Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

C S A S | **S C C S**

Canadian Science Advisory Secretariat | **Secrétariat canadien de consultation scientifique**

Research Document 2006/067 | **Document de recherche 2006/067**

Not to be cited without permission of the authors * | Ne pas citer sans autorisation des auteurs *

2005 Pup Production of Hooded Seals, *Cystophora cristata*, in the Northwest Atlantic

Production de nouveaux-nés chez les phoques à capuchon, *Cystophora cristata*, dans l'Atlantique Nord-Ouest en 2005

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

[1] Science Branch,
Fisheries and Oceans Canada
P.O. Box 5667
St. John's NL A1C 5X1

[2]Science Branch
Fisheries and Oceans Canada
Institute Maurice Lamontagne
P.O. Box 1000
Mont-Joli QC G5H 3Z4

ISSN 1499-3848 (Printed / Imprimé)

Canada

ABSTRACT

Photographic and visual aerial surveys to determine current pup production of Northwest Atlantic hooded seals (*Cystophora cristata*) were conducted off Newfoundland, in the Gulf of St. Lawrence in March 2004, and off Newfoundland, in the Gulf and in Davis Strait during 2005. Surveys in the Gulf and Front were corrected for the temporal distribution of births and the mis-identification of pups by readers. In 2004, pup production at the Front was estimated to be 123,862 (SE = 18,640, CV = 0.150). Pup production in the Gulf was estimated to be 1,388 (SE = 298, CV = 0.216) although this is considered to be negatively biased. In 2005, pup production at the Front was estimated to be 107,013 (SE = 7,558, CV = 0.071) while 6,620 (SE = 1,700, CV = 0.258) pups were estimated to have been born in the Gulf. Pup production in the Davis Strait whelping concentration was estimated to be 3,346 (SE = 2,237, CV = 0.668). Combing these areas resulted in an estimated pup production in the three northwest Atlantic whelping areas of 116,900 (SE = 7,918, CV = 6.8%). Comparison with previous estimates suggests that pup production may have increased since the mid 1980s. However, understanding if abundance has changed is hampered by our lack of understanding of the relationship among whelping areas.

RÉSUMÉ

On a effectué des relevés aériens (photographiques et visuels) afin de déterminer la production actuelle de nouveau-nés chez les phoques à capuchon (*Cystophora cristata*) dans l'Atlantique Nord Ouest au large des côtes de Terre-Neuve et dans le golfe du Saint-Laurent en mars 2004, de même qu'au large des côtes de Terre-Neuve, dans le Golfe et dans le détroit de Davis en 2005. Les résultats des relevés dans le Golfe et dans la région du Front ont été corrigés en fonction de la répartition temporelle des naissances et des erreurs d'identification des nouveau-nés commises par les lecteurs. En 2004, la production de nouveau-nés dans la région du Front a été estimée à 123 862 individus (erreur type = 18 640, CV = 0,150). La production de nouveau nés dans le Golfe a été estimée à 1 388 individus (erreur type = 298, CV = 0,216), mais ce nombre est considéré comme biaisé négativement. En 2005, la production de nouveau nés dans la région du Front a été estimée à 107 013 individus (erreur type = 7 558, CV = 0,071), tandis qu'on estimait que 6 620 nouveau nés (erreur type = 1 700, CV = 0,258) avaient vu le jour dans le Golfe. La production de nouveau-nés dans les aires de mise bas du détroit de Davis a été estimée à 3 346 individus (erreur type = 2 237, CV = 0,668). En combinant ces deux aires, on a pu estimer la production de nouveau nés dans les trois aires de mise bas de l'Atlantique Nord-Ouest à 116 900 individus (erreur type = 7 918, CV = 0,068). La comparaison des résultats avec des estimations antérieures semble indiquer une augmentation possible de la production de nouveau nés depuis le milieu des années 1980. Cependant, on ne peut déterminer si l'abondance a varié, car on comprend mal les rapports entre les aires de mise bas.

INTRODUCTION

Two populations of hooded seals (*Cystophora cristata*) are recognized in the North Atlantic. The Greenland Sea population whelps during March on the pack ice in Jan Mayen Island (West Ice) while the Northwest Atlantic population is considered to consist of seals that whelp in Davis Strait, off the coast of Labrador/Newfoundland (Front) and in the Gulf of St. Lawrence (Gulf) (Sergeant 1974; Bowen et al. 1987; Hammill et al. 1992; Stenson et al. 1997). The largest concentration of pupping occurs off the Front. Using sequential population analyses or survival indices, researchers estimated hooded seal pup production at the Front to be approximately 30,000 (Øritsland and Benjaminsen 1975; Sergeant 1976; Lett 1977, Winters and Bergflodt 1978). However, independent aerial survey estimates of pup production in the mid 1980s indicated that pup production was approximately 62,000 during the 1980s (Bowen et al 1987; Hay et al 1985) and 83,000 in 1990 (Stenson et al. 1997). There is less known about the abundance of animals in Davis Strait and in the Gulf. Bowen et al. (1987) estimated pup production in Davis Strait to be approximately 18,600 in 1984 based on an aerial survey. Fewer pups are born in the Gulf, with the most recent published estimates from aerial surveys being 2,000 and 4,000 animals in 1990 and 1994, respectively (Hammill et al. 1992, 1997).

Northwest Atlantic hooded seals have been hunted throughout their range for commercial and subsistence needs. Catch data are available from the Newfoundland commercial harvest from as early as 1895 (Sergeant 1974). Quotas limiting the catch were first instituted in 1964, with the closure of hooded seal hunting in the Gulf and limiting the Front catches to a quota of 15,000 animals (Hammill et al. 1992; Stenson et al. 1997). Due to poor markets resulting from an import ban on young hooded seals ('bluebacks') to the European Economic Community, hooded seal catches declined after 1982 and changes in the Canadian Marine Mammal Regulations banned the commercial catch of bluebacks in 1987 (Anon 2003, 2006). With the exception of 1991, when over 6,000 were taken, annual catches were in the range of a few hundred until the mid 1990s. In 1996 a large number of bluebacks were taken illegally while a subsidy for meat resulted in 7,000 and 10,000 older seals being harvested in 1997 and 1998, respectively. Since then the annual harvest of hooded seals in Canadian waters has numbered only a few hundred with less than 50 taken in the past two years (Anon 2006). In contrast, a large subsistence harvests occur off southern Greenland, particularly along the southeastern coast (Anon 2006). Since the mid 1970s annual catches in Greenland have fluctuated between 3,000 and 10,000 with the catches being in the 6,000–7,000 range in most years (Anon 2006). Hooded seals are not usually caught in the Canadian Arctic (Anon 2005).

In 2001, the Eminent Panel recommended that the management of seals in Atlantic Canada should have explicit objectives based on a generic set of control rules and Reference Points. They also recommended that estimates of Northwest Atlantic hooded seal abundance be updated (McLaren 2001). In 2003, an objective based fisheries management approach was developed and implemented in the 2003 Atlantic seal management plan (Hammill and Stenson 2003, Anon. 2003). Under this management approach, NW Atlantic hooded seals are considered data poor because of a lack of information on abundance and reproductive rates. The objective of this study was to estimate pup production of hooded seals in the northwest Atlantic during 2004 and 2005 to provide a basis for estimating current abundance of this population.

METHODS

The survey used the same basic design developed for aerial surveys of harp seals and used in the previous hooded seal survey flown in 1990. Reconnaissance surveys were flown to detect all whelping concentrations, visual and photographic surveys were flown to obtain estimates of pups on the ice, and changes in the proportion of pups in age specific developmental stages were monitored to model the temporal distribution of births (Bowen et al. 1987; Hammill et al. 1992; Stenson et al. 1993, 1997, 2002, 2003, 2005).

IDENTIFICATION OF WHELPING AREAS

Whelping concentrations (`patches') were located using fixed-wing and helicopter reconnaissance surveys of areas historically used by hooded seals. At the Front and in the northern Gulf of St. Lawrence, fixed-wing reconnaissance flights were conducted almost daily from 5 to 20 March in 2004 (Fig. 2) and 8–23 March in 2005 (Fig. 5). 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°30’N and 54°40'N at the Front and between the Strait of Belle Isle (~50°50'N) and 49°N in the northern Gulf.

In the southern Gulf, reconnaissance surveys were flown between 1-25 March. Flights were completed to the north, west and south of the Magdalen Islands using helicopters, and by a fixed-wing aircraft working with DFO Conservation and Protection Branch. 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 concentrations. Once whelping seals were located, VHF, satellite linked GPS and/or satellite transmitters were deployed within each concentration to monitor their movements as the pack ice drifted during the survey period.

The location of whelping hooded seals in the Davis Strait was determined with the assistance of the Department of National Defence. Reconnaissance flights were planned to cover all suitable pack ice through east-west lines extending from the eastern edge of the pack ice and well within the solid pack ice to the west. These lines, spaced 10 nm (18.5 km) apart, extended from the entrance of the Hudson Strait (60°N) to the north of the area where the Davis Strait patch was located in the 1970's and 1980's (65°N) (Bowen et al 1987; Sergeant 1974, 1976, 1977) (Fig. 7).

ESTIMATES OF ABUNDANCE

2004

Visual surveys: Hooded seals abundance at the Front was estimated during the harp seal surveys described in Stenson et al. (2005). Visual aerial surveys were flown using two helicopters at an altitude of 30.5 m. Two observers seated in the rear counted all pups within a known area on each side of the aircraft with a total strip width of 40 m. Correct altitude and transect spacing were maintained using a radar altimeter and GPS navigation systems. Surveys were conducted on March 15 and 18.

Gulf surveys were carried out on 19 and 20 March using the same basic method as described for the Front. However, the Gulf surveys were flown at an altitude of 45.7 m with a total strip width of 100 m.

2005

Visual surveys: Visual aerial surveys were flown using the same methods as in 2004. Surveys were flown at an altitude of 45.7 m at the Front and in the Gulf. In the Gulf, the total strip width was 100 m while at the Front it was 123 m in one helicopter and 176 m in the other. Strip widths were confirmed after the survey by comparing sighting areas with known distances on the ground. Surveys in the southern Gulf were conducted on March 8, 12 and 21, while surveys at the Front were carried out on March 15, 17, 22 and 23. No surveys extended southward of the Strait of Belle Isle as hooded seal pupping was not observed in the northern Gulf.

The Davis Strait patch was surveyed using a Canadian Armed Forces Arcturus, equipped with four observer stations with bubble windows, two in front of, and two behind, wings. All flights were done with 4 observers on duty at a speed of 370 km/h (200 knots) and a target altitude of 152 m or 305 m for reconnaissance flights and a fixed altitude of 152 m (500 ft) for the strip transect survey on 21 March. Observers recorded all pups within a strip that varied for each observer. No pre-calibrated marks for strip width were identified on the aircraft before the survey, so existing marks were used which resulted in different strip widths for each observer. The two forward observers were recording all observations from the bottom of the window to the tip of the inboard engine and the aft observers were recording all observations from the bottom of the window to the outside of the exhaust of the inboard engines. Following the survey, the strip width was estimated using inclinometers for observers at each station given the survey altitude of 152 m (500 feet). Observations were recorded independently on micro-cassettes for the forward stations (and time stamp for one station), and by manual counters in the back. Total counts were reported by each observer at the end of each line.

Photographic Surveys: Fixed-wing aerial photographic surveys were flown at the Front only, 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 200 m. The images covered an area of 297.2 X 297.2 m per photo. The surveys were designed to provide over 90% coverage along a transect line with no overlap. Due to changes in wind conditions, photos overlapped along some transects on March 22. This overlap was removed prior to the analysis.

Cameras were turned on before seals were encountered on a transect line. Cameras were turned off when 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. The majority of 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.

