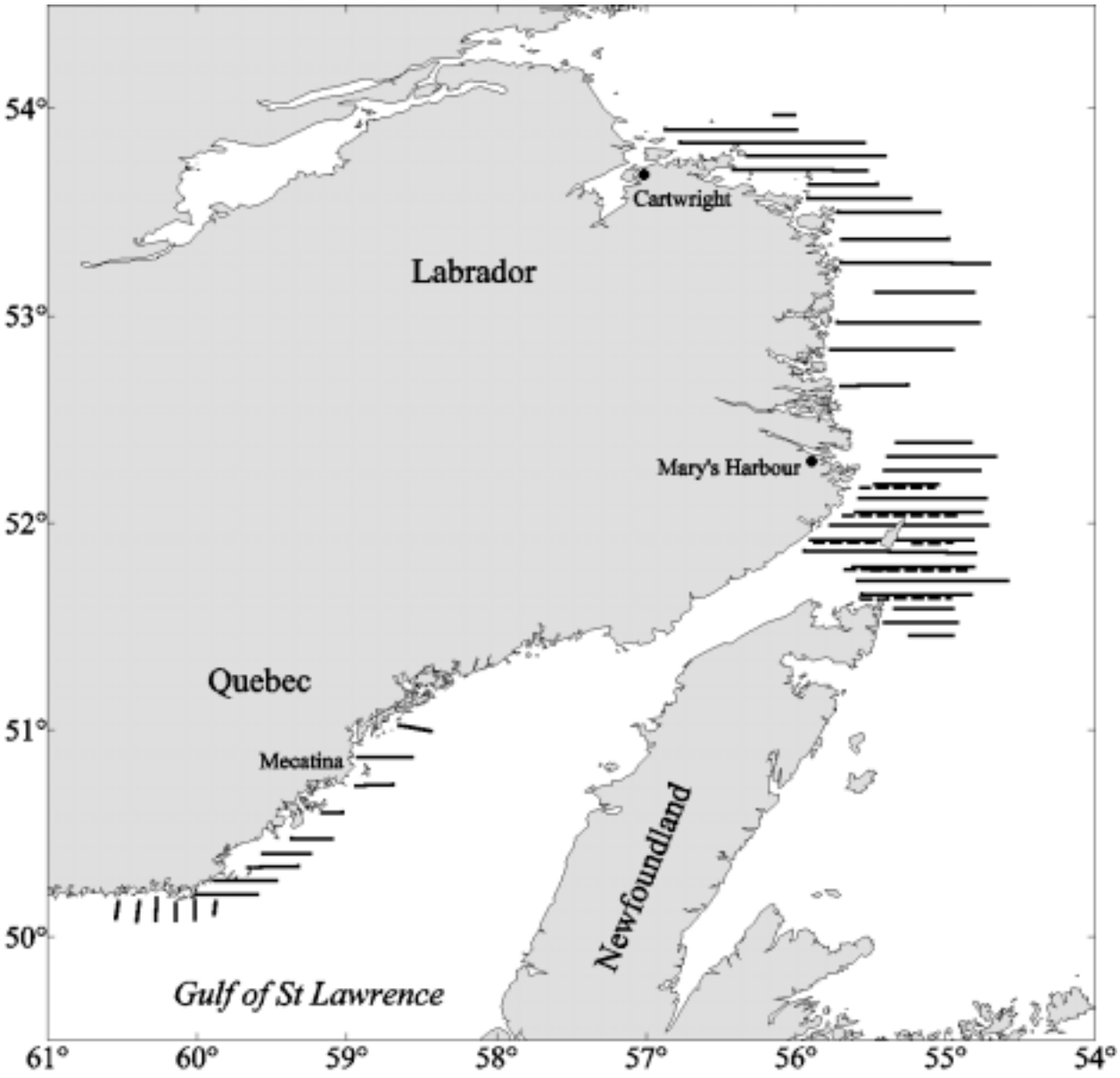

Figure 4. Photographic survey transects flown off Labrador and in the northern Gulf of St Lawrence from 21 to 24 March 1999. Mary's Harbour patch was surveyed on 21 March (dotted lines) and 24 March (solid lines).

