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Pup production of Northwest Atlantic grey seals in the Gulf of St. Lawrence

La production de jeunes phoques gris de l'Atlantique Nord-Ouest dans le golfe du Saint-Laurent

M.O. Hammill[1], and G.B. Stenson [2]

[1] Maurice Lamontagne Institute, Dept of Fisheries and Oceans
P.O. Box 1000, Mont Joli QC Canada G5H 3Z4

[2] Fisheries and Oceans, North Atlantic Fisheries Centre,
80 East White Hills Road, St. John's, Newfoundland and Labrador Canada A1C 5X1

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ABSTRACT

Pup production in the Gulf of St. Lawrence was estimated in 2010 using visual strip transect surveys of the whelping patches on the ice in the southern Gulf of St. Lawrence and complete counts on islands. Reconnaisance flights were also carried out to determine if any pupping occurred along the south and southwest coasts of Newfoundland and Anticosti Island. A small number of pups were found on Anticosti while no pupping occurred along Newfoundland. Where possible, counts were corrected for the proportion of pupping completed when the survey was completed. Total pup production is estimated to be 11,228 (SE=6,442) animals.

RÉSUMÉ

En 2010, on a estimé la production de jeunes dans le golfe du Saint-Laurent par des dénombrements aériens visuels par bande pour les aires de mise bas sur la glace dans le sud du golfe Saint-Laurent, ainsi que par des décomptes complets sur les îles. Des vols de reconnaissance ont aussi été effectués afin de déterminer s'il y avait eu des naissances le long des côtes du sud et du sud-ouest de Terre-Neuve et à l'île d'Anticosti. On a trouvé un petit nombre de jeunes sur l'île d'Anticosti, mais il n'y a eu aucune naissance sur la côte de Terre-Neuve. Lorsque possible, on a corrigé les dénombrements pour la proportion de naissances obtenues lorsque le relevé a été fait. La production totale de jeunes est estimée à 11 228 animaux (erreur type = 6 442).

INTRODUCTION

The grey seal (*Halichoerus grypus*) is distributed throughout the North Atlantic extending from the northeastern United States to Labrador in the west and from the United Kingdom to the Murmansk region in Russia and south throughout the Baltic Sea and along the coast of France in the east with reports of recent sightings from Greenland (Harkonen et al 2007; Rosing-Asvid 2010). Grey seals were abundant throughout their range historically, but underwent significant declines in some areas as early as the 2nd Century. Since the middle of the 20th Century, most populations have shown remarkable signs of recovery (Harkonen et al. 2007; Lavigueur and Hammill 1993; Hammill et al. 2007; Thomas et al. 2007).

The northwest Atlantic grey seal is considered to form a single stock (Boskovic et al. 1996), but within Canadian waters is subdivided into three components for management considerations: Sable Island, Gulf of St. Lawrence (Gulf), and Coast of Nova Scotia (Fig. 1). The three regions have had very different population trajectories. Sable Island, Nova Scotia, is a sand island located approximately 300 km east of Halifax (44.8 N, 60.8 W) and is home to the largest breeding colony of grey seals in the world (Bowen et al. 2007). Using pup production as an index of population size and trends, pup production on Sable Island has increased rapidly since the 1970's, from less than 2,000 animals in 1975 to over 25,000 pups in 1997 (Bowen et al. 2003) for an annual rate of increase of 12.8%. More recently, estimates of pup production, indicated that numbers had continued to increase (41,500 (SE=4,381) in 2004 and 54,482 (SE=1288) in 2007), but that the rate of increase had declined (Bowen et al. 2007; Thomas et al. 2007).

A relatively small number of animals breed on isolated islands along the Nova Scotia Eastern shore (Mansfield and Beck 1977). Significant culling efforts, particularly in the Basque Island area limited pup production in this area to the low 100's. The Basque Islands no longer exist due to the effects of erosion but pupping continues on Bowen's Ledge and White Islands. A new colony was discovered on Hay Island in 1993 by J. Conway (DFO-Halifax)(Fig. 1) and pup production has increased in this area from a few hundred to about 2,700 in 2007. Additional pupping occurs on Bowen's Ledge and White Island (N=113 in 2007). In the last few years, small colonies have also appeared along the southwestern shore of Nova Scotia on Flat and Noddy Islands (N=204; Hammill et al. 2007). Combining the estimates from the southwestern shore colonies and the Eastern Shore, results in a total estimate of about 3,000 animals in 2007.

In the Gulf of St. Lawrence, grey seals have traditionally had their young on the pack-ice located between Prince Edward Island and the Nova Scotia (Northumberland Strait) or on beaches and/or small islands in the Northumberland Strait and western Nova Scotia, and on Deadman Island in the central Gulf. Recently, pupping has been observed on Anticosti Island in the northern Gulf (Fig. 1). The trajectory of pup production in the Gulf has been much more variable than on Sable Island due to culling and scientific harvests (Stobo and Zwanenburg 1990; Hammill *et al*. 1998), and higher mortality rates associated with pupping on the pack-ice (Hammill et al. 2007; Thomas et al. 2007). Pup production estimates for the Gulf component range from a low of 5,436 (SE=672) in 1984, increasing to 10,700 (SE=1,300) by 1996, but since then subsequent surveys indicated that pup production has varied between 5,300 (SE=900) in 2000 and 14,200 (SE=1,200) in 2004. In 2007, pup production was estimated to be 11,400 (SE=1100)(Hammill et al. 2007).

Here we provide new estimates of grey seal pup production in the Gulf and northern portion of the Eastern Shore based upon aerial surveys and island counts completed in January-February 2010.

MATERIALS AND METHODS

RECONNAISSANCE SURVEYS

Pupping grey seals were located during reconnaissance aerial surveys flown in the southern Gulf and along the Nova Scotia Eastern Shore during January and February 2010. Flights were made at an altitude of 500 feet using a MMB105 helicopter. Additional low-altitude flights were made during January using the DFO Conservation and Protection (C&P) Super King Air fixed wing aircraft in the southern Gulf by enforcement personnel. Additional flights with science personnel onboard were flown along the south and west coast of Newfoundland and around the coast of Anticosti Island.

STRIP TRANSECT SURVEYS OF WHELPING CONCENTRATIONS ON ICE

Pups born on the ice were surveyed using a systematic visual strip transect survey design, flown at an altitude of 61 m using a MMB105 helicopter. Observers, seated in the left and right rear seats, counted all seals within a measured 50 m strip on each side of the aircraft. The strip was delimited prior to the surveys by placing tape marks on the windows while hovering at an altitude of 61 m over a measured distance marked out on the ice. Tape marks were also placed on the window to denote the horizon and the outside of the helicopter skid to aid the observer in maintaining a constant position. Following the survey, strip widths were checked again to confirm the areas surveyed.

