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Gulf of St. Lawrence**

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Hooded Seal (*Cystophora cristata*) Pup Production in the Gulf of St. Lawrence

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Systematic visual aerial surveys were flown in the southern Gulf of St. Lawrence during March 1990 and 1991 to estimate hooded seal (*Cystophora cristata*) pup production. In 1990, the main whelping patch, occupying an area of 264 km², was located near Cape Breton Island. One hundred and five pups were counted on 17 transects, resulting in a mean density of 1.74 pups·km⁻² and an estimated pup production of 1638 (SE = 466). In 1991, a large whelping patch was located to the west of the Magdalen Islands, a second off the coast of Prince Edward Island, and a small patch was later found south of the Magdalen Islands. The two major patches were surveyed, resulting in a pup production estimate of 1564 (SE = 101). During the 1991 surveys, an estimated 71–93% of the pups were on the ice. Correcting for the distribution of births results in a minimum 1991 pup production estimate of 2006 (SE = 190) for the Gulf of St. Lawrence.

Des relevés visuels aériens systématiques ont été effectués dans le sud du golfe Saint-Laurent en mars 1990 et 1991 pour déterminer la production de jeunes phoques à capuchon (*Cystophora cristata*). En 1990, la zone principale de mise bas, couvrant un territoire de 264 km², a été localisée près de l'Île du Cap Breton. Cent cinq petits ont été dénombrés au cours des 17 transects, soit une densité moyenne de 1,74 petits·km⁻² et une production de petits estimée à 1 638 (SE = 466). En 1991, une grande zone de mise bas a été localisée à l'ouest des Îles-de-la-Madeleine, une deuxième, au large de la côte nord de l'Île-du-Prince-Edouard et une petite zone, localisée plus tard au sud des Îles-de-la-Madeleine. Les relevés ont été effectués dans les deux zones principales, indiquant une production de petits estimée à 1 564 (SE = 101). Au cours des relevés de 1991, on a estimé que 71–93% des petits étaient présents sur la banquise. Après ajustement pour tenir compte de la distribution des naissances, la production minimale de petits pour le golfe Saint-Laurent est estimée à 2 006 (SE = 190).

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The hooded seal (*Cystophora cristata*) is a large phocid inhabiting pelagic waters of the North Atlantic. Whelping occurs on the pack ice around Jan Mayen Island, in Davis Strait, and off eastern Canada. In the Northwest Atlantic, the majority of pups are born in Davis Strait and off the south-eastern Labrador and northern Newfoundland coasts, an area known to sealers as the "Front" (Sergeant 1974). Aerial surveys flown in 1984 produced estimates of 19 000 (95% CI = 14 000–23 000) pups in Davis Strait and 62 000 (95% CI = 43 700–89 400) pups on the Front (Bowen et al. 1987b).

Hooded seals also whelp in the Gulf of St. Lawrence, but little is known of Gulf pup production or of the relationship between Gulf and Front hooded seals. In 1894, a single ship reportedly took 7562 animals consisting largely of hooded seals (Mosdell 1923; Horwood 1977). Throughout the early 1900's the population apparently declined, and in 1972 the commercial hunt for hooded seals was closed in the Gulf to protect the stock (Reeves and Ling 1981). Visual estimates of pup production from the 1980's ranged from 500 to 800 animals (D. E. Sergeant and W. Hoek, Department of Fisheries and Oceans, Mont Joli, Que. G5H 3Z4, unpubl. data; Stenson and Wakeham 1986), but this population has never been systematically surveyed.

Hooded seals give birth during a 2-wk period in March. Lactation period is short, lasting only 4 d, during which the pups

double in size from 22 kg at birth to 43 kg at weaning (Bowen et al. 1985, 1987a). After weaning, the pups may enter the water and disperse. Any attempt to estimate pup production must therefore correct for pups not born at the time of the survey and for pups that have already left the ice (Bowen et al. 1987b).