Photographs were examined by two readers. On each photograph the position of each pup was recorded on a clear acetate overlay. After all photographs were examined, each reader reread a series of the photographs in sequence. Readings of photos continued until the counts

from the first and second readings differed by less than 5%. If 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 survey day was examined by both readers and compared to determine a `best estimate' of the number of pups present. The original counts (*x*) 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 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:

t = the uncorrected number of pups on photo *z* of transect *j*

j = transect number;

Z = the number of photos on the transect.

The variance associated with the reading corrections were summed over transects and multiplied by the weighting factor (k_i, see below) to estimate the total measurement-error for the survey and added to the sampling variance.

SURVEY ANALYSIS

All 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. Pup production was estimated using the methods outlined in Stenson et al. (1993, 2002, 2003, 2005) and are briefly described here. The number of pups for the ith survey was estimated by

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

where:

J_i = the number of transects in the ith survey;

k_i = weighting factor for the ith survey determined by dividing the transect interval by the transect width;

x_j = the number of pups on the jth 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 number of seals in the zth frame on the jth transect;

l_j = the total transect length;

p_j = the frame length.

The estimates of error 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 ith group;

X_{ij} = the number of pups counted on the jth transect in the ith group;

and the end transects are the limits of the survey area.

The variance estimate was given by:

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

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:

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

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 uncorrected estimate for survey *i*;

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 three age-dependent morphometric and pelage specific stages was determined repeatedly throughout the whelping period. A series of random, low-level (<10 m altitude) helicopter surveys were flown over each whelping concentration during which pups were classified as Newborn, Thin,Fat and solitary (Bowen et al. 1987). Stage durations were Thin (μ = 1.15 d, se 0.053, *n* = 45), and Fat (μ = 2.36 d, se = 0.107, *n* = 63), were obtained from Bowen et al. (1987). Bowen et al. (1987) were unable to estimate the duration of the Newborn stage, but suggested that it only last for about 3 h. Assuming a 40% coefficient of variation, resulted in a estimate of the duration of the Newborn stage (μ = 0.12 d, se = .05). The model does not use data on the proportion of solitaries.

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

RESULTS

IDENTIFICATION OF WHELPING AREAS

2004

Whelping hooded seals were found within the two harp seal whelping concentrations identified at the Front. The first was located off Cartwright, Labrador (53°32'N 55°36'W) on March 6 while the second was found off the coast of southern Labrador (52°17'N 55°25'W) near Belle Isle. Strong winds resulted in considerable ice movement during the study period. However, the movements of the concentrations were monitored through the use of nine (9) VHF and two (2) satellite transmitters. A detailed description of the reconnaissance flights carried out and movements of the whelping concentrations is given in Stenson et al (2005).

In the Gulf hooded seals traditionally whelp off the north coast of Prince Edward Island (PEI). In 2004, hooded seals were found off the northwestern tip of PEI between Cape Breton Island and Cape North.

2005

A series of whelping concentrations were located at the Front in 2005 (Fig. 1). A small group of hooded seal pups were located on 11 March at 51°53'N 53°49'W while a second group was located on 18 March along the east coast of the northern Peninsula centred around the Grois Island (50°49'N 55°41W). GPS transmitters deployed in the two groups indicated that they both drifted southward into Notre Dame Bay prior to being surveyed on 23 March. Pupping hooded seals were also located along the coast of Labrador, south of the Cartwright group on 13 March (referred to as the Black Tickle concentration). Strong winds subsequently pushed this group into the Strait of Belle Isle by March 20. Another group of whelping hooded seals was found in the lower Strait of Belle Isle on 18 March and drifted southward into the northern Gulf. Another large concentration of hooded seals was located off Cartwright, Labrador (53°45'N 56°17'W) on 17 March. Part of this group remained in the area on ice pushed into the shore and bays while some of the animals subsequently drifted southward along the Labrador coast. A small group was located on 19 March in White Bay where it remained during the survey period.

In the southern Gulf, the northern edge of the search area was limited by open water in the Laurentian Channel region, while unsuitable ice, consisting of small pans occurred more than 60 km to the west of the Magdalen Islands, limiting the extent of flights to the west. The ice was quite thin to the south of the Magdalen Islands early in the season, but as the season progressed, ice along the west side of the Magdalen Islands drifted south and around the islands. Although hooded seals traditionally pup south of the Magdalen Islands flights to this area indicated the presence of poor ice conditions in 2005. Suitable ice conditions for hooded seals extended about 20 km to the north, and 40 km to the west and south of the Magdalen Islands. Reconnaissance flights in the Gulf located hooded seals to the west of the Magdalen Islands. As the whelping season progressed, the majority of this ice drifted around the north end of the islands while some animals drifted around to the south.

Davis Strait reconnaissance surveys were flown on the 17, 18 and 20 March with 4 observers on duty at a speed of 370 km/h (200 knots) and an altitude ranging from 91 to 305 m (300-100 ft) depending on cloud cover (Fig. 7). The seal patch was located along the eastern limit of the ice edge on the 20 March with its northern limit at latitude of 65°22'N.

PHOTOGRAPHIC AND VISUAL SURVEYS OF PUP PRODUCTION

2004

Front: A visual survey of the southern (Belle Isle) concentration was flown on March 15 (Table 1, Fig. 2). 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 658 pups were counted resulting in an estimated pup production of 45,411 (SE = 3,838).

The visual survey of the northern (Cartwright) concentration was carried out on March 18 (Fig. 3). By this time the concentration had drifted south to the area previously occupied by the southern concentration three days earlier (see Stenson et al 2005 for a description of drift). A total of 556 pups were counted on 29 transects flown 3.7 km apart (Table 2). Pup production in this group was estimated to be 45,411 (SE = 3,838).

Southern Gulf: In the Gulf, systematic survey flights were flown on 19 and 20 March 2004 (Table 3, Fig. 4). Coverage was incomplete because animals detected on thin ice in the northwestern end of the patch were no longer visible at the time of the survey. Ice at the time was extremely thin, and when tested, was unable to support the weight of the helicopter. These animals are presumed to have drowned. Combing the two surveys, a total of 30 animals were counted on transect, resulting in an estimate of 1,127 (SE = 246.7) pups before correcting for births.

2005

Reader corrections: Correction factors were developed for both readers and for all days. The regressions of the 'true counts' on the individual reader counts were significant. In all cases the intercepts were not significantly different from zero and so the regressions were re-estimated without an intercept parameter. Generally, only small corrections were required to the original counts and there was good fit to the regressions (Table 4).

Front: Three separate groups of whelping hooded seals were located near Cartwright (Table 5). A visual survey of one small group was carried out on 15 March (Fig. 5). Nineteen (19) east-west transects were flown 975 m apart. A total of 67 pups were counted resulting in an estimated pup production of 532 (SE = 88). Two additional surveys were flown on 17 March, one consisting of 8 transects spaced 975 m apart while the other involved 13 transects 3.7 km apart. Based on the 23 pups observed during the first transect and 1,393 counted on the second, pup production in these two groups were estimated to be 124 (SE = 23.5) and 33, 521 (SE = 4,795), respectively. Combining these visual surveys resulted in an estimated 34,177 (SE = 4,796) pups in the area prior to correcting for the temporal distribution of births.

A photographic survey of this concentration was carried out on 22 March (Table 6, Fig. 6). By this time some of the pups surveyed earlier had drifted south along the Labrador coast. In the northern area 18 transects were flown with 3.7 km spacing. An additional 11 transects, spaced 5 nm (9.25 km) apart were flown further south. The number of pups present on the ice was estimated to be 48,879 (SE = 7,526).

The number of hooded seals present along the coast of southern Labrador (referred to as the Black Tickle concentration) was previously estimated on 18 March (Table 7, Fig. 6). A total of 11 transects spaced either 18.5 km (transects 1-3) or 9.25km (transects 3-11) resulted in an estimate of 11,427 (SE = 3,572) pups. Based on the movements of the transmitters, this

group had drifted into the Lower Strait of Belle Isle by the time of the 22 March survey in the same area.

Pupping in the Lower Strait of Belle Isle was estimated based upon 15 transects, spaced 4 nm (7.4km) apart, flown on 19 March, 2005 (Table 8, Fig. 6). A total of 1,327 (SE = 1,461) pups were estimated to be present on the ice.

During reconnaissance and staging flights on 22 March, a group of young pups were discovered in the Strait of Belle Isle. A survey was carried out on 23 March consisting of 43 transects flown at a spacing of 1.85 km (Table 9, Fig. 5). Survey data indicated that this group contained approximately 70% attended pups. Although estimates of drift indicated that the Black Tickle concentration were further south, it is possible that some of these animals were counted during the 18 March Black Tickle survey or drifted down from the Cartwright area. However, any animals born prior to the earlier surveys would have been weaned by 23 March. Therefore, we only estimated the number of attended pups in this group. A total of 13,276 (SE = 1,318) attended pups were estimated to be present on the ice on 23 March. This estimate is likely negatively biased as some of the solitary pups present may have drifted in on ice from the east of the earlier survey area or been born after the 18 March survey.

The pups located in White Bay were surveyed on 22 March. Fifteen (15) transects were flown with spacing of either 3.7 km (transects 1-11) or 1.85 km (transects 11-15) (Table 10, Fig. 5). Transects ended when the bay ice ended. Pup production was estimated to be 2,620 (SE = 230).

Two groups of seals, previously located northwest of St. Anthony and along the east coast of the northern Peninsula south of St. Anthony, drifted into Notre Dame Bay. This combined group was photographed on 23 March (Table 11, Fig. 6). The survey involved two components; one consisted of 11 north - south transects flown 4 nm (7.4km) apart while the other required 17 transects spaced at intervals of 4 nm (Transects 1-3), 2 nm (transects 4-11) and 4 nm (transects 11-17). Pup production was estimated to be 24,823 (SE = 3,201).

Southern Gulf: In the southern Gulf, two groups were identified on 7 March. Systematic visual surveys were flown over a western patch on 8 March and an eastern patch on 12 March (Table 12, Fig. 4). A total of 82 pups were counted during the 8 March survey resulting in an estimated abundance of 2,584 (SE = 1,285). Seventeen animals were counted during the 12 March survey resulting in an estimated abundance of 315 (SE = 498) animals. As the season progressed, the distinction between the two patches disappeared due to ice movement and additional pupping. This resulted in a third visual survey of the whole region. A total of 55 animals were counted during the 21 March survey resulting in an estimated abundance of 6,445 (SE =1,751) animals. (Table 12).

Davis Strait: Thirteen east-west lines were surveyed on the 21 March from 65°22'N to 64°58'N (Table 13, Fig. 7). The lines extended from the eastern ice edge and they were terminated to the west after an extended period (>5 min) without detecting seals or seal tracks on the ice. One experienced observer completed the whole survey at the port forward station, while 2 observers rotated at all other stations after the first 6 transects. The difference in counts between the experienced observer, and the less experienced observers suggested that the latter were missing pups along the high density transects. Based on this observation, our most reliable estimate was considered to be the one produced using only the transect densities recorded by this experienced observer who was also on duty for the whole survey (port forward). A total of 414 bluebacks were counted by this observer resulting in an abundance estimate of 3,346 (SE = 2237). The estimates using only the total counts of 149, 159 and 160

for the starboard forward, port aft and starboard aft stations respectively, provided abundance estimates of 2,203 (SE = 1200), 3,514 (SE = 1878) and 3,749 (SE = 2786).

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 in both 2004 and 2005. The data obtained are presented in Table 14 and 15. Staging at the Front in 2005 was limited due to poor weather conditions. No staging data were obtained from the Davis Strait whelping concentration.

The majority of surveys required only minor corrections to account for pups that had not been born at the time of the survey (Table 16). With a few exceptions, more than 70% of the pups were estimated to be present on the ice during the surveys. The model did not fit well to the 2004 Front staging data or surveys of the Black Tickle and Lower Straits concentrations in 2005. Although we were unable to model the timing of births in White Bay during 2005, no attended pups were present on the day of the survey and it was assumed that no correction was necessary.