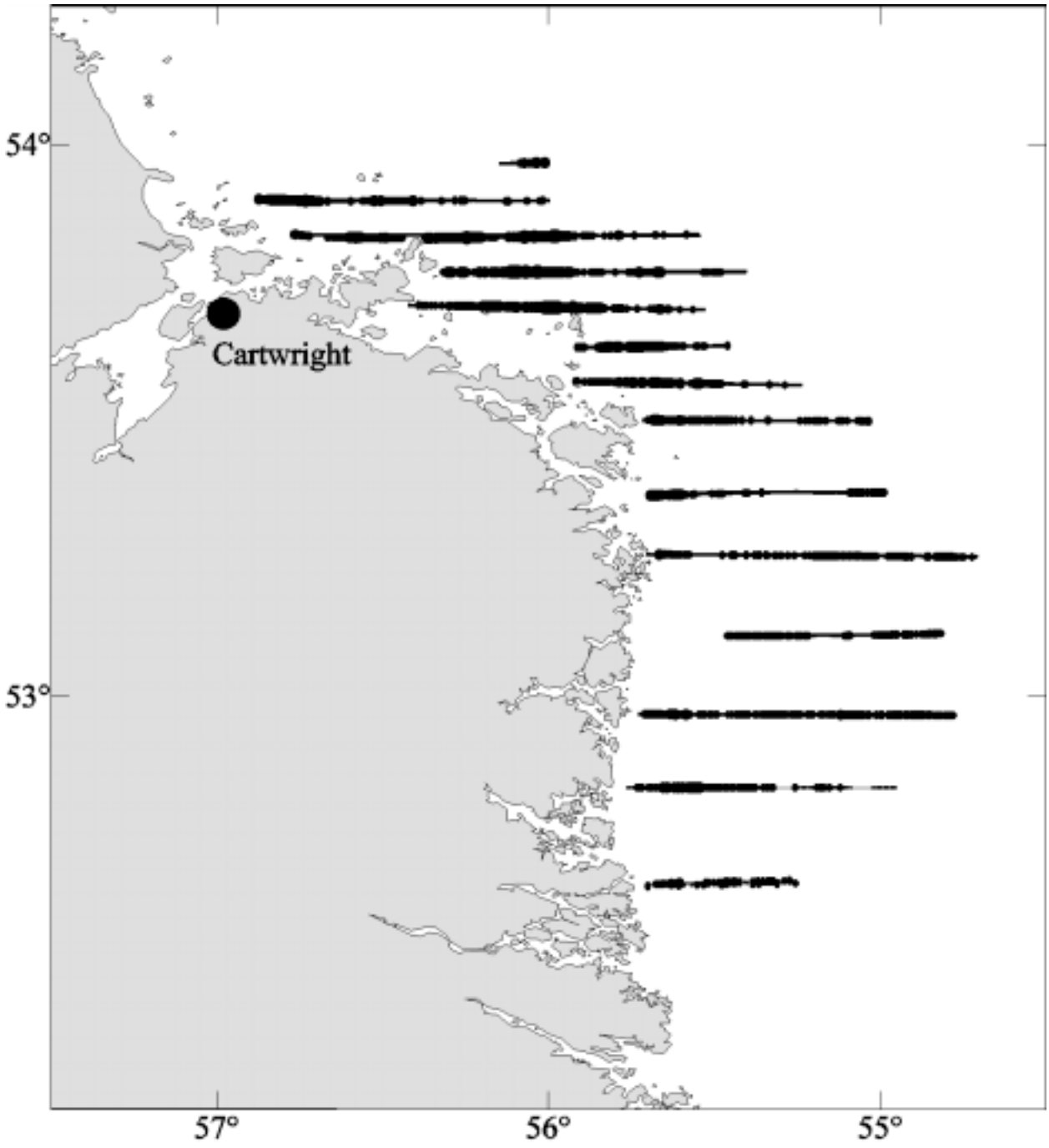

Figure 5. Photographic survey transects flown on Cartwright patch on 22 March 1999. Higher densities of seals are represented by wider sections.