Since protection in 1972, it is likely that the hooded seal population in the Gulf has increased. Information on hooded seal diet indicates that hooded seals may compete with fishermen by feeding on commercially important fish (Stenson et al. 1991). In order to assess the impact of hooded seals on commercial fisheries, information on population size is required. In this paper, we estimate hooded seal pup production in the Gulf of St. Lawrence using visual aerial surveys and a model to correct for pups not born at the time of the survey (Bowen et al. 1987b; Stenson and Myers 1988).

Methods and Materials

Whelping occurs on the pack ice some 30 miles (48 km) south of the Magdalen Islands near Prince Edward Island or off the Cape Breton Island coast in the southern Gulf of St. Lawrence (Sergeant 1974; D. E. Sergeant and W. Hoek, unpubl. data) (Fig. 1). In this area the direction of ice drift is to the northeast along the Cape Breton Island coast and out to the Atlantic Ocean through Cabot Strait (El-Sabh 1976).

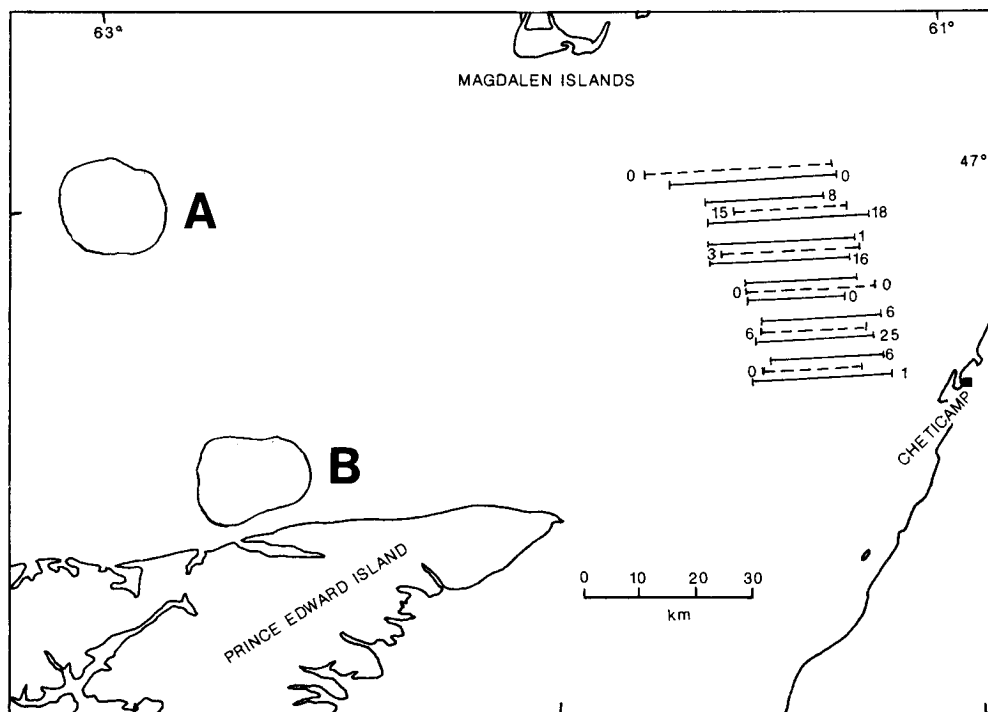


FIG. 1. Location of transects flown during the 1990 survey. Numbers of animals observed on each transect are plotted at the end of each transect line. Solid lines were flown 19 March 1990; broken lines were flown 20 March 1990. A and B represent the locations of the Magdalen Island and Prince Edward Island patches, respectively, surveyed in 1991.

Survey Design

Systematic strip transect surveys were flown in 1990 and 1991 in a Bell 206 helicopter equipped with Loran C for navigation. Altitude was maintained using a pressure altimeter calibrated with the recorded pressure at Cap aux Meules airport (1990) or with a radar altimeter (1991).