ESTIMATING TOTAL 2005 PUP PRODUCTION

Table 17 presents the estimated hooded seal pup production in 2004 and 2005 after adjusting the survey estimates to take into account births occurring after the surveys were flown. Combining the two surveys carried out at the Front in 2004 resulted in an estimated pup production of 123,862 (SE = 18,640, CV = 0.150). Pup production in the Gulf was estimated to be 1,388 (SE = 298, CV = 0.216) although this is considered to be negatively biased.

In 2005, pup production at the Front was estimated to be 107,013 (SE = 7,558, CV = 0.071) while 6,620 (SE = 1,700, CV = 0.258) pups were estimated to have been born in the Gulf. Pup production in the Davis Strait whelping concentration was estimated to be 3,346 (SE = 2,237, CV = 0.668). Combing these three areas resulted in an estimated pup production in the three northwest Atlantic whelping areas of 116,900 (SE = 7,918, CV = 6.8%).

DISCUSSION

The methods used in this survey are very similar to those used during the 1984 and 1990 surveys (Bowen et al. 1987; Hammill et al. 1992; Stenson et al. 1997). The basic design involves detecting concentrations of whelping animals, estimating the number of animals present on the ice, and correcting these estimates for any births that may have occurred after the counting surveys have been flown. Using this approach, the estimates are most sensitive to the assumption that all pupping concentrations were detected and surveyed (Myers and Bowen 1989).

Previous surveys of pack-ice breeding harp, hooded and grey seals, have corrected survey estimates for births that have occurred after the survey flights (Bowen et al. 1987, Hammill et al. 1992; Stenson et al. 1997, 2003; Hammill and Gosselin 2005). In hooded seal surveys completed in 1984 (Bowen et al. 1987), 1990 (Stenson et al. 1997) and 1991 (Hammill et al. 1992) pups were classified into four stages, assumptions were made concerning the start date of birth, and a log-logistic, normal or gamma distribution were fit to the stage data to determine the temporal distribution of births. In a 1999 survey of harp seals, a new method was developed that used only three stage categories and assumed that the temporal distribution of

births could be described by a normal distribution (Stenson et al. 2003). This model was used to estimate the temporal distribution of births in 2004 and 2005. The model was also applied to the 1991 and 1994 surveys of hooded seal pupping in the Gulf (Hammill et al.1992, 1997). The resulting estimate of pup production in 1991 decreased slightly from 2,000 (SE = 190) to 1,700 (SE = 130, Table 18). This slight decrease is consistent with earlier findings on harp seals that suggested that corrections obtained from the normal model are more conservative than the those obtained from the previous one (Stenson et al. 2003). The 1994 estimate, however, increased significantly from 3,978 (SE = 974) to 8,652 (SE = 1,767) as no correction had been applied previously.

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, are less costly 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. At the same time, photographic surveys are much more time consuming to analyse (equivalent to 1.5 person years in the current survey), and are more difficult logistically to set up because the 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, 2005, 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. Also, each survey method has its own biases. By combining estimates using different methods, we endeavour to reduce the impact of biases associated with a single method. For these reasons, we do not feel that it is appropriate to use only a single survey method for Northwest Atlantic harp and hooded seals.

Although the distribution of pupping in the Gulf was similar to the historical pattern, at the Front pupping appeared to be highly dispersed in 2004 and 2005. Whelping females were found over large areas from southern Labrador (approximately 54°N) to Notre Dame Bay and into the Strait of Belle Isle. Throughout these areas, low density concentrations were found that covered large areas. This is in contrast to previous studies (Bowen et al. 1987, Stenson et al. 1997) that found relatively dense concentrations within areas of lower density pupping (referred to as ‘scattered’). Hooded seal pupping was generally outside of the harp seal whelping concentrations that are present at the same time. These distinctions were not obvious in 2004 and 2005; the hooded seals were mixed with the harps and spread over the entire area at a similar density. The differences are likely due to the lower ice coverage and the strong winds encountered during this study. This resulted in more mixing between the two species and allowed us to estimate hooded seal pup production in 2004 during the harp seal survey (Stenson et al. 2005).

It is difficult to determine how the abundance of northwest Atlantic hooded seals has changed. Although births occur during the month of March, they are often spread over a number of weeks and the timing of peak births appears to vary among concentrations and/or years resulting in large corrections for the timing of births in some surveys. Also, hooded seals are often dispersed over large areas at low concentrations which can make surveys difficult to carry out and as a result, estimates are often imprecise. The degree of precision in the survey estimates varies greatly among years due, in part, to changes in the distribution of the seals and/or ice. The estimates of standard errors are greater if the seals are clumped. Also, combining multiple surveys of individual concentrations (e.g. visual and photographic survey of Cartwright patch in 2005) will also improve the precision of the estimate.

Although visual and photographic surveys are often consider underestimates, the degree to which they may occur is difficult to determine. Unlike harp seals, hooded seals are easier to locate on photographs with their dark backs. Also, pups are usually found in low densities which make them easy to count during visual surveys. Therefore, reader or counter errors are likely to be small when estimating pup production of hooded seals. However, because pupping tends to be highly dispersed, it is possible to miss animals, especially as they are often found along the edges of the pack ice. The loss of pups before the 2005 survey in the Gulf resulted in an underestimate of this component of pupping. Given the large area, some pups may also have been missed in the Davis Strait despite the extensive reconnaissance. The limited ice present, repeated coverage and similarity of the two estimates between 2004 and 2005 suggests that pup production at the Front was well estimated. Since this component accounts for such a large portion of the total pupping, underestimates in the other areas would be unlikely to change our understanding of total pupping significantly.

There is also considerable uncertainty about the relationships among the three whelping areas considered to be part of this population. Seals from all three areas are known to migrate to the Denmark Strait to moult and to overlap in the northern feeding areas. Preliminary results of genetic analysis indicate that the three areas cannot be distinguished using either mitochondrial DNA or microsatellites (Coltman et al. [in press]). However, these techniques may be uninformative for this question as it does not distinguish northwest Atlantic seals from Greenland Sea hooded seals which are considered to be a separate population. Therefore, it is not possible to determine if the three whelping areas identified for the northwest Atlantic population represent independent breeding groups that have not differentiated significantly to be identified using DNA or are in fact, part of a single population with some, possibly limited, exchange among them.

If each whelping area is considered separately, it would appear that pup production at the Front has increased from ~62,000 in the mid 1980s to ~115,000 in the mid 2000s (Table 18). An increase in pup production may be expected based upon the reduced level of hunting that has occurred in this area; with the exception of some high catches in the late 1990s, Canadian catches have remained low with less than a few hundred taken annually (Stenson 2006). However, these estimates would represent an annual increase in pup production of approximately 3% per year which is lower than that seen in harp seals prior to the resumption of the large scale Canadian hunt in the mid 1990s (Stenson et al. 2005). This slower rate of increase may be due to catches in Greenland and the high Canadian catches of the mid 1990s (Stenson 2006), the higher level of unreported mortality estimated when fitting the population model (Hammill and Stenson 2006) and/or low reproductive rates which are poorly estimated with current data. The survey estimates for the Gulf component are highly variable ranging from less than 2,000 to 8,700 between 1990 and 2005. This variability may reflect interannual differences in timing or location of pupping in the Gulf and/or the *ad hoc* nature of some of these surveys. Only two estimates of pup production in Davis Strait are available. These suggest a decrease in pup production from 1984 to 2005 possibly due to hunting in

Greenland, but may reflect the limited nature of the recent survey. Alternatively, changes among the different areas may reflect a possible redistribution of seals among the whelping areas, possibly due to changes in local environmental conditions.

If you assume that northwest Atlantic hooded seals whelp in all three areas and that interchange can occur among them, we are limited in having only a single estimate from all three areas in the same year (2005). This situation appears to occur among harp seals that whelp in the Gulf of St. Lawrence and at the Front (Stenson et al. 2003, 2005). A total of 81,400 (SE = 11,924) hooded seal pups were born at the Front and in Davis Strait in 1984 (Table 19). Assuming a relatively small number of seals pupping in the Gulf, total pup production would be only slightly higher. Comparing this estimate to the combined estimate for 2005 (116,900 SE = 7,916) suggests that the population may have increased slightly over this period (Z-test, $p < 0.5$).

Although poor ice conditions have occurred a number of times in the past, the frequency of poor ice years, particularly in the southern Gulf of St. Lawrence, appears to have increased in recent years (Hammill and Stenson 2005, 2006). Hooded seals are adapted to transient ice conditions; for example, their nursing period is extremely short (average of 4 days, Bowen et al. 1985). However, poor ice and/or storms during the whelping period can result in increased mortality among young as was observed in 2005 (Stenson, pers. observation). If poor ice conditions or frequent storms continue (or increase), changes in whelping locations or population growth rates may occur. Therefore, continued monitoring of this population is important to determine how this species, which is dependent upon ice for pupping and other important periods of its life history, copes with changes to the climate of the northwest Atlantic.

ACKNOWLEDGEMENTS

We thank W. Penney, D. McKinnon, D. Wakeham, B. Stockwood, J. Drew, P. Carter, T. Haug, L. Lindstrom, S. Tucker, P. Abgrall, D. Austin, 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 captains and crew of the CCGS Ann Harvey provided us with a safe haven. We also thank the pilots and crew of the DND aircraft we flew to Davis Strait. We are especially grateful to D. Wakeham, and D. McKinnon for reading the photos. Support for this work was provided under the Atlantic Seal Research Program Department of Fisheries and Oceans Strategic Research Fund.

REFERENCES

Anonymous 2003. Atlantic seal hunt 2003-2005 management plan. Available at: http://www.dfo-mpo.gc.ca/seal-phoque/reports-rapports/mgtplan-plangest2003/mgtplan-plangest2003_e.htm#3

2005. The Nunavut Wildlife Harvest Study. Nunavut Wildlife Management Board. Iqaluit Nunavut.

2006. Report of the Joint ICES/NAFO Working Group on Harp and Hooded Seals (WGHARP). ICES CM 2006/ACFM:6.

Bowen, W.D., Oftedal, O.T., and Bowness, D.J. 1985. Birth to weaning in 4 days: remarkable growth in the hooded seals, *Cystophora cristata*. Can. J. Zool. 63:2841-2846.

Bowen, W.D., Myers, R.A., and Hay, K. 1987. Abundance estimation of a dispersed, dynamic population: hooded seal (*Cystophora cristata*) in the Northwest Atlantic. Can. J. Fish. Aquat. Sci. 44:282-295.

Coltman, D.W., Stenson, G., Hammill, M.O., Haug, T., Davis, C.S. and Fulton. T.L. In press. Panmictic population structure in the hooded seals (*Cystophora cristata*). Molecular Ecology. 00:000-000.

Hammill, M.O.and Gosselin J.-F. 2005. Pup production of non-Sable Island grey seals, in 2004. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/033.

Hammill, M.O. and Stenson, G.B. 2003. Application of the Precautionary Approach and Conservation Reference Points to the management of Atlantic seals: A Discussion Paper. DFO Can. Sci. Advis. Res. Doc. 2003/067. 23 p.

2006. Abundance of northwest Atlantic hooded seals (1960-2005). DFO Can. Sci. Advis. Sec Res. Doc 2006/068.

Hammill, M.O., Lyderson, C., Kovacs, K.M., and Sjare, B. 1997. Estimated fish consumption by hooded seals (*Cystophora cristata*), in the Gulf of St. Lawrence. J. Northw. Atl. Fish. Sci. 22: 249-257.