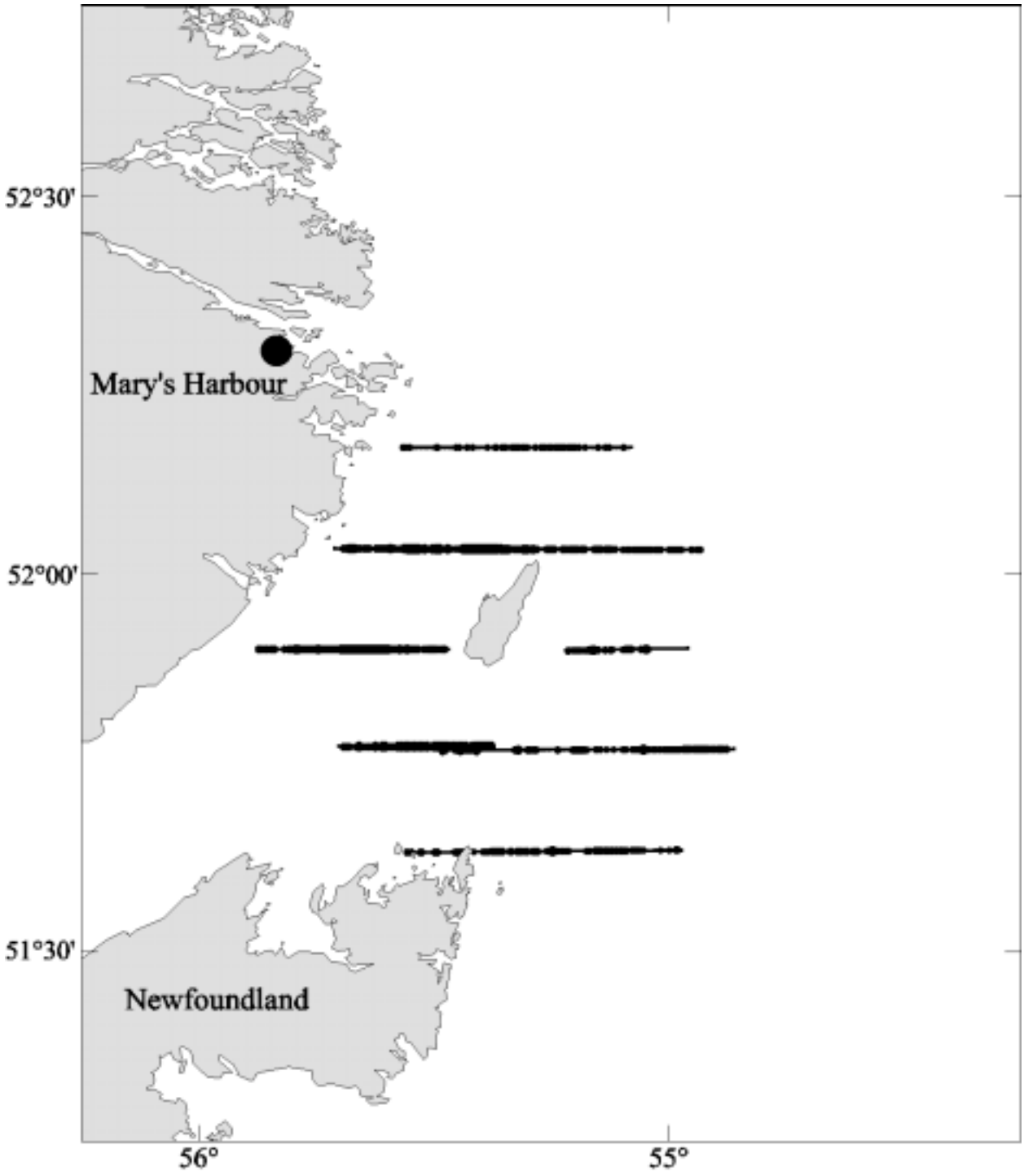

Figure 6. Photographic survey transects flown on Mary's Harbour patch on 21 March 1999. Higher densities of seals are represented by wider sections.