In 1990, whelping occurred in a single patch. Two surveys were flown. In the first survey, transects were evenly spaced at intervals of 3.6 km. During the second survey, transects were spaced 7.2 km apart, with the first transect offset from the previous day's lines by 1.8 km. Both surveys were flown at an altitude of 61 m. Observers were seated in the left front seat beside the pilot and right rear seat. Each observer counted seals in a strip 80 m wide on his side of the aircraft. Strips were delineated by aligning sighting marks on the aircraft window with distances measured on the ice with a metre wheel and marked with fluorescent powder.

The 1990 survey had a coefficient of variation of 28%. In 1991, we attempted to reduce this by increasing survey intensity. Two whelping patches, a Prince Edward Island patch and a Magdalen Island patch, were surveyed. In both surveys, evenly spaced transects 0.9 km apart were flown perpendicular to the long axis of the patch. The survey of the Prince Edward Island patch was flown at an altitude of 91 m and had a strip width of 200 m on each side of the aircraft. During the survey of the Magdalen Island patch, we discovered harp seal (*Phoca groenlandica*) beaters in the northern part of the hooded seal patch. In order to distinguish between solitary hooded seal pups and harp seal beaters, we reduced the altitude to 61 m and the strip width to 120 m on each side of the aircraft.

Data Analysis

Survey data were analysed using the methods outlined by Kingsley and Hammill (1991). The estimate for the number of pups is given by $N_i = k_i (x_{i1}/2 + \sum_{j=2}^{J_i-1} x_{ij} + x_{iJ_i}/2)$ where

J_i = the number of transects in the i th group, x_{i1} is the number of pups counted on the first transect in the i th group, x_{ij} is the number of pups counted on the j th transect in the i th group, and k_i is a weighting factor equal to the transect spacing divided by the strip width of the i th group. The serial difference method for calculating error variance (Kingsley et al. 1985) was modified to take into account that the statistic of interest is the population total and not the spatial density of animals (Kingsley and Hammill 1991). Error variance for total numbers of seals in each group was then calculated using $V_i = k_i (k_i - 1)/2 \times \sum_{j=1}^{J_i-1} (x_j - x_{j+1})^2$ where the end transect is outside the patch.

The combined estimate for the total population was $N = \sum_{i=1}^I N_i$, $V = \sum_{i=1}^I V_i$ where I is the number of groups of transects.

Stage Determination

In 1991, pups were classified into four identifiable stages based on morphology and presence or absence of the female (Bowen et al. 1987b; Stenson and Myers 1988). The two whelping patches were each surveyed three times. In each survey, transects spaced approximately 2 km apart were flown per-

pendicular to the long axis of the herd from one end of the patch to the other. Transects were flown at an altitude of 15 m, and all pups seen within 50 m were assigned a developmental stage. Information on the proportions of animals in each of these stages was used to model the distribution of births over time, which provided an estimate of the proportion of pups on the ice at the time of the survey. We used the model and computer programs developed for hooded seals by Bowen et al. (1987b). Confidence limits for the parameters of the birthing distribution were calculated by the log-likelihood for pairs of parameter values. The approximate 95% confidence region is the set of parameter values where the difference in the log-likelihood is approximately greater than 4 from the maximum (Cox and Hinkley 1974). Population estimates from the visual survey were corrected for pups not born at the time the survey was flown by dividing by the estimated proportion of pups present on the ice at the time of the survey. During our surveys and while working on the ice, no pups were observed in the water. Therefore, we fixed the proportion of stage 4 pups on the ice at 100%. The standard error of the corrected estimate was obtained from the standard formula for the variance of ratios of two random variables (equation 10.17; Stuart and Ord 1987).

Results

In 1990, a weaned hooded seal pup was observed in the harp seal patch, north of Magdalen Islands (47°N, 62°W), on 11 March, indicating that pupping had begun as early as 7 March. Reconnaissance flights flown 14 March, to the south and southeast of the Magdalen Islands, located hooded seals and pups near Cheticamp off Cape Breton Island over an area of 264 km² of ice (Fig. 1). No other hooded seal patch was located. Systematic strip-transect surveys of the hooded seal patch were flown on 19 and 20 March. During the first survey, 11 transects were flown. Survey intensity was 4.3% of a total survey area of 929 km². Eighty-one pups were counted on transect, resulting in an estimate of 1875 (SE = 556) animals. On 20 March, the patch was surveyed a second time. Six transects were flown between 46°41'N and 47°01'N, resulting in a survey intensity of 2.2% of a total area of 929 km². Twenty-four pups were counted on transect resulting in an estimate of 1111 (SE = 687) pups. Based on Loran C coordinates for limits of the herd, there appeared to be very little movement of the whelping patch between the two days of surveys. Combining the two surveys and treating them as one survey resulted in a mean density estimate of 1.74 animals·km⁻² and total pup production not corrected for the distribution of births over time of 1638 (SE = 466).