Hammill, M.O., Stenson, G., and Myers, R.A. 1992. Hooded seal pup production in the Gulf of St. Lawrence. Can. J. Fish. Aquat. Sci. 12: 2546-2550

Hay, K., Stenson, G.B., Wakeham, D., and Myers, R.A. MS 1985. Estimation of pup production of hooded seal (*Cystophora cristata*) at Newfoundland during March 1985. CAFSAC Res. Doc., 1985/96, 39 p.

Lett, P.F. 1977. A model to determine stock size and management options for the Newfoundland hooded seal stock. CAFSAC Res. Doc., 1977/25, 19 p.

McLaren, I.A., Brault, S., Harwood, J., and Vardy, D. 2001. Report of the eminent panel on seal management. 145 pp. Report to the Department of Fisheries and Oceans. Available at: http://www.dfo-mpo.gc.ca/seal-phoque/report-rapport_e.htm

Mood, A.M., Graybill, F.A., and Boes, D.C. 1974. Introduction to the Theory of Statistics, 3rd edition. McGraw-Hill, Toronto. xvi, 564p.

Myers, R.A., and Bowen, W. D. 1989. Estimating bias in aerial surveys for harp seal pup production. Journal of Wildlife Management 53:361-372.

Øritsland, T., and Benjaminsen, T. 1975. Additional data on the sex ratio, age composition and mortality of Newfoundland hooded seals, with an estimate of pup production and sustainable yield. ICNAF Res. Doc., No. 122, Serial No. N3626, 22 p.

Satterthwaite, F.E. 1946. An approximate distribution of estimates of variance components. Biometrics Bulletin. 2:110-114.

Sergeant, D.E. 1974. A rediscovered whelping population of hooded seals, *Cystophora cristata* Erxleben and its possible relationships to other populations. Polarforschung 44:1-7.

Sergeant, D.E. 1976. Research on hooded seals *Cystophora cristata* Erxleben in 1976. ICNAF Res. Doc., No.126 {Revised), Serial No. N4012, 8 p.

Stenson, G.B. 2006. Hunt induced mortality in northwest Atlantic hooded seals. DFO Can. Sci. Advis. Sec Res. Doc 2006/066.

Stenson, G.B., Myers, R.A., Ni, I-H. and Warren, W.G. 1997. Pup production and population growth of hooded seals (*Cystophora cristata*) near Newfoundland, Canada. Can. J. Fish. Aquat. Sci. 54:209-216. Supplement 1.

Stenson, G.B., Rivest, L.-P., Hammill, M.O., Gosselin, J.-F., and Sjare, B. 2003. Estimating Pup Production of Harp Seals, *Phoca groenlandica*, in the Northwest Atlantic. Marine Mammal Science 19:141-160.

Stenson, G.B., Hammill, M.O., Lawson, J., J.F. Gosselin, and Haug, T. 2005. 2004 Pup production of harp seals, *Pagophilus* Gosselin *groenlandicus*, in the Northwest Atlantic. DFO Can. Sci. Advis. Sec. Res. Doc. 2005/037.

Winters, G.H., and Bergflødt, B. 1978. Mortality and productivity of the Newfoundland hooded seal stock. ICNAF Res. Doc., No.91 , Serial No. N5307 , 6 p.

Table 1. Number of hooded seal pups counted on east-west transects obtained during visual surveys of the Southern concentration on 15 March 2004. Transects 10 and 20 are corrected for changes in transect spacing. Sighting strip widths were 40m. SE given in parentheses.

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
2	52 10	55 26	55 17	7	647.5
3	52 08	55 33	55 17	2	185
4	52 06	55 32	55 15	6	555
5	52 04	55 31	55 11	32	2960
6	52 02	55 34	55 08	45	4162.5
7	52 00	55 34	55 06	56	5180
8	51 58	55 38	55 06	33	3052.5
9	51 56	55 38	55 04	22	2035
10	51 54	55 46	55 05	91	6313
11	51 53	55 50	55 04	64	2960
12	51 52	55 49	55 05	33	1526.25
13	51 51	55 51	55 04	38	1757.5
14	51 50	56 00	55 03	30	1387.5
15	51 49	56 00	55 00	35	1618.75
16	51 48	55 59	54 58	28	1295
17	51 47	56 03	54 58	12	555
18	51 46	56 07	54 59	17	786.25
19	51 45	56 04	55 00	6	277.5
20	51 44	56 07	55 02	10	694
21	51 42	56 06	54 45	9	832.5
22	51 40	56 14	54 40	14	1295
23	51 38	56 15	55 20	7	647.5
24	51 36	56 21	55 59	2	185
25	51 34	56 30	56 03	5	462.5
26	51 32	56 35	56 11	1	92.5
27	51 30	56 39	56 14	15	1387.5
28	51 28	56 35	56 21	6	555
29	51 26	56 40	56 26	15	1387.5
30	51 24	56 49	56 37	5	462.5
31	51 22	56 48	56 39	2	185
Total				**658**	**45,411 (3,838)**

Table 2. Number of hooded seal pups counted on east-west transects obtained during visual surveys of the Northern concentration on 18 March 2004. Sighting strip widths were 40m. SE given in parentheses

Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	Seals counted	Estimated pups
1	52 24	55 31	54 56	1	98
2	52 22	55 30	54 57	0	0
3	52 20	55 21	54 52	1	96
4	52 18	55 29	54 54	3	287
5	52 16	55 28	54 57	30	2,873
6	52 14	55 28	55 00	21	2,011
7	52 12	55 26	54 51	21	2,011
8	52 10	55 25	54 59	37	3,543
9	52 08	55 24	54 54	32	3,064
10	52 06	55 23	54 55	38	3,639
11	52 04	55 36	54 44	17	1,673
12	52 02	55 29	54 45	21	2,067
13	52 00	55 41	54 42	31	3,052
14	51 58	55 45	54 44	15	1,477
15	51 56	55 41	54 43	31	3,052
16	51 54	55 50	54 44	5	443
17	51 52	55 50	54 44	9	971
18	51 50	55 49	54 53	16	1,417
19	51 48	55 48	54 53	17	1,835
20	51 46	55 58	54 58	57	5,047
21	51 44	55 57	54 59	106	11,894
22	51 42	56 10	54 57	14	1,240
23	51 40	55 24	54 51	5	527
24	51 38	55 24	54 54	6	633
25	51 36	55 19	54 57	3	268
26	51 34	55 14	54 55	2	209
27	51 32	55 15	54 51	4	357
28	51 30	55 16	54 49	9	919
29	51 28	55 07	54 49	4	357
Total				**556**	**55,058 (8,681)**

Table 3. Transects, number of pups seen and estimated number of hooded seal pups obtained from visual strip transects surveys flown on 19 and 20 March 2004. SE given in parentheses.

Date	Start Lat deg/min	Long deg/min	End Lat deg/min	Total	Estimate
March 19	46 52	62 55	46 43	1	25.19
	46 36	62 53	46 53	4	100.75
	46 39	62 51	46 48	0	0
	46 43	62 49	46 35	1	25.19
	46 35	62 47	46 53	6	151.12
	46 53	62 45	46 37	3	75.56
	46 37	62 43	46 52	1	25.19
	46 51	62 41	46 36	0	0
Subtotal				16	403 (78)
March 20	46 30	62 34	46 49	0	0
	46 46	62 24	46 31	1	125.94
	46 30	62 14	46 45	2	251.87
	46 41	62 4	46 29	0	0
	46 23	61 54	46 40	2	62.97
	46 22	61 52	46 38	0	0
	46 40	61 49	46 22	7	220.39
	46 38	61 46	46 23	0	0
	46 37	61 44	46 20	2	62.97
	46 21	61 39	46 40	0	0
	46 18	61 34	46 39	0	0
	46 36	61 29	46 20	0	0
Subtotal				14	724.13 (234)
Total				30	1,127 (246.7)

Table 4. Regression statistics used to correct for misidentified pups on photographs obtained from the Front in 2005. Each reader read 50 photographs to develop the regression. In all cases the intercept was not significantly different from zero. The number of photographs read, slope and adjusted r^2. A total of 6,502 photographs were read.

Reader	Date	Photos read	Slope (SE)	R^2
1	18	1,764	1.023 (0.0089)	0.996
	19	1,173	0.978 (0.0236)	0.977
	23	1,471	1.096 (0.0140)	0.992
2	22	2,094	0.965 (0.0076)	0.997

Table 5. Number of hooded seal pups counted on east-west transects obtained during visual surveys of the Cartwright concentration on 15 and 17 March 2005. SE given in parentheses.

Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	Strip Width (m)	Seals counted	Estimated pups
A March 15						
1	53 24.0	55 47	55 52	123	1	7.8
2	53 23.5	55 43	55 51	123	2	15.6
3	53 23.0	55 50	55 44	123	6	48.7
4	53 22.5	55 43	55 50	123	7	58.1
5	53 22.0	55 52	55 44	123	8	61.5
6	53 21.5	55 45	55 51	123	6	46.7
7	53 21.0	55 50	55 44	123	7	56.8
8	53 20.5	55 43	55 49	123	1	8.4
9	53 20.0	55 44	55 48	123	1	7.8
10	53 19.5	55 39	55 50	123	3	23.1
11	53 19.0	55 42	55 48	123	11	88.6
12	53 18.5	55 38	55 48	123	1	8.1
13	53 18.0	55 41	55 47	123	5	38.4
14	53 17.5	55 37	55 48	123	3	23.2
15	53 17.0	55 40	55 45	123	0	0.0
16	53 16.5	55 34	55 43	123	3	24.2
17	53 16.0	55 41	55 46	123	1	7.7
18	53 15.5	55 40	55 45	123	1	7.8
19	53 15.0	55 39	55 42	123	0	0.0
Subtotal					67	532.3 (88)
B March 17						
1	53 28.5	55 41	55 46	176	1	5.3
2	53 28.0	55 40	55 46	176	0	0
3	53 27.5	55 40	55 45	176	3	15.9
4	53 27.0	55 40	55 45	176	2	10.9
5	53 26.5	55 41	55 46	176	2	10.9
6	53 26.0	55 41	55 48	176	5	27.2
7	53 25.5	55 40	55 48	176	6	32.6
8	53 25.0	55 40	55 47	176	4	21.2
Subtotal					23	124.1 (23.5)
C March 17						
1	53 36	55 40	56 05	176	7	153.9
2	53 38	55 40	56 20	176	38	806.7
3	53 40	55 43	56 25	176	59	1,284.1
4	53 42	55 44	56 29	176	140	2,972.1
5	53 44	55 43	56 27	176	138	2,929.6
6	53 46	55 48	56 25	176	330	7,092.5
7	53 48	55 48	56 34	176	282	5,986.7
8	53 50	55 42	56 44	123	179	5,504.8
9	53 52	55 39	56 44	123	98	3,051.9
10	53 54	55 41	56 45	123	57	1,752.9
11	53 56	55 47	56 48	123	33	1,000.2
12	53 58	55 45	56 49	123	17	529.4
13	54 00	55 48	56 33	123	15	455.7
Subtotal					1,393	33,521 (4,795)
Total						**34,177 (4,796)**

Table 6. Number of hooded seal pups counted on east-west transects obtained during a photograph survey of the Cartwright concentration (Front) on 22 March 2005. Surveys were flown at 200m.

Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	No. Photos	Pups counted	Corrected counts	Photo variance
A							
1	53 58	56 05	56 41	123	2	1.93	0.000116
2	53 56	56 13	56 48	120	1	0.96	0.000057
3	53 54	56 06	56 44	140	2	1.93	0.000116
4	53 52	56 09	56 44	124	25	24.13	0.003069
5	53 50	56 02	56 45	149	23	22.20	0.00249
6	53 48	56 00	56 46	160	131	126.43	0.079166
7	53 46	55 57	56 26	94	600	579.06	1.629531
8	53 44	56 01	56 27	93	525	506.68	0.850787
9	53 42	55 54	56 27	117	708	683.29	1.834424
10	53 40	55 50	56 23	108	264	254.79	0.336701
11	53 38	55 49	56 24	120	476	459.39	0.656955
12	53 36	55 47	56 21	113	67	64.66	0.058433
13	53 34	55 42	55 58	56	166	160.21	0.248327
14	53 32	55 39	55 56	60	268	258.65	0.416156
15	53 30	55 39	55 52	29	33	31.85	0.018821
16	53 28	55 37	55 45	30	51	49.22	0.041986
17	53 26	55 34	55 45	39	42	40.53	0.033126
18	53 24	55 34	55 43	37	30	28.95	0.016215
Subtotal				1,712	3,414	3,295	
B							
1	53 10	55 30	55 38	28	6	5.79	0.001158
2	53 05	55 27	55 39	43	12	11.58	0.003475
3	53 00	55 26	55 37	39	18	17.37	0.00776
4	52 55	55 27	55 38	39	58	55.98	0.056638
5	52 50	55 25	55 36	41	10	9.65	0.004749
6	52 45	55 23	55 36	46	28	27.02	0.009382
7	52 40	55 26	55 37	40	47	45.36	0.033879
8	52 35	55 30	55 38	28	15	14.48	0.004228
9	52 30	55 29	55 37	32	26	25.09	0.006255
10	52 25	55 28	55 35	24	6	5.79	0.000695
11	52 20	55 26	55 39	42	26	25.09	0.004517
Subtotal				402	252	243	
Total				2,114	3,666	3,528	

Table 7. Number of hooded seal pups counted on east-west transects obtained during a photograph survey of the Black Tickle concentration (Front) on 18 March 2005. Surveys were flown at 200m. Transects 1-3 were flown at 18.5km spacing while transects 3-11 were flown at 9.75 km spacing.

Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	No. Photos	Pups counted	Corrected counts	Photo variance
1	53 00	55 17	55 45	102	30	30.68	0.004785
2	52 50	55 16	55 50	123	64	65.46	0.016746
3	52 40	55 37	55 46	28	7	7.16	0.000718
4	52 35	55 22	55 47	82	26	26.59	0.004466
5	52 30	55 10	55 48	136	20	20.45	0.002392
6	52 25	55 15	55 39	71	18	18.41	0.002073
7	52 20	55 15	55 50	124	28	28.64	0.006539
8	52 15	55 11	55 42	80	2	2.045	0.000159
9	52 10	55 05	55 42	128	2	2.045	0.000159
10.1	52 05.1	55 27	55 43	59	27	27.61	0.005024
10.2	52 05.2	55 13	55 23	37	0	0	0
10.3	52 05.3	55 09	55 10	5	0	0	0
11	52 00	55 34	55 52	88	12	12.27	0.001116
Total				1,063	236	241	

Table 8. Number of hooded seal pups counted on east-west transects obtained during a photograph survey of the Lower Straits concentration (Front) on 19 March 2005. Surveys were flown at 200m.

Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	No. Photos	Pups counted	Corrected counts	Photo variance
1	51 36	56 24	55 52	94	63	61.60	0.06962
2	51 32	56 08	56 33	90	47	45.96	0.039544
3	51 28	56 18	56 44	91	27	26.40	0.021721
4	51 24	56 33	56 48	55	12	11.73	0.011139
5	51 20	56 43	56 54	44	31	30.31	0.035088
6	51 16	56 46	57 02	57	21	20.53	0.016152
7	51 12	56 47	57 02	54	35	34.22	0.040658
8	51 08	56 53	57 25	119	28	27.38	0.026734
9	51 04	56 57	57 20	86	61	59.64	0.060709
10	51 00	57 14	57 23	33	10	9.78	0.010025
11	50 56	57 18	57 25	24	11	10.76	0.011696
12	50 52	57 18	57 25	29	15	14.67	0.023949
13	50 48	57 19	57 26	28	15	14.67	0.020608
14.1	50 44.1	57 37	57 53	61	2	1.96	0.001114
14.2	50 44.2	57 21	57 28	23	15	14.67	0.017266
15	50 40	57 29	57 45	57	14	13.69	0.017823
Total				945	407	398	

Table 9 Number of attended pups counted on east-west transects obtained during visual surveys of the Upper Straits concentration on 23 March 2005. SE given in parentheses.

	Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	Strip width (m)	Seals counted	Estimated pups
A	1	51 38	55 07	55 48	123	0	0.0
	2	51 39	55 07	55 49	123	0	0.0
	3	51 40	55 05	55 21	123	0	0.0
	4	51 41	54 59	55 23	123	3	46.5
	5	51 42	55 03	55 27	123	5	75.8
	6	51 43	54 58	55 24	123	21	322.9
	7	51 44	55 00	5524	123	22	332.2
	8	51 45	55 01	55 22	176	20	211.8
	9	51 46	55 02	55 22	176	22	234.8
	10	51 47	55 02	55 20	176	28	298.9
	11	51 48	55 02	55 20	176	14	148.6
	12	51 49	55 02	55 18	176	4	42.7
	13	51 50	55 02	55 15	176	3	31.8
	Subtotal					142	1,746 (222)
B	1	51 55	55 27	55 54	176	1	10.6
	2	51 54	55 27	55 55	176	2	21.2
	3	51 53	55 27	55 57	176	3	31.7
	4	51 52	55 28	55 58	176	10	105.7
	5	51 51	55 24	55 59	176	9	95.2
	6	51 50	55 24	55 59	176	16	171.2
	7	51 49	55 22	56 02	176	36	381.1
	8	51 48	55 22	56 03	176	30	321.4
	9	51 47	55 23	5605	176	40	423.9
	10	51 46	55 44	56 07	176	88	943.8
	11	51 45	55 25	56 08	176	23	244.0
	12	51 44	55 28	56 10	123	13	197.4
	13	51 43	55 47	56 10	123	17	259.3
	14	51 42	55 48	56 14	123	23	349.7
	15	51 41	55 48	56 14	123	31	472.4
	16	51 40	55 47	56 17	123	24	364.8
	17	51 39	55 44	56 18	123	19	290.4
	18	51 38	55 51	56 21	123	21	320.0
	19	51 37	55 56	56 22	123	25	382.5
	20	51 36	55 59	56 27	123	30	457.0
	21	51 35	56 00	56 27	123	56	854.6
	22	51 34	56 03	56 30	123	39	594.7
	23	51 33	56 04	56 31	123	48	732.3
	24	51 32	56 09	56 35	123	122	1,864.9
	25	51 31	56 13	56 34	123	57	873.2
	26	51 30	56 13	56 37	123	26	398.5
	27	51 29	5616	56 40	123	6	92.0
	28	51 28	56 20	56 42	123	6	91.8
	29	51 27	56 22	56 43	123	7	107.7
	30	51 26	56 24	56 45	123	4	61.4
	31	51 25	56 30	56 48	123	1	15.3
	Subotal					833	11,530 (1,299)
	Total						**13,276 (1,318)**

Table 10. Number of attended hooded seal pups counted on east-west transects obtained during visual surveys of the White Bay concentration on 22 March 2005. Strip width was 123 m. Transect 11 was corrected for change in transect spacing. SE given in parentheses.

Transect	Latitude (deg/min)	Start Longitude (deg/min)	End Longitude (deg/min)	Seals counted	Estimated pups
1	49 42	56 43	56 47	0	0.0
2	49 44	56 41	56 47	0	0.0
3	49 46	56 40	56 48	0	0.0
4	49 48	56 39	56 50	3	63.1
5	49 50	56 35	56 46	4	84.6
6	49 52	56 32	56 44	9	189.2
7	49 54	56 32	56 45	7	147.5
8	49 56	56 25	56 44	10	213.5
9	49 58	56 23	56 46	12	256.2
10	50 00	56 21	56 45	8	127.4
11	50 02	56 20	56 44	7	74.7
12	50 03	56 18	56 42	11	115.6
13	50 04	56 18	56 41	11	116.1
14	50 05	56 17	56 40	23	242.4
15	50 06	56 15	56 38	19	200.7
Total				**124**	**2,620 (230)**

Table 11. Number of hooded seal pups counted on north-south transects obtained during a photograph survey of the Notre Dame Bay concentration (Front) on 23 March 2005. Surveys were flown at 200 m. Counts adjusted for changes in transect spacing. Transect B-5 was flown over open water.

Transect	Longitude (deg/min)	Start Latitude (deg/min)	End Latitude (deg/min)	No. Photos	Pups counted	Corrected counts	Photo variance
A							
1	56 04	50 03	50 09	32	2	2.19	0.000782
2	56 00	50 03	50 08	26	23	25.22	0.017003
3	55 56	50 03	50 08	29	18	19.74	0.005472
4	55 52	50 03	50 10	39	36	39.47	0.021108
5	55 48	50 00	50 12	71	132	144.73	0.19974
6	55 44	50 00	50 12	70	54	59.22	0.054332
7	55 40	50 00	50 10	48	13	14.25	0.008795
8	55 36	50 01	50 10	45	101	110.74	0.126059
9	55 32	50 01	50 07	26	42	46.05	0.042606
10	55 28	50 02	50 03	33	21	23.03	0.007622
11	55 24	50 02	50 03	57	78	85.53	0.092639
Subtotal				476	520	570	
B							
1	55 36	49 41	49 49	47	95	104.17	0.109642
2	55 32	49 37	49 40	69	144	157.89	0.155571
3	55 28	49 34	49 44	60	91	99.78	0.09088
4	55 26	49 35	49 45	62	44	48.25	0.055114
5	55 24	49 34	49 45	Water	0	0	0
6	55 22	49 33	49 44	65	191	209.43	0.323063
7	55 20	49 37	49 45	43	200	219.30	0.429578
8	55 18	49 35	49 44	52	262	287.28	0.74111
9.1	55 16.1	49 35	49 44	50	40	43.86	0.020326
9.2	55 16.2	49 44	49 50	36	1	1.096	0.000195
10	55 14	49 34	49 46	69	18	19.74	0.005081
11.1	55 12.1	49 49	49 58	47	2	2.19	0.000391
11.2	55 12.2	49 33	49 43	61	27	29.60	0.008013
12.1	55 08.1	49 35	49 42	42	33	36.18	0.011922
12.2	55 08.2	49 48	49 50	12	0	0	0
13	55 04	49 33	49 42	53	20	21.93	0.007036
14	55 00	49 35	49 47	68	37	40.57	0.017394
15	54 56	49 33	49 43	58	13	14.25	0.002932
16	54 52	49 36	49 43	39	12	13.16	0.002736
17	54 48	49 41	49 45	23	7	7.67536	0.001368
Subtotal				956	1,237	1,357	
Total				1,432	1,757	1,927	

Table 12. Number of hooded seal pups counted on visual strip-transects flown in the southern Gulf during March 2005. Transects were spaced 2.5 minutes of longitude apart on 8 March, 1 and 3 minutes of latitude on 12 March, and 3 minutes on 21 March. SE given in parentheses.