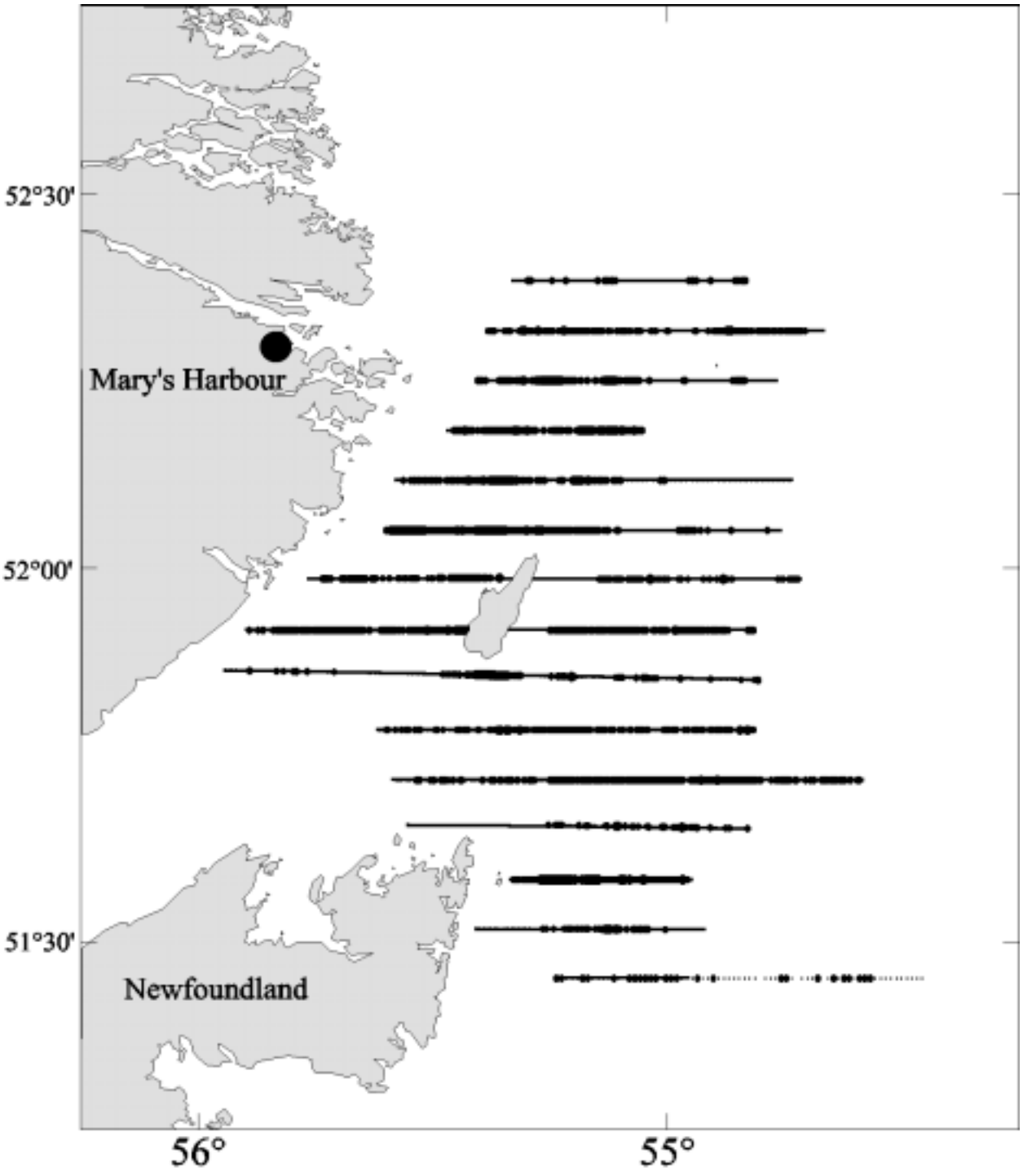

Figure 7. Photographic survey transects flown on Mary's Harbour on 24 March 1999. Higher densities of seals are represented by wider sections.