The data were analysed using the methods outlined in Hammill *et al*. (1992). Survey strata were defined based on homogeneous transect spacing. For each group a weighting factor k_i was calculated as:

$$k_i = S_i / W_i \qquad (3)$$

where S_i is the transect spacing (km) for the i^{th} group and W_i is the transect width (km) for the i^{th} group.

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

given by:
$$N_i = k_i \left[\sum_{j=1}^{J_i} x_j \right] \qquad (4)$$

where x_j is the number of seals counted on a transect and J_i is the number of transects in the i^{th} survey.

The error variance was calculated based on the serial difference between transects (Cochran 1977; Kingsley *et al*. 1985) using:

$$V_i = \frac{k_i(k_i-1)J_i}{2(J_i-1)} \sum_{j=1}^{J_i-1} (x_j - x_{j+1})^2 \qquad (5)$$

If transect spacing changed the estimate of the number of animals became:

$$N_i = k_i \left[x_{i1}/2 + \sum_{j=2}^{J_i-1} x_{ij} + x_{iJ_i}/2 \right] \qquad (6)$$

and the variance estimate became:

$$V_i = \frac{k_i(k_i-1)}{2} \sum_{j=1}^{J_i-1} (x_j - x_{j+1})^2 \qquad (7)$$

The estimate for the total population and its variance estimate became:

$$N = \sum_{i=1}^{I} N_i \qquad (8)$$

$$V = \sum_{i=1}^{I} V_i \qquad (9)$$

where I is the number of groups of transects.

ISLAND COUNTS

Pups born on islands, in Hillsborough Bay and along the shore ice off the north coast of Prince Edward Island (PEI) were counted using several different techniques. The number of pups on the beaches were counted by two observers, or a single observer counted the pups twice, at Amet Island, Saddle Island, Deadman Island, and White Island and Bowen's Ledge. At Hillsborough Bay, Oak and Brion Islands and the North shore of PEI, only a single count was completed by a single observer from the air. At Henry Island, Pictou, and Margaree Islands animals were counted by two observers seated on the left side of the helicopter from the air at 20-30 m and moving along the beach about 20 m offshore. Counts were averaged between observers. At Anticosti Island aerial photographs were taken from the King Air and images were counted.

TEMPORAL DISTRIBUTION OF BIRTHS

Non-Sable Island Northwest Atlantic grey seals begin pupping on the islands in December and births continue until early February. The majority of births, particularly of ice breeding animals, occur in January. Aerial survey and island estimates were corrected to account for births that occurred after counts were completed by modelling the distribution of births over the period of the survey. The model assumes that births follow a normal distribution and uses the change in the proportion of pups of different ages as the season advances to develop the birthing ogive (details described in Stenson *et al*. 2003). Estimates of the

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

$$N_i = N_{uncor} / P_i \qquad (1)$$

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):

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

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 stage surveys were conducted by walking through the colony from one end to the other, or by flying over the colony at low altitude and assigning pups to stages. Pups were assigned to one of three distinct age-related categories based on a combination of morphometric and pelage features to model the distribution of births (Bowen *et al*. 2003;). New data resulted in some changes to the stage duration data, (W.D. Bowen, DFO, Dartmouth, N.S. pers. comm.; Hammill et al. 2007) and these were used to correct the survey counts .

Stage 1- animals very thin, movements uncoordinated, and the fur has a yellowish hue from the placental fluids (Mean duration in days: 3.0, SE=0.64);

Stage 2- animals are thin, although they are beginning to show signs of fattening, a distinct neck is still visible, movements are more coordinated and the pelage no longer has a yellowish hue (Mean=3.0, SE=0.65)

Stage 3- the fur is white in colour and the animals have become so fat that a distinct neck is no longer discernable; no sign of moult (Mean=11.8, SE=2.53).

The study area was surveyed repeatedly by carrying out random transects across all pupping areas and the change in the proportion of pups in each of the age dependent categories was determined.

RESULTS

RECONNAISSANCE SURVEYS

The areas where pupping is known to occur in Northumberland Strait, and around Cape Breton Island were searched and assessed frequently during January and February (Fig. 2). The King Air operated by the Conservation and Protection Branch within DFO completed surveys throughout the southern Gulf and provided reports on sightings as well as joint flights with science to search specific areas (Fig. 3). Any observations of animals in new areas, reported by the C&P flights were verified. New colonies discovered since the 2007 survey were observed on Saddle Island and Brion Island (Fig. 2).

STRIP-TRANSECT SURVEYS

Strip transect surveys were flown the 24 January, 2 and 6 February (Table 1) The survey completed on 24 January covered all known concentrations of ice with hauled out seals and pups (Fig. 4, top). Patches were located near Amet Island in the west and near Pictou Island in the east (Fig. 4) and were dominated by Stage 2 (5 day old) and Stage 3 (13 day old; Bowen et al 2003) animals. This survey resulted in an estimate of 608 (SE=255) animals.

On 26 January a storm with strong westerly winds of up to 30 knots destroyed much of the ice in the area. The remaining ice quality was poor and it is likely that most pups drowned. Staging flights carried out on 1 Feburary located scattered seals about 5 miles to the northeast of Pictou Island with a large number of ragged jackets (approx 22 days old: Bowen et al. 2003) in very rotten slush ice. These animals were likely animals from the group surveyed on 24 January. However, this group was not seen in a staging survey flown on 2 February and no significant numbers of ragged jacket or beater seals were observed in any subsequent staging surveys over the ice.

A second survey of the entire area where there was suitable ice for seals to the east of the previously surveyed herd was carried out on 2 February (Fig 4). This survey produced an estimate of 2,389 (SE=5,195).

In the Strait area, the ice drift is to the east, north east. Stage surveys of seals on the ice identified large numbers of thin-whitecoats, and fat-whitecoats, but did not identify any quantities of ragged-jacket animals. This group was considered to be a new group and therefore a third survey along the Cape was flown February 6. This survey produced an estimate of 981 (Se=2,207) animals.