Mean counts were compared between the front and rear observers to test for any major differences. Mean number of pups counted per transect were 3.76 (SE = 1.20) and 2.41 (SE = 0.91) for the front and rear observers, respectively, but the differences were not significant ($t = 0.9$, $df = 32$, $p > 0.05$).

On 11 March 1991, whelping hooded seals (the Magdalen Island patch) were observed with some harp seals present at 47°38'N, 62°12'W. A second, very large patch (the Prince Edward Island patch) was observed on 14 March off Prince Edward Island (46°33'N, 62°43'W) (Fig. 1, 2). Hooded seals were also seen on 16 March at 46°42'N, 62°08'W, but we were unable to locate them until the final day when the helicopter was returning to Halifax.

The Prince Edward Island group distributed over 266 km² of ice was surveyed 18 March. A total of 412 pups was counted

on the 19 transects, resulting in an estimate of 954 (SE = 69) pups and a survey coefficient of variation of 7%. Survey intensity was 44%. The second patch (Magdalen Island patch), surveyed 19 March, covered an area of 158 km² and was located about 64 km south southwest of the Magdalen Islands (Fig. 2). One hundred and fifty-eight animals were counted on the 14 transects, resulting in an estimate of 610 (SE = 73) pups and a survey coefficient of variation of 12%. Survey intensity was 27%.

Little difference was observed between observers for the mean number of seals counted per line. In the Prince Edward Island patch, the left observer counted an average of 9.79 (SE = 2.03) pups per transect, and the right observer counted an average of 11.89 (SE = 2.64, $t = 0.6$, $df = 36$, $p > 0.05$) pups per line. In the Magdalen Island patch, the left observer's counts ($\bar{x} = 5.79$, SE = 1.72) were slightly higher than the right observer's counts ($\bar{x} = 5.50$, SE = 1.5, $t = 0.12$, $df = 26$, $p > 0.05$).

Surveys of the Prince Edward Island patch to determine the distribution of pup births began on 15 March. Five solitary (stage 4) pups were observed at this time, indicating that pupping began at least as early as 11 March. No new pups were observed in this patch after 22 March (K. Kovacs, pers. comm.). To calculate the distribution of births over time, we assumed that pupping started on 11 March and ended on 22 March and that 100% of the stage 4 pups were on the ice at the time of the survey. Using a beta distribution to fit the distribution of births over time, we estimated that 71% (SE = 0.06%) of the pups had been born at the time of the 18 March 1991 survey. Applying this correction to the survey data resulted in an estimate of 1350 pups (SE = 150) for the Prince Edward Island patch.

Staging surveys of the Magdalen Island patch were first flown on 11 March (Table 1). The presence of fat blueback pups (stage 3) indicated that pupping may have begun as early as 8 March. During the final staging survey of this patch on 19 March, some thin blueback (stage 2) pups, but no newborn (stage 1) pups, were observed. To calculate the distribution of births over time, we assumed that pupping began 9 March and was complete by 22 March. At the time of the 19 March 1991 survey, we estimated that 93% (SE = 0.02) of the births had occurred. Applying this correction to the survey data resulted in an estimate of 656 pups (SE = 80) for the Magdalen Island patch.

Combining these estimates, total hooded seal pup production in the Gulf of St. Lawrence was 2006 (SE = 190) in 1991.