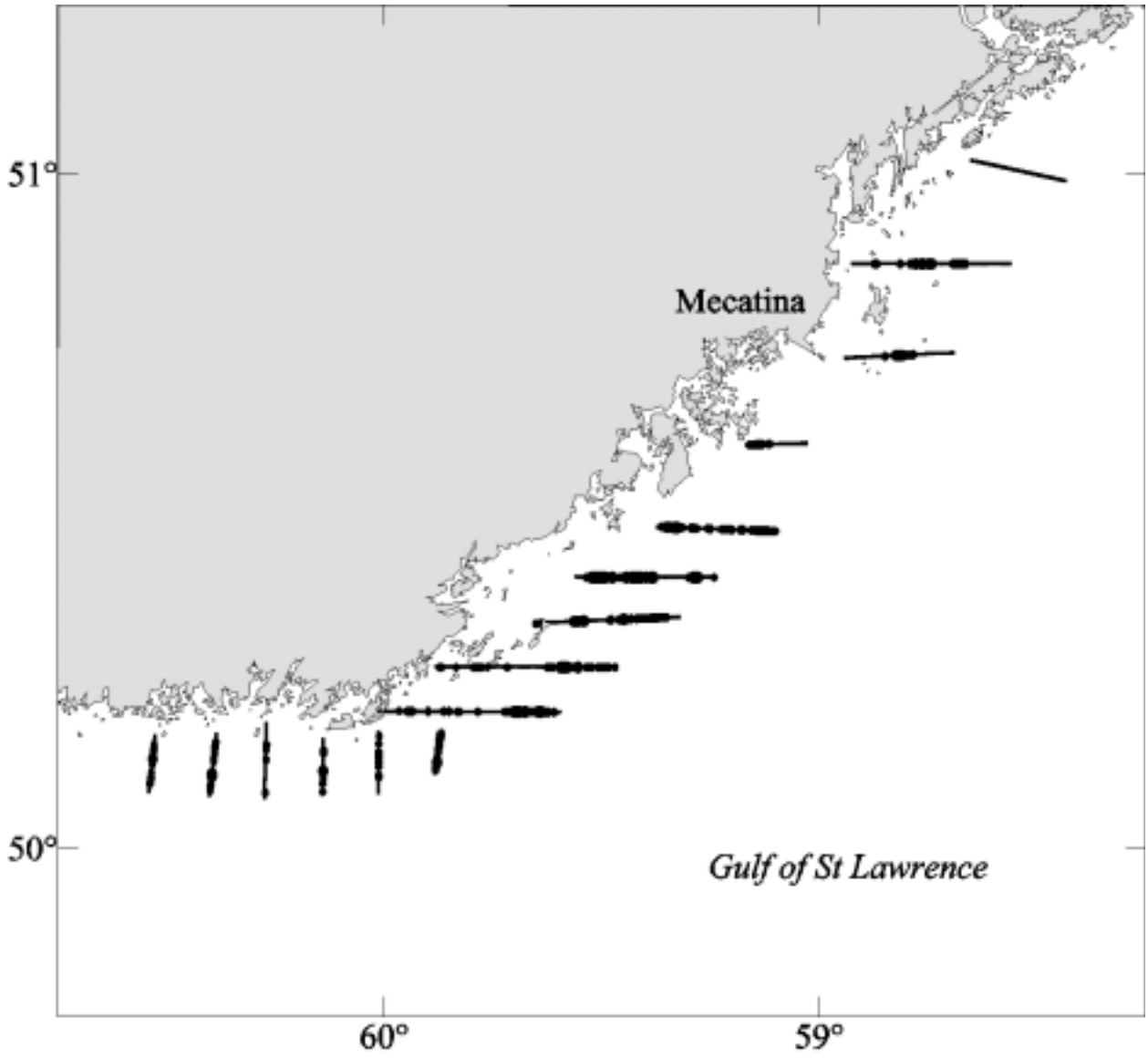

Figure 8. Photographic survey transects flown on Mecatina patch on 21 March 1999. Higher densities of seals are represented by wider sections.