Total pup counts

The number of pups counted on the islands in the Gulf and along the Eastern Shore are listed in Table 3. Pups were also observed on the ice in Hillsborough Bay (including Pt Prim), and the north side of PEI, but numbers were too few to set up a transect survey. Therefore, a total count of animals hauled out on the ice was made, as well as counts of pups on the ice along the north side of Prince Edward Island and counts at the different islands (Table 3). New colonies were observed at Brion Island (n=23), and Saddle Island (1,306, se=59). A few pups were observed at Kouchibouguac Park on the New Brunswick coast as well as at Oak Island, but the latter which was the location of a large number of

pups for the first time in 2007, had only 4 animals. Approximately 50 pups were also seen on Anticosti Island, which was a new colony in 2007.

Stage surveys

Stage surveys were flown over pups on the ice as well as the larger island breeding colonies (Table 4).

The strip-transect and pup surveys were combined, taking into account the proportion of births that had occurred when surveys or counts were completed. Because of the loss of ice and subsequent absence of older pups in the area, we assumed that the patch seen on 24 January was lost during the storm of 26 January and not resurveyed on 2 February. Between this survey and the time of the storm it was estimated that about 12% more births would have occurred. It was also assumed that the seals counted on Feb 6 were not counted earlier. Combining the transect surveys and total counts of pup, pup production in the Gulf of St. Lawrence in 2010 was 11,228 (SE=6,442)(Table 5).

DISCUSSION

The method used to evaluate the pup production of Gulf grey seals has evolved over time since assessments began in the early 1980s. Early studies used mark-recapture methods based on live recaptures at Sable Island of marked animals in the year of their birth, or by the recovery or resighting of marked animals from shot samples in the same or subsequent years to marking (Myers et al. 1997; Hammill *et al*. 1998). Aerial survey techniques, similar to the approaches used to assess harp seals (Stenson *et al*. 2003), where extensive reconnaissance is carried out to detect all concentrations, systematic surveys are flown to estimate the number of animals present on the ice, and a parallel set of surveys are completed to work out the proportion of pupping that has occurred since the counting survey was flown, were initiated in 1996 (Hammill *et al*. 2007). Within the time series there are also estimates of pup production available for the Gulf of St. Lawrence from 1966 and 1975, but the methods used to obtain these estimates, particularly for pups born on the ice are poorly described and are likely to be underestimates (Table 6).

Historically, less than 1% of the pups in the Gulf have been born on land, with the remainder born on the ice in Northumberland Strait between Prince Edward Island and Nova Scotia (Fig. 1). However, beginning in the early 1990s, ice cover has become more variable (Bajzak et al submitted; Johnston et al. 2005), making it more difficult to find suitable ice in the Northumberland Strait area (Fig. 1, 5). Since the 1990s, the proportion of births occurring on the islands has been quite variable with almost 60% of births occurring on the islands in some years (Table 6). Estimates of pup production for the Gulf have also varied considerably between surveys.

New colonies have appeared throughout the Gulf and along the Eastern shore including Hay Island (1993), Henry Island (1997), Oak Island (2007), Pictou Island (2007 assessment, but reports of some pupping since 1997), Kouchibouguac National Park (2007) and Anticosti Island (2007), Brion Island (2010) and Saddle Island (2010). The presence of pups at Anticosti Island is particularly surprising, since conditions were considered to be unfavourable in the northern gulf and along eastern New Brunswick for pup survival and animals are thought to leave the northern Gulf during winter (Hansen and Lavigne 1997; Goulet *et al*. 2001). However, if mild winters continue, then expansion may

be expected in areas where there is little disturbance. So far no pupping has been observed around Newfoundland although a number of suitable beaches are found along the south coast and on Miquelon.

For grey seals reconnaissance flights have been flown throughout the southern gulf to detect pup concentrations in areas with suitable ice cover. In addition, in recent years the Conservation and Protection Branch has been flying extensively throughout the Gulf during winter and spring and provide reports of any seal observations. These efforts have lead to the detection of new colonies, resulting in an extension of the survey area.

Compared to harp seal visual surveys, grey seal surveys are less precise in spite of animals being larger and occurring in a smaller area. The CVs of the estimates are generally in the range of 11-13% for grey seals (but was 57% in 2010), compared to 8-10% for harps. A number of biological and habitat differences contribute to complicate survey efforts for grey seals. Harp seals pup over a two week period between the last week in February and the first week in March in the southern Gulf of St. Lawrence. They are strongly associated with particular ice types, thin and medium first-year ice, 30-120 cm thick made up of small to medium floes (20-500 m across). Harp seal females often leave their pups to enter the water but will lead their pups to more stable ice and occasionally across leads to new pans. Because there is considerable cover of stable ice in most years, normal storm activity does not appear to have much of an impact on harp seals in normal years.

In contrast, grey seals pup over a 6 week period in the southern Gulf and small patches of animals are widely dispersed across the survey area. Grey seals pup on thinner ice, with pups born on young to thin first year ice (10-70 cm) made up of ice-cake to medium floes (2 -500 m across). Female greys do not lead their pups across leads and abandon their pups relatively readily when disturbed which is thought to result in considerable mortality among grey seals in the Gulf (Mohn and Bowen 1996, Hammill et al. 2007). Also, grey seal whelping groups are less concentrated than harp seals. As a result, surveys are less precise. Increasing survey coverage would improve survey precision, but given the large areas involved, it would likely result in the whole herd not being covered in a single day. This would not be a problem in good ice years when the herd drift can be monitored, but in most years there is a high risk of loss of animals due to destruction of the relatively poorer thin ice and poor mother-pup association in this species. Therefore attempts to fly more closely spaced lines across several days may improve precision, at the expense of increasing bias. Similarly, repeated surveys of the same patch would also help to improve precision, but if animals are lost due to ice destruction, bias will increase.

In poor ice years, the extended pupping season means that patches forming early in the season might be lost before being surveyed, as seen in 2010. Flights made following the 26 January storm indicated that the ice in the Strait was largely destroyed and that mortality among animals from the 24 January survey was likely to be high. Although mortality may not have been 100% since some animals may have drifted ashore, the absence of any significant number of older animals in any of the stage or transect surveys indicates that mortality was extensive. This would have resulted in the loss of up to 700 animals or about 16% of the animals born on the ice in 2010. Additional sources of mortality for young of the year grey seals also include coyotes near islands such as Pictou and Saddle Island and predation from Bald Eagles in the area.