Transect	Direction	Start (deg/min)	End (deg/min)	Axis (deg/min)	Seals counted	Estimated pups
	March 8, 2005					
1	North-south	47 45	48 00	61 30.0	0	0
2	North-south	47 49	48 00	61 32.5	0	0
3	North-south	45 59	47 50	61 35.0	1	32
4	North-south	47 49	48 00	61 37.5	0	0
5	North-south	47 45	47 59	61 40.0	3	95
6	North-south	47 48	48 00	61 42.5	2	63
7	North-south	47 45	47 57	61 45.0	48	1513
8	North-south	47 48	47 58	61 47.5	21	662
9	North-south	47 46	48 00	61 50.0	5	158
10	North-south	47 45	47 58	61 52.5	2	63
Total					82	2584 (1,285)
	March 12					
1	East-west	61 50	62 3	47 56	0	0
2	East-west	61 51	62 3	47 57	1	19
3	East-west	61 49	62 2	47 58	1	19
4	East-west	61 49	62 4	47 59	11	204
5	East-west	61 53	62 1	48 00	1	19
6	East-west	61 49	62 1	48 01	2	37
7	East-west	61 53	62 1	48 02	1	19
Total					17	315 (498)
	March 21					
1	East-west	61 36	62 4	47 41	0	0
2	East-west	61 36	62 9	47 38	11	611
3	East-west	61 37	62 41	47 35	4	222
4	East-west	61 43.6	63 1	47 32	9	500
5	East-west	61 46	62 40	47 29	2	111
6	East-west	61 53	63 0	47 26	2	111
7	East-west	61 57	62 41	47 23	0	0
8	East-west	61 57	62 34	47 20	0	0
9	East-west	61 59	62 41	47 17	1	56
10	East-west	62 1	63 0	47 14	5	278
11	East-west	61 59	62 30	47 11	3	167
12	East-west	61 55	62 32	47 8	8	444
13	East-west	61 50	62 28	47 5	10	556
14	East-west	61 49	63 0	47 2	2	111
15	East-west	61 47	62 19	46 59	0	0
16	East-west	61 54.7	62 32	46 56	55	3 056
17	East-west	61 40	62 15	46 53	3	167
18	East-west	61 39	62 30	46 50	1	56
Total					55	6445 (1,751)

Table 13. Recorded counts and strip width for each line surveyed during the systematic strip transect survey of the Davis Strait patch, on 21 March 2005. The counts for 2 transects were not available (na) for the aft observers.

Obs. station	Port forward		Starboard forward		Port aft		Starboard aft	
Line	Count	Width	Count	Width	Count	Width	Count	Width
64^0 58'N	3	421	2	271	1	256	2	154
65^0 00'N	13	421	2	271	8	256	7	154
65^0 02'N	34	421	10	271	Na	256	Na	154
65^0 04'N	115	421	44	271	59	256	56	154
65^0 06'N	65	421	17	271	41	256	26	154
65^0 08'N	171	421	54	271	50	256	61	154
65^0 10'N	12	421	9	199	Na	111	Na	168
65^0 12'N	0	421	4	199	0	111	2	168
65^0 14'N	0	421	5	199	0	111	3	168
65^0 16'N	0	421	0	271	0	256	0	154
65^0 18'N	0	421	0	199	0	111	1	168
65^0 20'N	1	421	1	199	0	111	0	168
65^0 22'N	0	421	2	199	0	111	2	168

Table 14. Numbers of hooded seal pups in individual age dependent stages at the Front during March 2004 and 2005.

	Surveys	Staging	Newborn	Thin	Fat	Solitary	TOTAL
2004							
Southern	March 15	March 9	10	125	14	2	151
		March 10	15	48	22	4	89
		March 16	0	37	193	200	430
		March 19	0	0	12	195	207
		March 22	0	0	2	272	274
Northern	March 17	March 10	3	80	3	1	87
		March 12	1	613	68	31	713
		March 17	5	182	147	339	673
		March 19	0	25	98	100	223
		March 22	0	30	85	241	356
2005							
Cartwright	March 15	March 14	0	383	75	44	502
	March 17	March 17	0	13	10	17	40
	March 22	March 22	0	8	46	599	653
Notre Dame Bay	March 23	March 11	0	26	4	2	32
		March 18	0	106	38	62	206
		March 22	0	6	28	754	788
White Bay	March 22	March 22	0	0	0	136	136
Lower Strait & Black Tickle	March 18	March 18	0	39	37	63	139
	March 19	March 20	0	0	0	129	129
Upper Strait	March 23	March 22	0	91	179	146	416
		March 23	0	30	170	83	283

Table 15. Numbers of hooded seal pups in individual age dependent stages in the Gulf of St. Lawrence during March 2005.

	Survey	Date	Newborn	Thin	Fat	Total
2004						
	19 March	15 March	0	10	7	17
	20 March	19 March	3	6	20	29
		20 March	0	1	2	3
2005						
Patch 1	8 March	7 March	6	20	37	63
		9 March	0	23	82	105
		12 March	7	52	33	92
		15 March	0	6	50	56
		16 March	6	45	57	108
		22 March	1	7	63	71
Patch 2	12 March	7 March	0	4	2	6
		9 March	1	22	31	54
		12 March	1	46	53	100
		15 March	0	25	75	100
		16 March	1	2	16	19
Combined	21 March	7 March	6	24	39	69
		9 March	1	45	113	159
		12 March	8	98	86	192
		15 March	0	31	125	156
		16 March	7	47	73	127
		22 March	2	14	126	142

Table 16. Estimate of proportions of Northwest Atlantic hooded seal pups on the ice at the time of the surveys. ND indicates that the SE cannot be determined.

Area	Date	Estimate	Std Err
2004			
Front (Cartwright)	18 March	0.714	0.107
Front (Belle Isle)	15 March	0.972	0.147
Gulf	19 March	0.765	0.014
	20 March	0.839	0.015
2005			
S. Gulf 2005	8	0.435	0.261
	12	0.682	0.056
	21	0.968	0.038
Cartwright	15	0.3212	0.0053
	17	0.6096	0.0052
	22	0.9836	0.0008
Black Tickle	18	0.977	ND
Lower Straits	19	0.9986	ND
White Bay	22	1.0	0
Upper Straits	23	0.9915	0.0005
Notre Dame Bay	23	1.0	0

Table 17. Estimated pup production, corrected for the temporal distribution of births of hooded seals at the Front during 2004 and 2005. Final estimates are in bold.

Concentration	Date	Method	No	SE	CV
2004					
Southern	15 March	Visual	46,750	8,098	0.173
Northern	18 March	Visual	77,112	16,789	0.218
Total			**123,862**	**18,640**	**0.150**
Gulf	**19/20 March**	**Visual**	**1,388**	**298**	**0.216**
2005					
Cartwright	Mach 15	Visual	1,657	277	0.167
	March 17	Visual	55,191	7,880	0.143
	Total	Visual	56,849	7,885	0.139
	March 22	Photo	49,694	7,651	0.154
	Combined		53,164	5,491	0.103
Lower Strait	March 19	Photo	1,329	1,461	1.100
Upper Strait	March 23	Visual	13,389	1,329	0.099
Black Tickle	March 18	Photo	11,688	3,572	0.306
Notre Dame Bay	March 23	Photo	24,823	3,201	0.129
White Bay	March 22	Visual	2,620	230	0.088
Total			**107,013**	**7,558**	**0.071**
Gulf	**March 21**	**Visual**	**6,620**	**1,700**	**0.258**
Davis Strait	**March 21**	**Visual**	**3,346**	**2,237**	**0.668**

Table 18. Estimated pup production and standard errors of northwest Atlantic hooded seals from aerial surveys. All estimates are rounded to the nearest hundred.

Year	Front	Gulf	Gulf [1] (corrected this study)	Davis Strait
1984	62,400 (43,700-89,400)			19,000 (14,000-23,000)
1985	61,400 (16,500-119,500)			
1990	83,100 (SE=12,700)	1,600[2] (SE=500)		
1991		2,000 (SE=190)	1,700 (SE=130)	
1994		4,000 (SE=1,000)	8,700 (SE=1,800)	
1996		4,678[2] (SE=748)		
2004	124,000 (SE=18,600)	1,400[3] (SE=300)		
2005	107,000 (SE= 7,600)	6,600 (SE=1,700)		3,300 (SE=2,200)

[1] Published estimates corrected for the temporal distribution of birth using the normal model described in this paper.

[2]Surveys were flown but insufficient stage data were collected to determine temporal distribution of births.

[3] Incomplete counts because animals were missed.

Table 19. Estimated pup production and standard errors for Northwest Atlantic hooded seals from aerial surveys in years when two or more whelping areas are surveyed. All estimates are rounded to the nearest hundred.

	1984		1990		2004		2005	
	Est	SE	Est	SE	Est	SE	Est	SE
Front	62,400	11,700	83,100	12,700	124,000	18,600	107,000	7,600
Gulf			1,600	500	1,400	300	6,600	300
Davis St.	19,000	2,300					3,300	2,200
Total	81,400	11,924	84,700	12,710	125,400	18,602	116,900	7,918

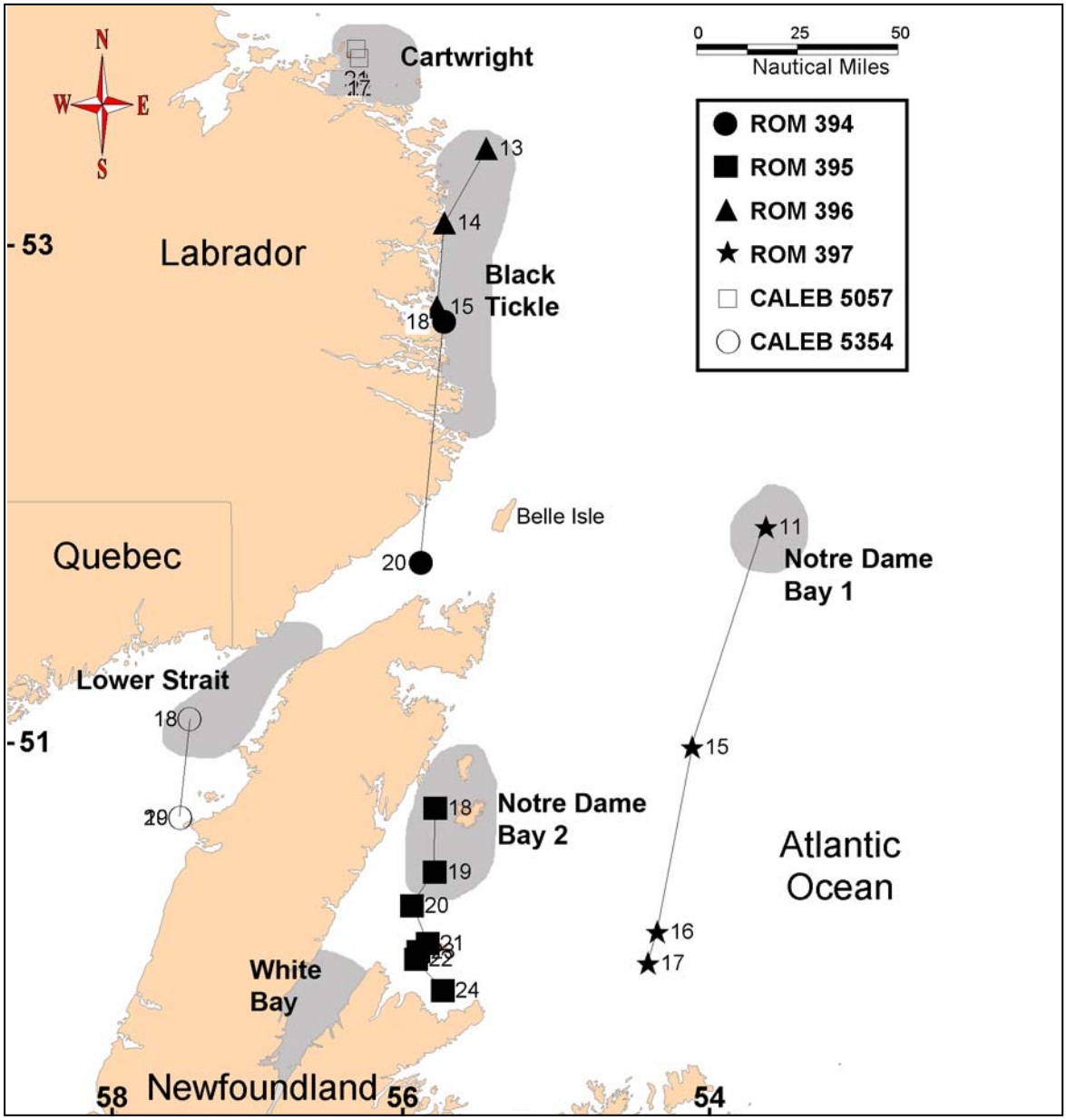

Figure 1. Location of whelping concentration located during hooded seal surveys in March 2005 and satellite linked ice beacons used to monitor drift.