Discussion

Visual aerial surveys may be subject to negative biases owing to difficulties in detecting all animals lying within the survey strip (Caughley 1974; Caughley et al. 1976). For Gulf hooded seals, we do not believe that this is a serious source of error in our estimates. The dark hooded seal pup is easily detected on the white ice. Also, the relatively low densities and the presence of the large female and often at least one male in the vicinity (Kovacs 1990) facilitate pup detection. Some pups hidden by ice ridges could have been missed, but the similarity in estimates obtained between years for surveys flown at similar times suggests that this is not a serious source of error or that it is at least consistent.

A more serious source of bias results from failure to detect all major patches of whelping animals (Myers and Bowen 1989). In 1990, a few hooded seal pups were observed dispersed

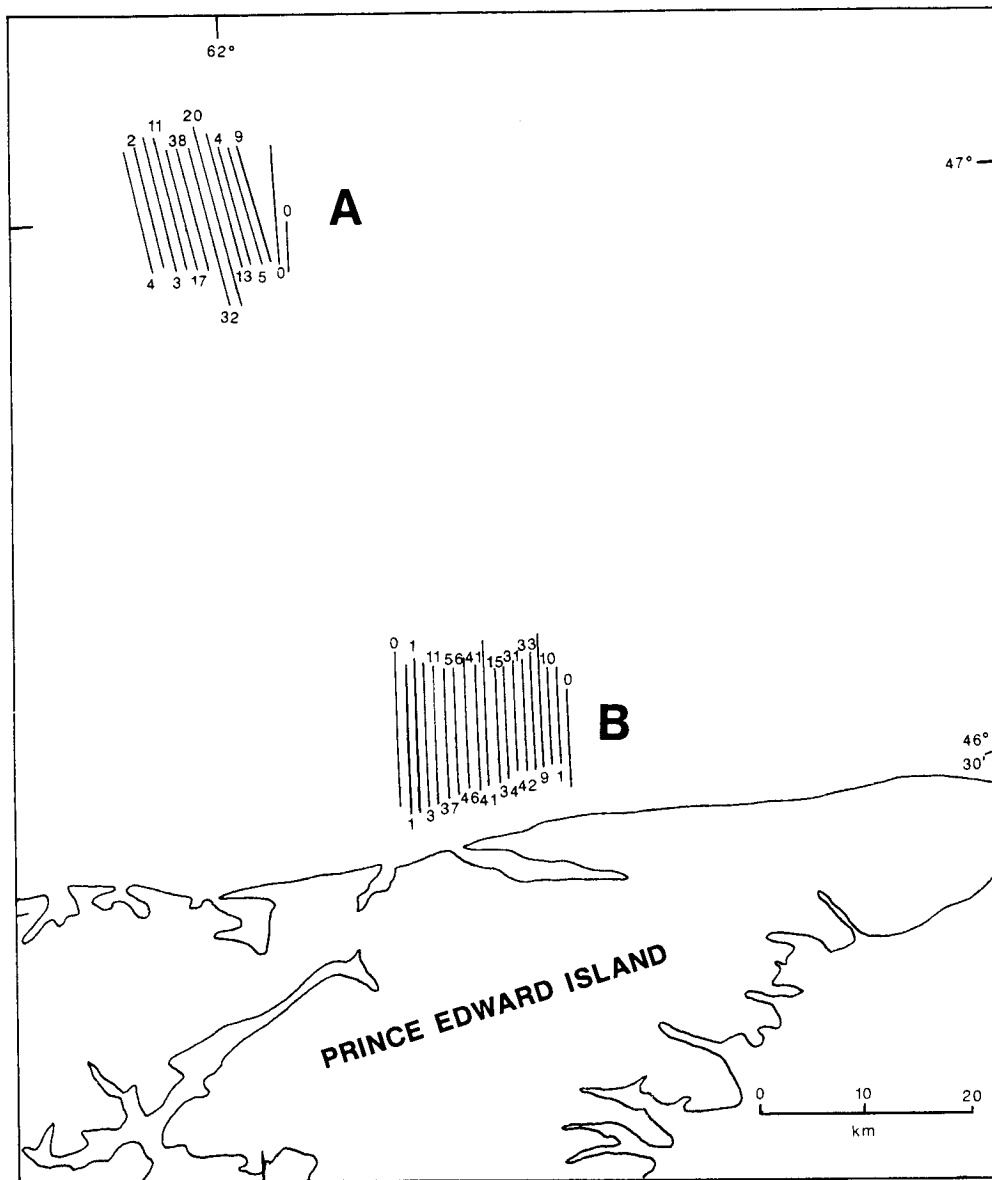


FIG. 2. Location of survey lines flown in 1991 surveys of the (A) Magdalen Island patch and (B) Prince Edward Island patch. Numbers of animals observed on transect are plotted at the end of each line.

TABLE 1. Stage data from 1991 aerial surveys of hooded seal pups in the southern Gulf of St. Lawrence.

Place and date	Stage				Total
	1	2	3	4	
Prince Edward Island patch					
March 15	0	68	44	14	126
17	0	34	94	38	166
19	0	36	83	71	190
Magdalen Island patch					
March 11	1	4	3	0	8
14	1	43	20	1	65
18	0	5	16	11	32
19	0	4	14	17	35

amongst the harp seal patch as early as 11 March, but surveys around the Magdalen Islands and in the southern Gulf failed to detect any other concentrations of hooded seals in the tradi-

tional whelping areas (D. E. Sergeant and W. Hoek, unpubl. data; Stenson and Wakeham 1986). The possibility of whelping elsewhere in the Gulf is unlikely, but cannot be completely discounted. Comeau (1945) found a newborn hooded seal pup near Point des Monts in the St. Lawrence River estuary in February 1898. The other most likely area for whelping to occur is in the northeastern part of the Gulf where suitable ice is sometimes found. In 1990, this area was surveyed for harp seals at which time only a single male hooded seal was observed, although pupping had already begun elsewhere. In 1991, we were informed by a helicopter pilot of a third hooded seal patch, but were unable to locate it. After our surveys had finished and the helicopter was returning to Halifax, one of us (G.B.S.) spotted a small group estimated to number <30 pups in the area that the third group had been reported.