The grey seal is the only species that regularly breeds on both land and on ice. The appearance of new colonies underlines how adaptable this species appears to be. On the small islands in the area, the colonies are relatively isolated and little disturbed. However, other colonies such as Oak Island are easily accessible and ease of access for all-terrain vehicles and snowmobiles may account for why this colony was not used extensively in 2010. A continued decrease in ice cover in the Northumberland Strait area will likely lead to an increase in pup mortality for this herd (Fig. 5). At some point, pupping may only continue on the small islands. If mild winters continue it is unlikely that much expansion in the herd in the southern gulf will occur because grey seals appear avoid areas with considerable human traffic or easy access for terrestrial predators such as coyotes. For example the Antigonish beach area would appear to provide suitable habitat bt the area is often disturbed. The absence of suitable sites in the southern Gulf may limit expansion of the herd in this area. However, areas such as Brion Island, Anticosti Island and northern shore of the northern Gulf would appear to offer additional potential pupping habitat.

Estimates of pup production in the Gulf of St. Lawrence are imprecise and quite variable. This is associated with the variable distribution of small concentrations or groups of pups on the ice and likely elevated mortality related to poor ice conditions. Improving survey coverage by reducing the spacing between survey lines, increasing strip width, or repeated surveys of the same patch would contribute to improving survey precision. Improving our understanding of how variable ice conditions might affect numbers of pups on the ice available for counting might contribute to reducing inter-survey variability.

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Table 1. Number of pups counted on north-south transects during visual surveys of Northumberland Strait during January/February 2010. Different strata or surveys flown labelled as Survey A, B, etc) are separated by a blank line.

Date	Transect	Latitude Deg/min		Longitude Deg/min		Latitude Deg/min		Transect spacing	Weight	Right	Left	Total pups
Survey A												
24-01-2010	1	45	46	63	9	45	52	0.50	6.46	0	0	0
24-01-2010	2	45	52	63	9.50	45	48	0.50	6.46	0	0	0
24-01-2010	3	45	46.60	63	10	45	52	0.50	6.46	4	6	10
24-01-2010	4	45	52	63	10.50	45	46.60	0.50	6.46	1	0	1
24-01-2010	5	45	47	63	11	45	52	0.50	6.46	2	5	7
24-01-2010	6	45	53	63	11.50	45	47	0.50	6.46	1	6	7
24-01-2010	7	45	54	63	12	45	47.70	0.50	6.45	5	8	13
24-01-2010	8	45	47.70	63	12.50	45	51.90	0.50	6.46	10	1	11
24-01-2010	9	45	51.90	63	13	45	46	0.50	6.46	0	9	9
24-01-2010	10	45	46	63	13.50	45	51	0.50	6.46	0	0	0
24-01-2010	11	45	51	63	14	45	48.70	0.50	6.46	0	0	0
24-01-2010	12	45	48.70	63	14.50	45	53	0.50	6.45	1	0	1
Survey B												
24-01-2010	1	45	49	62	41	45	44	0.5	6.46	0	0	0
24-01-2010	2	45	49	62	41.5	45	46	0.5	6.46	0	2	2
24-01-2010	3	45	45	62	42	45	49	0.5	6.46	4	0	4
24-01-2010	4	45	49	62	42.5	45	45	0.5	6.46	1	1	2
24-01-2010	5	45	50	62	43	45	45	0.5	6.46	1	4	5
24-01-2010	6	45	45	62	43.5	45	50	0.5	6.46	1	0	1
24-01-2010	7	45	50	62	44	45	45	0.5	6.46	2	2	4
24-01-2010	8	45	45	62	44.5	45	48	0.5	6.46	5	1	6
24-01-2010	9	45	48	62	45	45	45	0.5	6.46	0	0	0
24-01-2010	10	45	45	62	45.5	45	49	0.5	6.46	0	1	1
24-01-2010	5	45	42	62	34	45	47	0.5	6.47	0	0	0
24-01-2010	6	45	47.9	62	34.5	45	42	0.5	6.47	0	0	0
24-01-2010	7	45	44	62	35	45	47.9	0.5	6.46	2	1	3
24-01-2010	8	45	47	62	35.5	45	44	0.5	6.46	0	0	0
24-01-2010	9	45	48	62	36	45	47	0.5	6.46	0	0	0
24-01-2010	10	45	49	62	36.5	45	45	0.5	6.46	0	0	0

24-01-2010	11	45	45	62	37	45	49	0.5	6.46	0	0	0
24-01-2010	12	45	49	62	37.5	45	45	0.5	6.46	0	2	2
24-01-2010	13	45	48	62	38	45	45	0.5	6.46	0	3	3
24-01-2010	14	45	45	62	38.5	45	49	0.5	6.46	2	0	2
Survey C												
02-02-2010	1	45	43	61	30	45	44	2	25.87	0	0	0
02-02-2010	2	45	46	61	32	45	44	2	25.86	2	3	5
02-02-2010	3	45	44	61	34	45	45	2	25.87	2	1	3
02-02-2010	4	45	45.5	61	36	45	45.3	2	25.86	0	3	3
02-02-2010	5	45	45.3	61	38	45	46	2	25.86	0	0	0
02-02-2010	6	45	47	61	40	45	46	2	25.85	1	2	3
02-02-2010	7	45	46	61	42	45	48	2	25.85	1	6	7
02-02-2010	8	45	50	61	44	45	48	2	25.83	1	5	6
02-02-2010	9	45	48	61	46	45	50	2	25.83	0	1	1
02-02-2010	10	45	51	61	48	45	50	2	25.82	0	0	0
02-02-2010	11	45	51	61	50	45	52	2	25.81	1	0	1
02-02-2010	12	45	53	61	52	45	51	2	25.81	1	1	2
02-02-2010	13	45	51	61	54.6	45	52.8	2	25.81	0	0	0
02-02-2010	14	45	53	61	56	45	58	2	25.78	1	2	3
Survey D												
02-02-2010	1	45	53	61	57	45	52.8	1	12.90	0	1	1
02-02-2010	2	45	54	61	58	45	51	1	12.90	2	2	4
02-02-2010	3	45	51.8	61	59	45	54	1	12.90	0	4	4
02-02-2010	4	45	48	62	0	45	53	1	12.91	2	4	6
02-02-2010	5	45	54	62	1	45	50	1	12.90	6	0	6
02-02-2010	6	45	50	62	2	45	54	1	12.90	2	2	4
02-02-2010	7	45	50	62	3	45	54	1	12.90	3	2	5
02-02-2010	8	45	54	62	4	45	48	1	12.91	4	6	10
02-02-2010	9	45	54	62	5	45	47	1	12.91	1	4	5
02-02-2010	10	45	54	62	6	45	47	1	12.91	4	5	9
02-02-2010	11	45	47	62	7	45	54	1	12.91	10	17	27
02-02-2010	12	45	47	62	8	45	54	1	12.91	7	2	9
02-02-2010	13	45	54	62	9	45	46	1	12.91	7	8	15
02-02-2010	14	45	45	62	10	45	54	1	12.91	6	6	12
02-02-2010	15	45	46	62	11	45	54	1	12.91	0	0	0