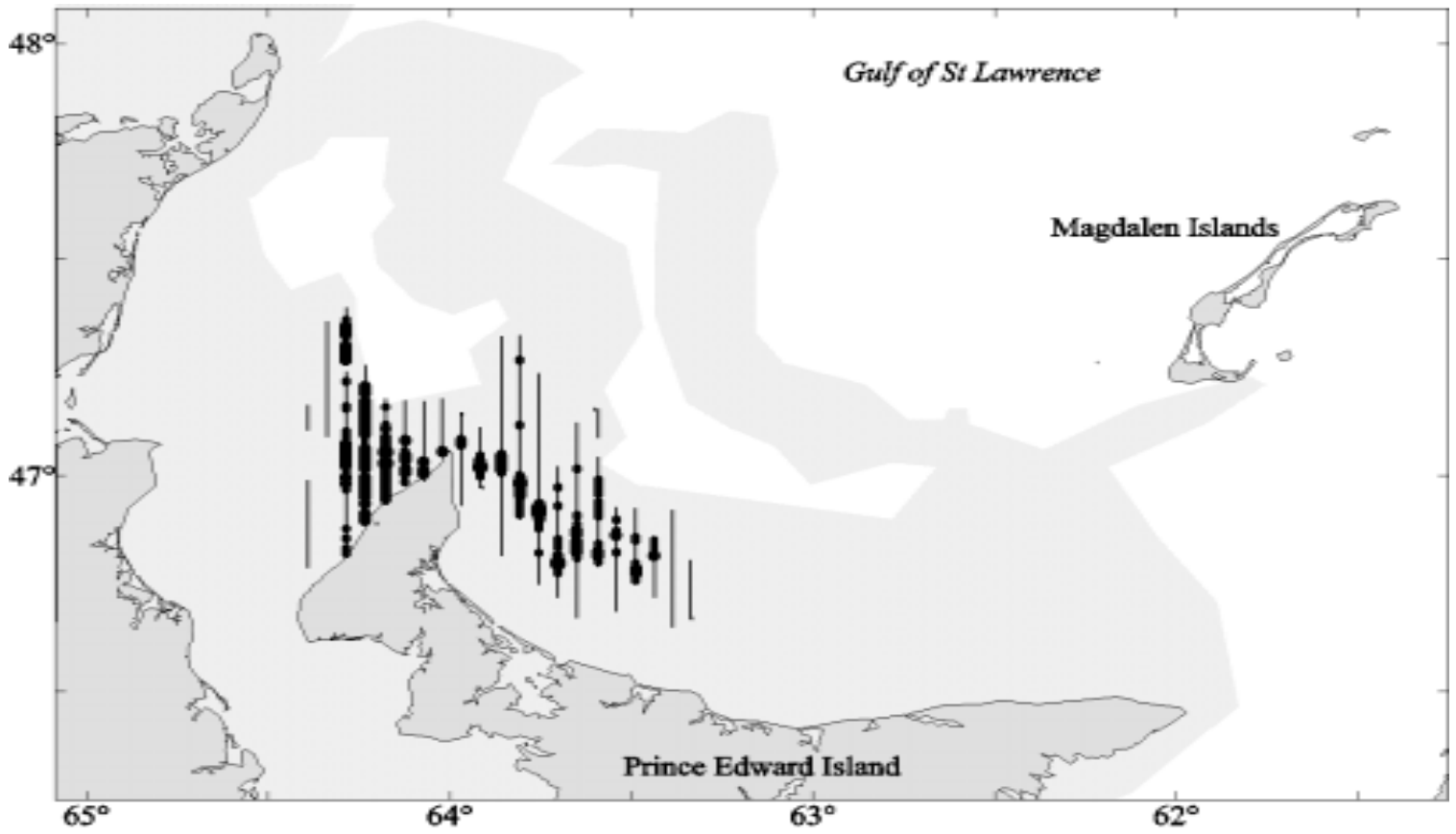

Figure 9. Photographic survey transects flown in the southern Gulf of St Lawrence on 14 March 1999. Areas with more than 50% of ice thicker than 15-30 cm are indicated by shade