Survey coefficient of variation declined from 28% in 1990 to less than 13% in 1991. This improvement in survey precision was achieved by increasing survey strip width and by decreasing the distance between transects. Although further reductions

in precision are desirable, it is unlikely that they can be achieved by increasing survey intensity, due to potential problems of crossing lines and double counting. In this study, we were forced to alter our protocol between the surveys of the Prince Edward Island and Magdalen Island patches in order to be able to identify harp seal beaters present within the hooded seal patch. Future studies must take this into account and be prepared to alter the survey design on short notice.

In 1990, the one observer sat in front and directed the survey. The greater visibility of the front seat combined with the difficulties in both counting and directing the survey resulted in 50% higher and much more variable counts compared with those of the rear observer. In 1991, both observers counting seals sat in the rear, and the survey was directed by a third person sitting in the front seat. As a result, less variability and smaller differences in counts were seen between observers. We recommend that a third person be used to direct surveys in future, especially in studies where the aircraft is slow moving and transect lines are closely spaced, conditions under which the potential for crossing lines is high.

We estimated that 71–93% of the pups were present on the ice during our surveys. This proportion on the ice is higher than the 44% estimated by Bowen et al. (1987b) for hooded seals at the Front and likely reflects real differences in survey conditions between the two studies. In the Gulf, hooded seals are observed on much larger pans of ice and the pupping platform appears to be much more stable than that observed at the Front (G. Stenson, pers. obs.). In this study, we assumed that no pups were in the water at the time of the survey. Fixing this parameter improved survey precision, but may have introduced some error into the estimate if this assumption was incorrect.

An estimated minimum pup production of 2006 pups is much greater than the 500–800 reported by earlier studies (D. E. Sergeant and W. Hoek, unpubl. data; Stenson and Wakeham 1986). Although the herd has probably increased since hunting ended in 1972 (Sergeant 1976), much of the difference between the two estimates reflects the fact that our study is the first quantitative survey of Gulf hooded seals.

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