02-02-2010	16	45	44	62	12	45	54	1	12.92	0	0	0
Survey E												
02-02-2010	1	45	53	62	16	45	42	4	51.69	0	0	0
02-02-2010	2	45	41	62	20	45	53.5	4	51.69	0	0	0
02-02-2010	3	45	53	62	24	45	41	4	51.69	0	0	0
02-02-2010	4	45	49	62	28	45	53	4	51.63	0	0	0
02-02-2010	5	45	55	62	32	45	49	4	51.62	0	0	0
02-02-2010	6	45	39	62	36	45	55	4	51.69	0	0	0
02-02-2010	7	45	56	62	40	45	39	4	51.69	0	0	0
02-02-2010	8	45	51	62	44	45	56	4	51.59	0	0	0
02-02-2010	9	45	56	62	48	45	51.5	4	51.59	0	0	0
Survey F												
06-02-2010	1	45	56	61	57	45	52	1	12.90	0	1	1
06-02-2010	2	45	52	61	58	45	56	1	12.90	1	1	2
06-02-2010	3	45	52	61	59	45	56	1	12.90	0	0	0
06-02-2010	4	45	56	62	0	45	51	1	12.90	5	1	6
06-02-2010	5	45	51	62	1	45	55	1	12.90	5	2	7
06-02-2010	6	45	55	62	2	45	50	1	12.90	1	3	4
06-02-2010	7	45	50	62	3	45	55	1	12.90	3	5	8
06-02-2010	8	45	55	62	4	45	48	1	12.91	3	8	11
06-02-2010	9	45	48	62	5	45	55	1	12.91	16	5	21
06-02-2010	10	45	55	62	6	45	47	1	12.91	3	12	15
06-02-2010	11	45	47	62	7	45	56	1	12.91	1	0	1
06-02-2010	12	45	56	62	8	45	46	1	12.91	0	0	0

Table 2. Estimated pup production from strip transect surveys over pack ice, not corrected for births after survey completed.

Date	Estimate	Standard error
24-01-2010 (Survey A)	381	78
24-01-2010 (Survey B)	162	39
24-01-2010 (Survey C)	65	240
Total	608	255
02-02-2010 (Survey D)	879	2,727
02-02-2010 (Survey E)	1,510	4,421
Total	2,389,	5,195
06-02-2010 (Survey F)	981	2,207

Table 3. Counts of pups on islands/small ice patches.

Location	Date	Count (SE)
Ice		
Hillsborough Bay	02-02-2010-	87
North side PEI	13-02-2010	23
Gulf Islands		
Saddle Island*	22-01-2010	1,306 (59)
Oak Island	06-02-2010	4
Amet Island	21-01-2010	296
Pictou Island*	24-01-2010	2,908 (143.5)
Henry Island	25-01-2010	1,006 (79.5)
Margaree Island	15-01-2010	40
Deadman Island*	03-02-2010	392 (5.5)
Brion island	28-02-2010	23
Anticosti Island		50**

*2 counts

** approximate

Table 4. Number of grey seal pups in different stages.

Site	Date	Stage 1	2	3	4	5	Total
Ice	2010-01-22	13	33	1	0	0	47
	2010-01-24	4	25	18	0	0	47
C. George to Canso	2010-02-01	5	69	114	83	1	235
	2010-02-02	0	23	67	0	1	91
	2010-02-05	18	140	267	8	2	435
	2010-02-06	3	34	43	2	1	83
	2010-02-13	2	26	376	81	22	507
Hillsborough Bay	2010-02-02	0	7	79	1	0	87
	2010-02-06	0	1	52	6	0	59
	2010-02-13	0	1	26	23	6	56
Saddle Island	2010-01-14	26	226	81			333
	2010-01-19	73	443	195	1		722
	2010-01-22	35	338	1148	12	9	1604
	2010-02-01	2	18	322	57	47	446
	2010-02-06	0	1	89	83	50	223
Amet Island	2010-01-14	3	140	95			238
	2010-01-19	10	94	90			197
	2010-01-21	6	53	171	10	2	250
	2010-01-23	2	24	93	1	4	243
	2010-01-31	0	1	63	66	32	162
	2010-02-13	0	0	0	13	32	45
Pictou Island	2010-01-14	24	691	130	0	0	861
	2010-01-21	253	1023	637	2	2	1917
	2010-01-24	7	242	412	2	1	664
	2010-02-01	11	154	696	8	32	971
	2010-02-06	0	0	455	167	95	717
	2010-02-13	0	0	230	398	504	1132
Henry Island	2010-01-15	36	351	205	0	0	592
	2010-01-21	17	447	216	0	0	680
	2010-01-25	19	114	261	6	1	401
	2010-02-01	2	9	59	35	6	311
	2010-02-06	0	4	123	158	77	362
	2010-02-13	0	1	87	189	279	556
Margaree Island	2010-01-15	5	25	10			40
	2010-01-21	0	18	16	0	0	34
	2010-02-01	0	1	7	0	1	9
Deadman Island	2010-02-03	6	43	126	75	42	308
	2010-02-16	0	19	36	29	45	129
	2010-02-28	0	2	4	6	8	20

Table 5. Total pup production in the Gulf of St. Lawrence after correcting for births.

Date	Estimate	SE	Proportion born (se)	Corrected estimate	SE
Surveys					
24 January	608	255	0.88 (.09)	691	298
2 February	2,389	5,195	0.87 (0.06)	2,755	5,995
6 February	981	2,207	0.95 (0.173	1,028	2,321
Total				4475	6,435
Counts					
Hillsborough Bay	87		1 (.002)	87	
PEI north side	23			23	
Saddle Island	1,306	59	0.94 (0.03)	1,385	80
Oak Island	4			4	
Amet Island	288+8 dead		0.97 (.01)	304	15
Pictou Island	2,892+16 dead	144	0.89 (0.05)	3,258	240
Henry Island	1,006	80	0.91 (0.02)	1,110	91
Margaree Island	40		0.49 (0.06)	82	109
Deadman Island	392	6	0.92 (0.23)	428	109
Brion Island	23			23	
Anticosti Island	50			50	
Total counts				6,754	291
Total				11,228	6,442

Table 6. Estimates of Gulf grey seal pup production, from mark-recapture (M-R) and aerial surveys, with estimates separated into ice and island estimates where possible, rounded to the nearest 100. Standard errors are in brackets.