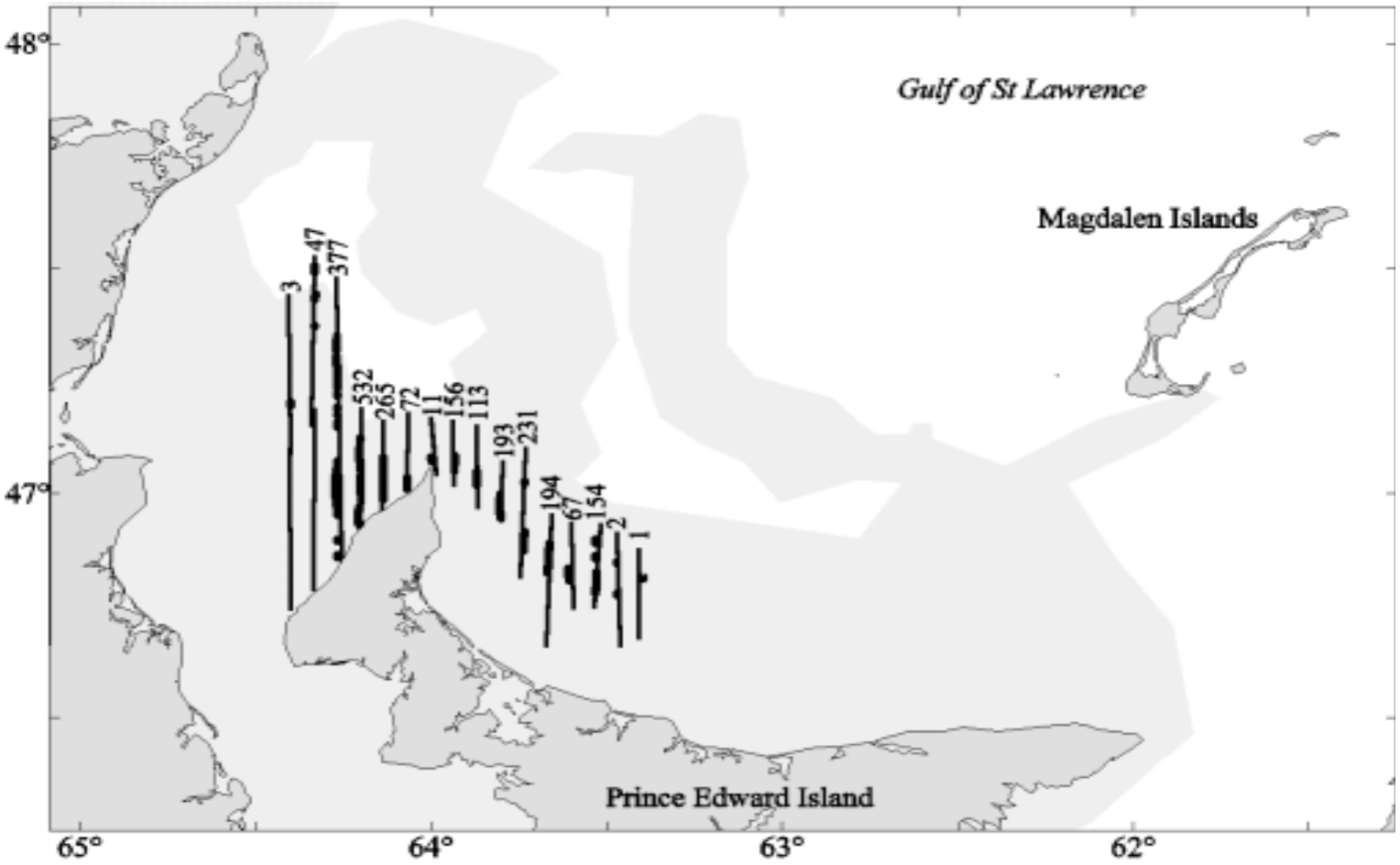

Figure 10. Visual survey transects flown in the southern Gulf of St Lawrence on 14 March 1999. Areas with more than 50% of ice thicker than 15-30 cm are indicated by shade. The number of seals counted are indicated at the end of each line.