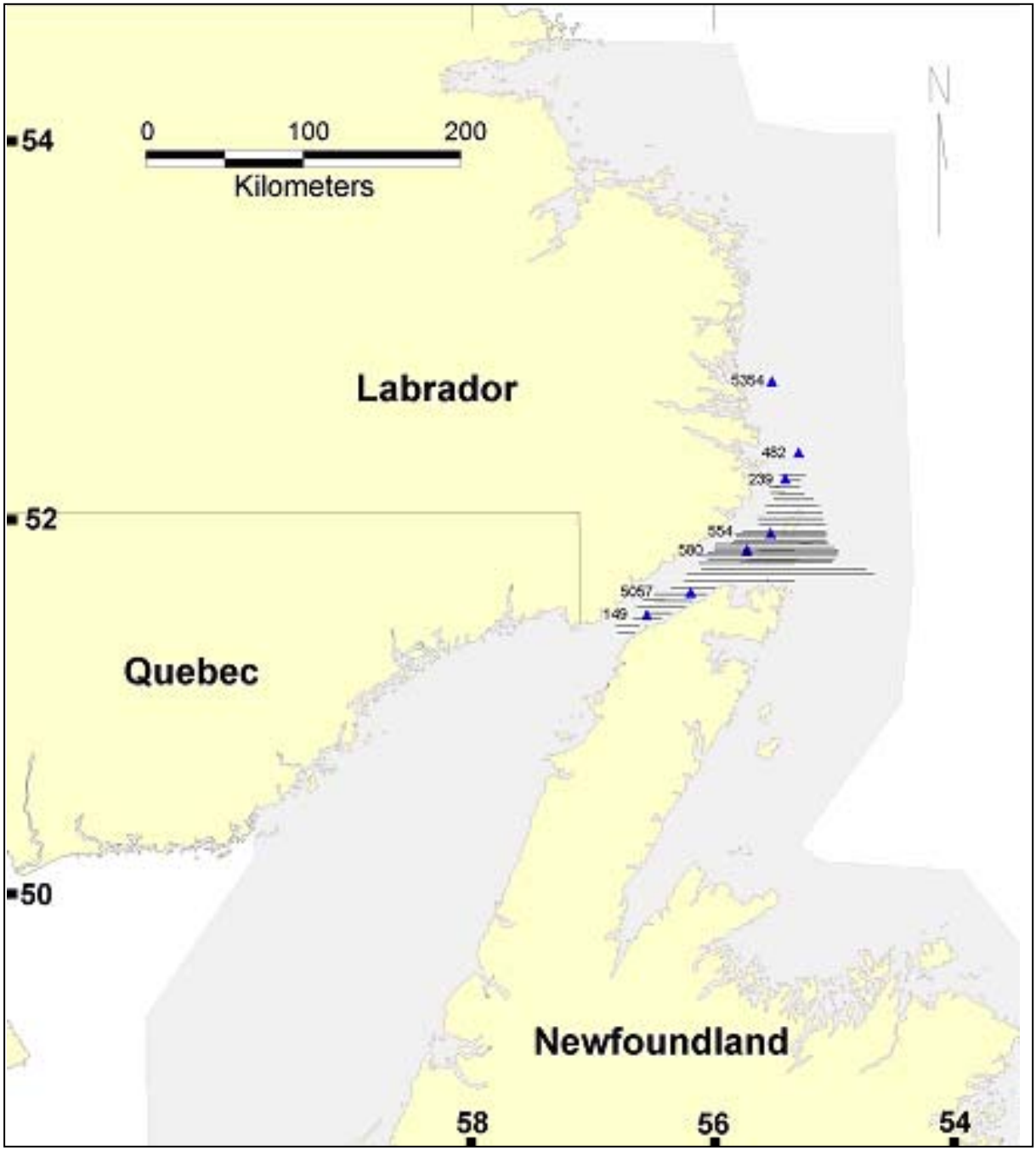

Figure 2. Location of visual survey transects flown to determine hood seal pup production in the southern (Belle Isle) whelping concentration on 15 March 2004. Ice-based transmitter positions are indicated by triangles and individual numbers. Shading indicates areas where reconnaissance surveys were flown.

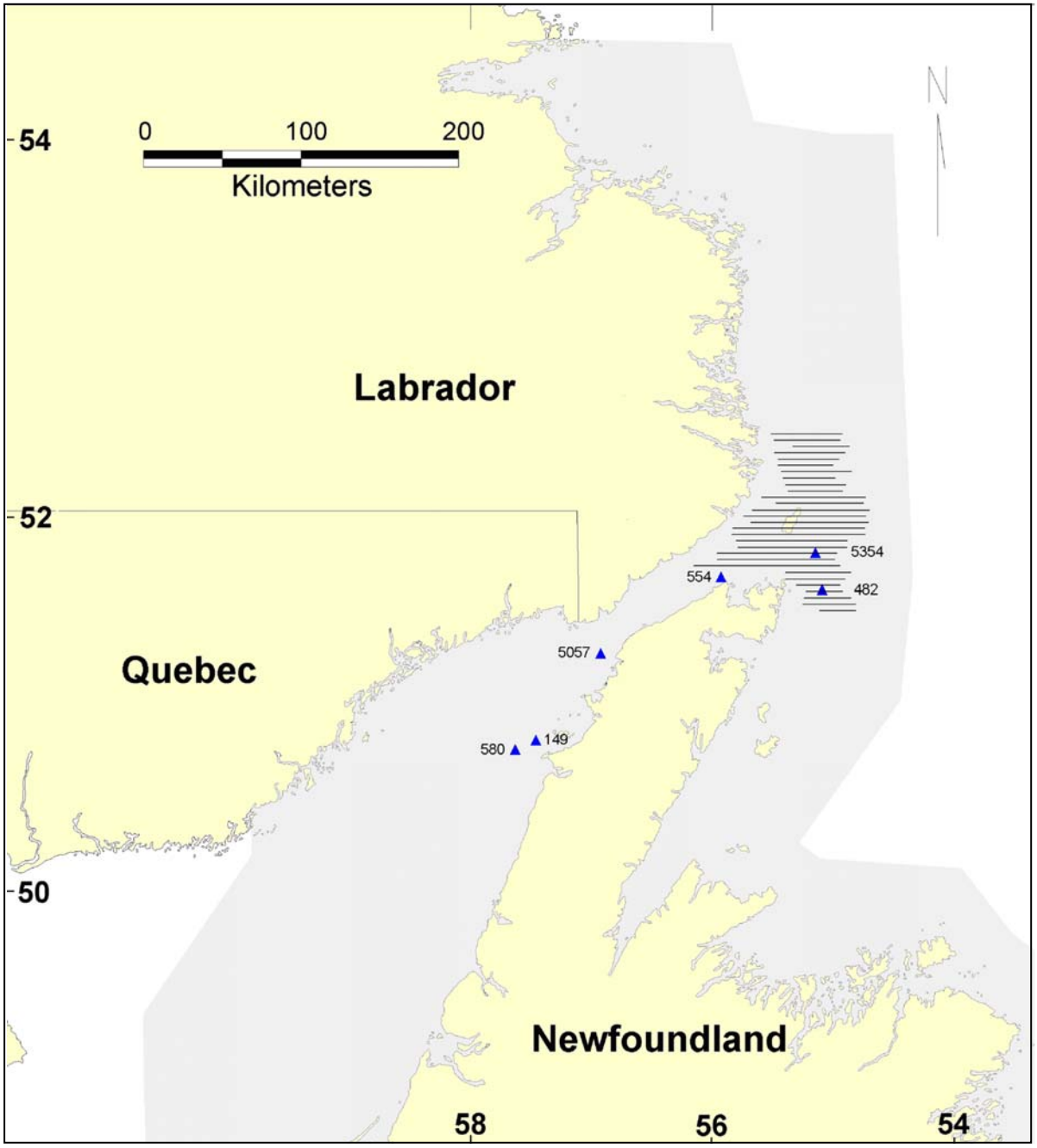

Figure 3. Location of visual survey transects flown to determine hooded seal pup production in the northern (Cartwright) whelping concentration on 18 March 2004. Ice-based transmitter positions are indicated by triangles and individual numbers. Shading indicates areas where reconnaissance surveys were flown.

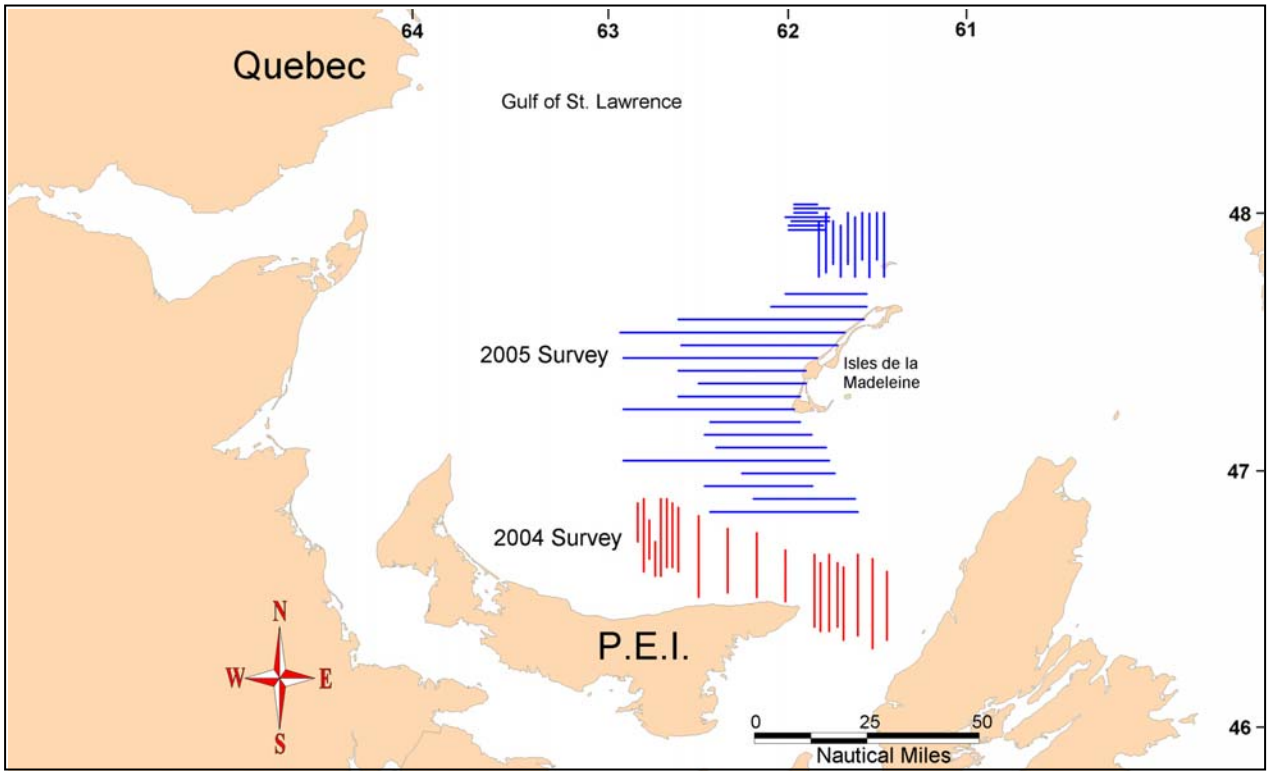

Figure 4. Location of visual survey transects flown to determine hooded seal pup production in the southern Gulf of St. Lawrence in March 2004 and 2005.