Year	Ice		Island			Total	
	Estimate	SE	Estimate	SE	Estimate	SE	CV
1962							
1963							
1964							
1965							
1966[5]	900				900		
1967							
1968							
1969							
1970							
1971							
1972							
1973							
1974							
1975[4]	3,300		500		3,800		
1976							
1977							
1978							
1979							
1980							
1981							
1982							
1983							
1984[1]	7,169	911			7,169	911	12.7
1985[1]	6,706	795			6,706	795	11.8
1986[1]	5,588	679			5,588	679	12.2
1989[1,2]	9,352	1,756			9,352	1,756	18.8
1990[1,2]	9,176	649			9,176	649	7.1
1996[3]	10,691	1,306	26		10,717	1,306	12.2
1997[3]	5,810	780	1,029	30	6,839	800	11.7
2000[3]	4,850	910	410		5,260	910	17.3
2004[3]	13,473	1,216	737	65	14,210	1,200	8.4
2007[3]	4,615	940	6,798	526	11,413	1,077	9.4
2010[3]	4,585	6,435	6,643	291	11,228	6,442	57.4

[1] Hammill *et al*. 1998
[2] Myers *et al*. 1997, Several estimates available from 1 &2 for 1989, 1990. These were averaged.
[3] Hammill *et al*. 2007, and current study.
[4] Mansfield and Beck 1977 assuming 500 pups born on Amet and Deadman Is.
[5] Mansfield 1966, estimated by subtracting 500 pups from estimates of pup production on Sable and Basque Is.

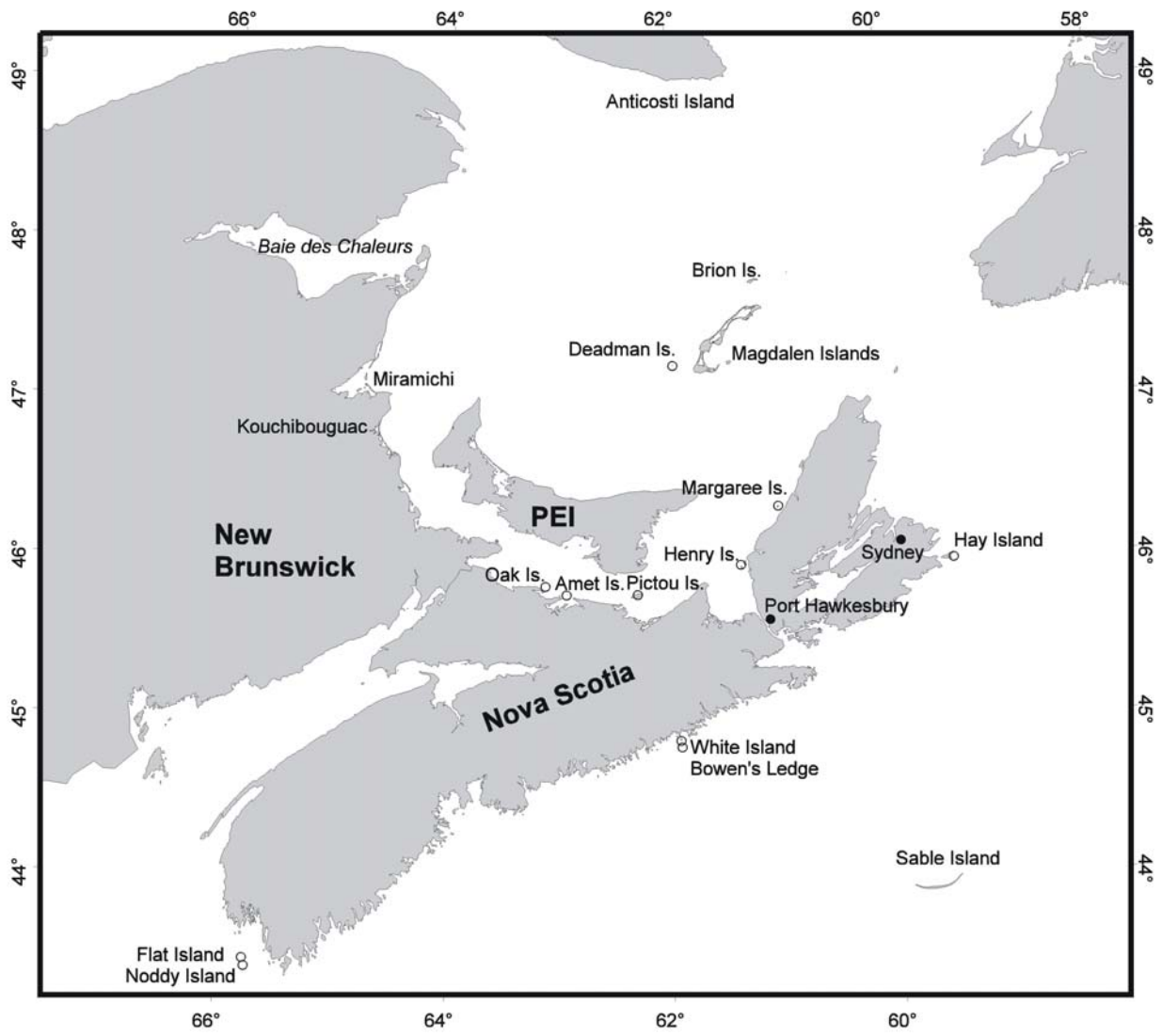

Figure 1. Map of study area. PEI is short for Prince Edward Island. Hillsborough Bay is the large bay, just underneath the "I" in PEI. Saddle Island is located just to the west of Amet Island on the peninsula.

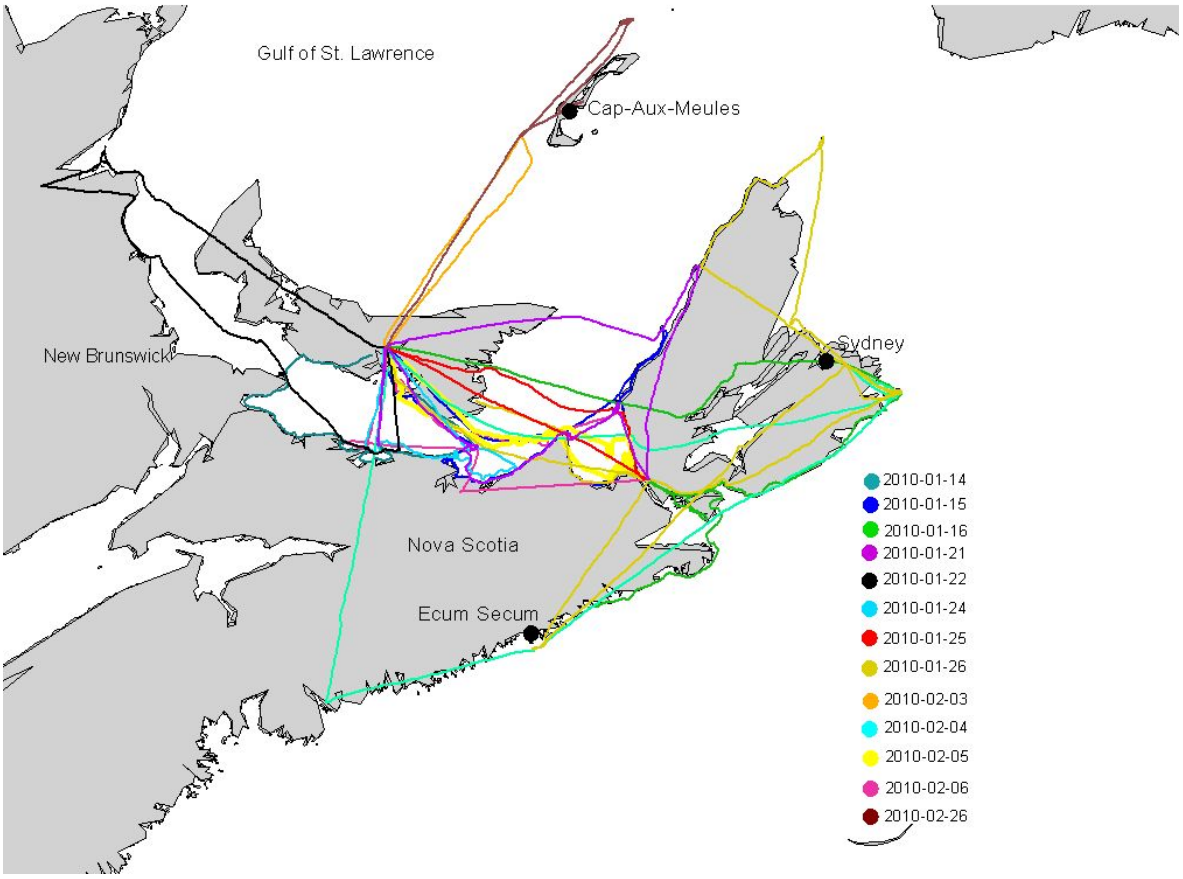

Figure 2. Reconnaissance surveys flown in the southern Gulf of St. Lawrence during January-February 2010.

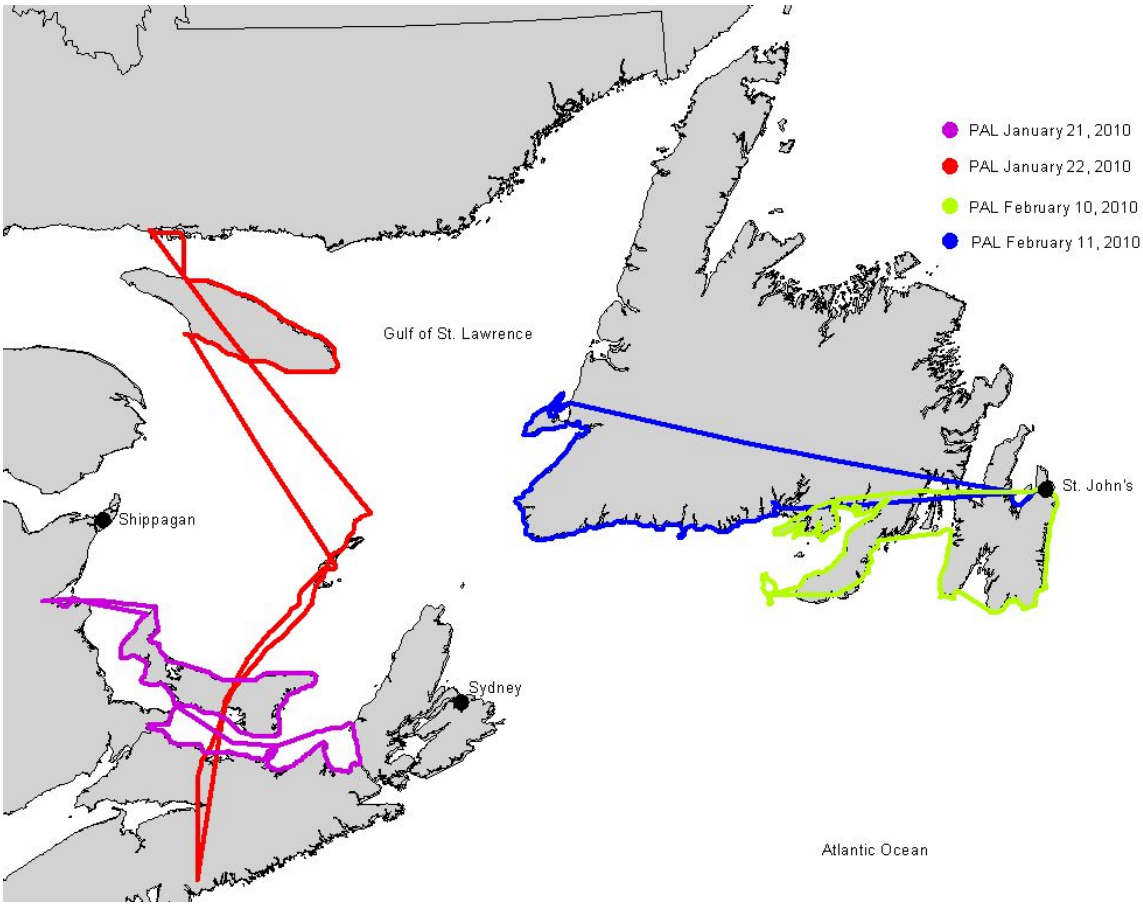

Figure 3. Joint C&P/Science reconnaissance flights during January 2010.