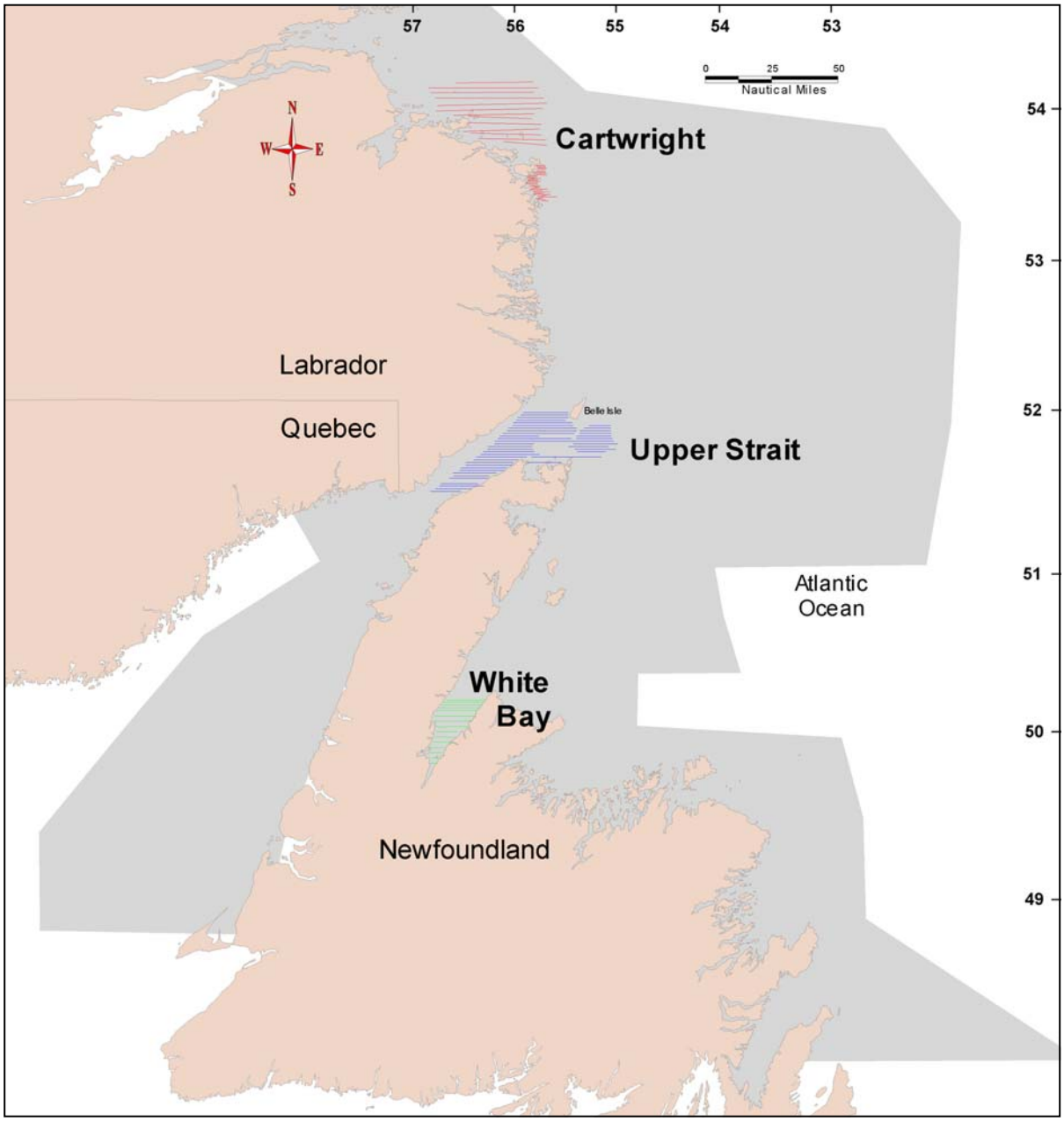

Figure 5. Location of visual survey transects flown to determine hooded seal pup production in March 2005. Shading indicates areas where reconnaissance surveys were flown.

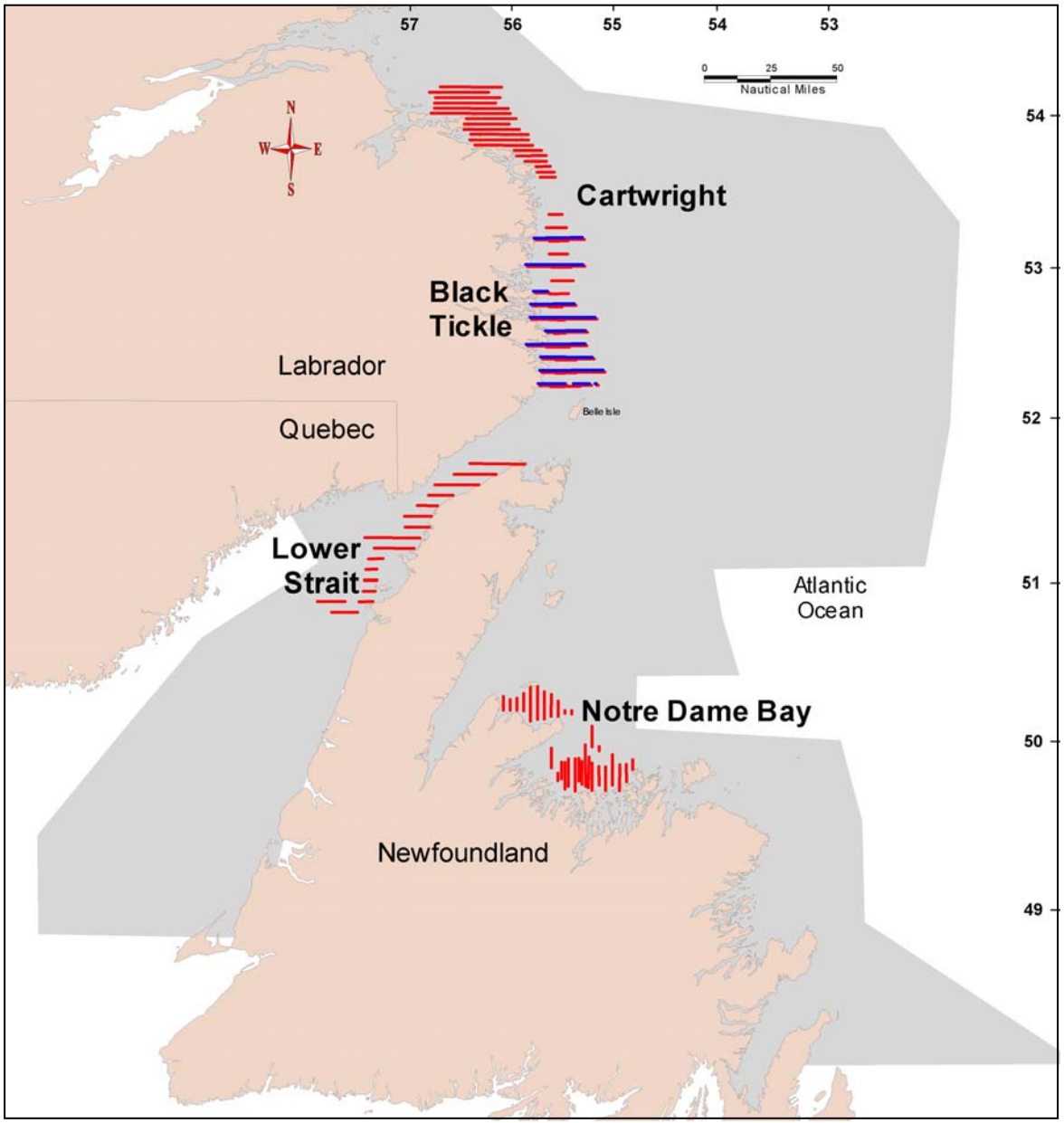

Figure 6. Location of photographic survey transects flown to determine hooded seal pup production in March 2005. Shading indicates areas where reconnaissance surveys were flown.

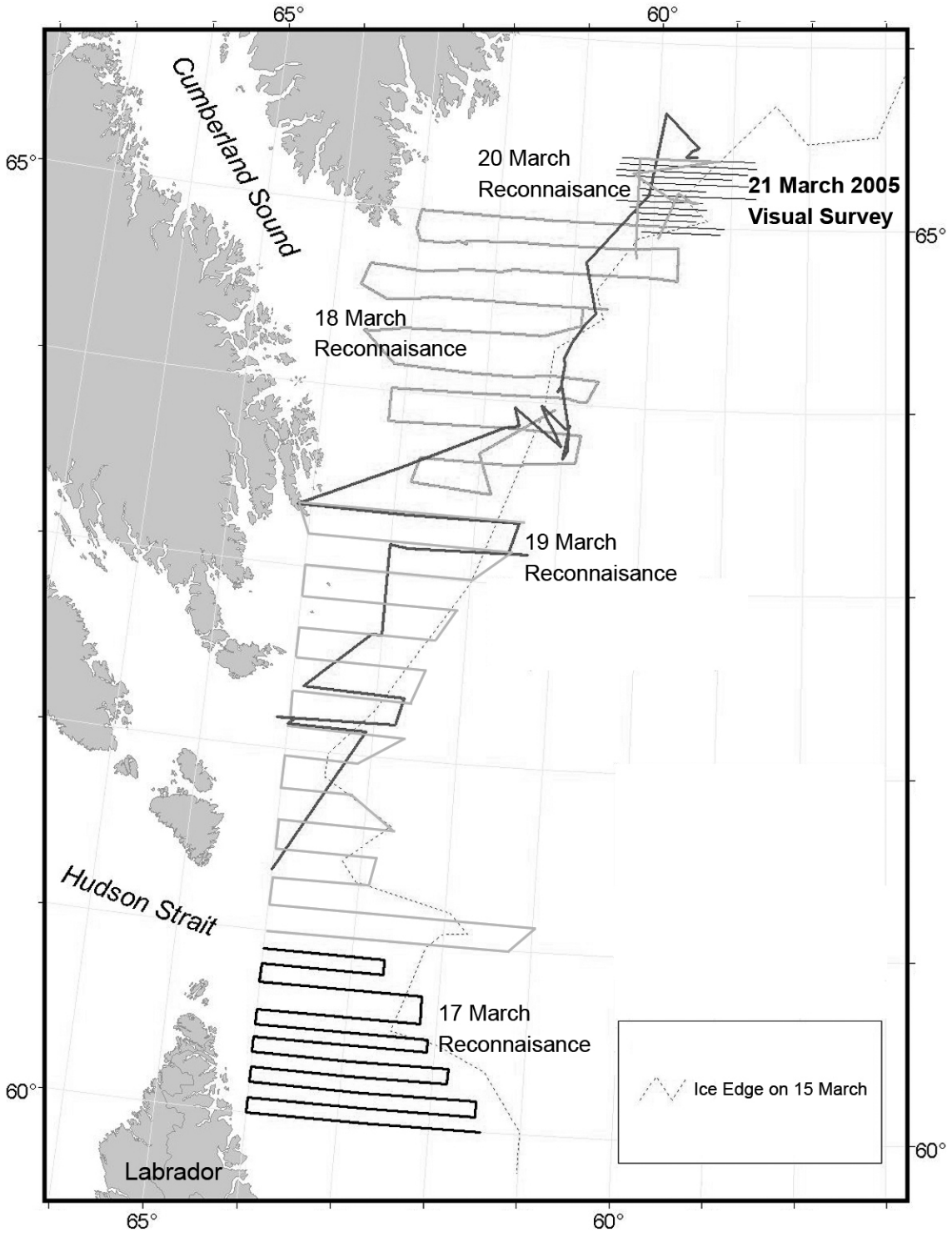

Figure 7. Location of reconnaissance and visual survey transects flown to determine hooded seal pup production in Davis Strait during March 2005.