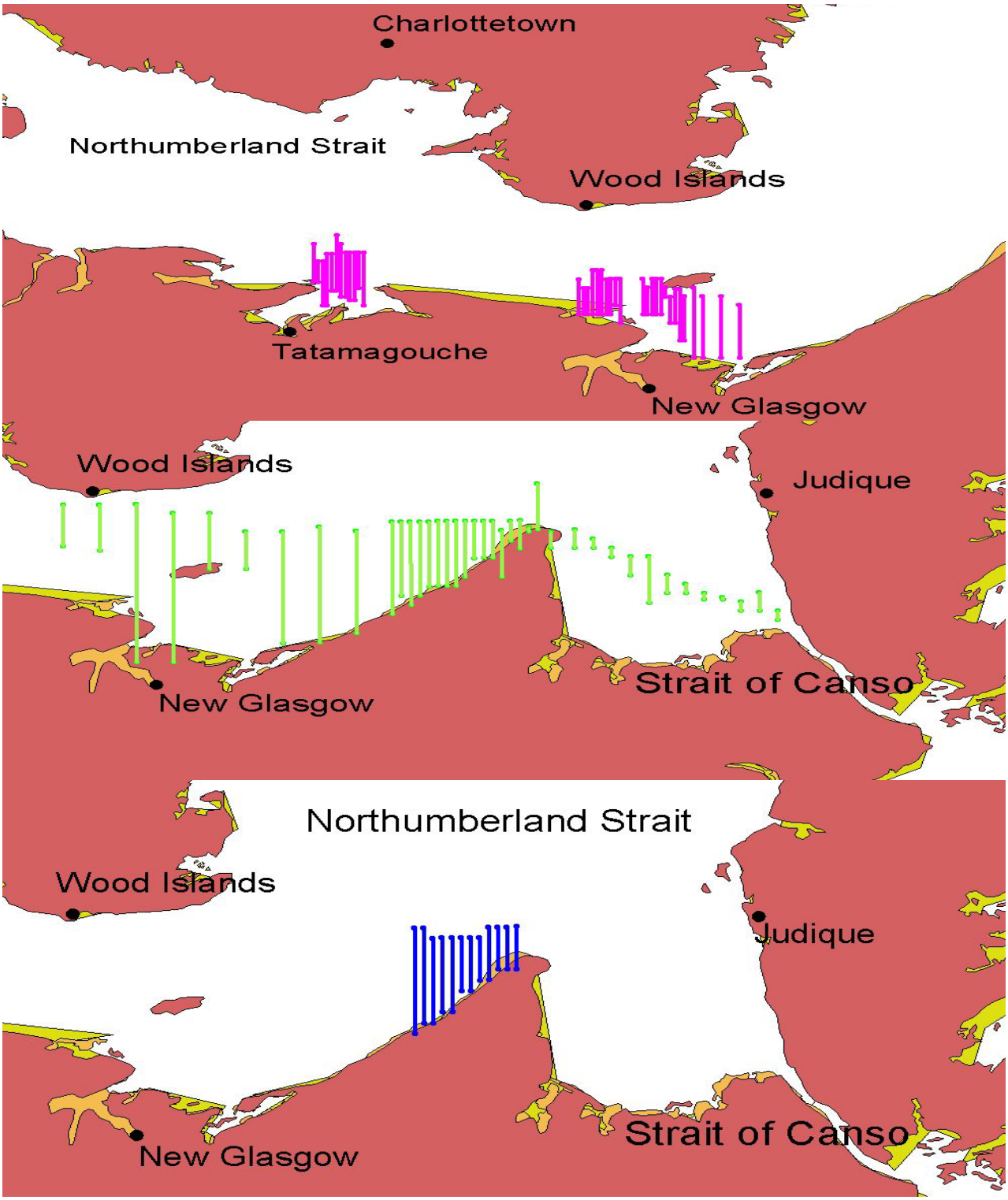

Figure 4. Transects completed on 24 January (top), 2 February (middle) and 6 February 2010 (bottom).

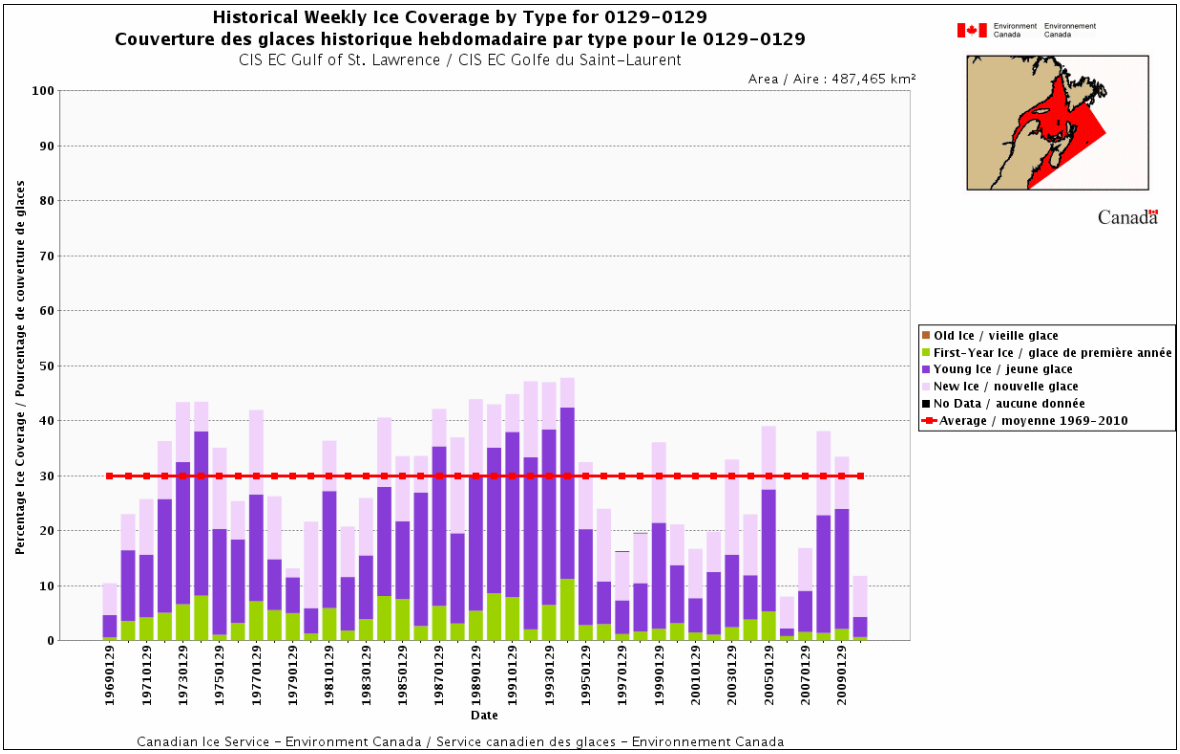

Figure 5. Ice cover in the Gulf of St Lawrence on 29 January from 1969-2010 (From Environment Canada: http://ice-glaces.ec.gc.ca/IceGraph/), where new ice is <10 cm, young ice is <30 cm and first-year ic is 30 cm thick.