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Harbour seals in Newfoundland and Labrador: a preliminary summary of new data on aspects of biology, ecology and contaminant profiles

Le phoque commun à Terre-Neuve et Labrador : une synthèse préliminaire des nouvelles données concernant certains aspects de la biologie, de l'écologie et du profil de contamination

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Abstract

Little is known about the current status of harbour seals (*Phoca vitulina)* in Newfoundland and Labrador given the last, and only comprehensive, study was conducted in the 1970s. Based on a limited number of reconnaissance boat surveys, opportunistic shore-based haulout counts and interviews with fishermen during 2001-2003, the current distribution of harbour seals is generally consistent with observations made in the 1970s. There is also limited evidence suggesting that local abundance of seals at some known haulout sites in the more southern portions of the province may have increased while abundance at sites in more northern areas of the west, northeast and Labrador coast are generally consistent with reports from the 1970s. Analyses of stomach samples collected from 1985-2003 indicated harbour seals consumed a wide variety of fish and invertebrate prey, but ten fish species accounted for almost 95% of the wet mass of food consumed. Winter flounder, Arctic cod, shorthorned sculpin and Atlantic cod were the most important overall. However, there was evidence of regional variation in the diets of seals sampled from the south, west, northeast and Labrador coasts. Seals fed on fish prey that were 10.4–41.3 cm in length (mean=18.8 cm, SD=6.80). From 2001-2003, a total of 66 tissue samples were collected from harbour seals throughout the province and analysed for heavy metal, trace elements and persistent organic pollutant (POPs) contaminant levels. The relative differences in heavy metal concentrations among tissue types were consistent with values in the published literature. The mean within-sample site concentration of trace elements, and the range among sites in Newfoundland and Labrador, corresponded well with data from harbour seals in Alaska and with northern pinnipeds in general. The trace elements Hg, Se, and Cd showed the greatest variability within and among sampling sites. Changes in renal cadmium concentration with body size were dependent on site; higher concentrations being found in seals sampled along the south and east coasts of the province. The source of cadmium is unknown at this time but it may be Placentia Bay, or alternatively, contaminants are being transported along the southern coast of the province and into Placentia Bay from the St Lawrence River. Based on the suite of persistent organic pollutants (POPS) examined, harbour seals sampled from Newfoundland waters were less contaminated than those from the St Lawrence Estuary population and generally similar to those from the Southern Gulf of St. Lawrence. Mirex and ΣPCB concentrations were 5-10 times higher in the Estuary population while Σ DDTs and Σ Chlordanes were 2-5 times higher than in Newfoundland seals. Similar PCB patterns and POP proportions were observed among Newfoundland seals of the same sex and age category suggesting that animals were permanent residents of a limited geographic area from which they extracted POPs. Mature males had higher POP levels than females, but there were no differences between male and female young of the year and juveniles. These new data on the general distribution, local abundance, diet and initial contaminant profiles of harbour seals will provide a basis for future ecological studies, population assessments and for understanding how contaminants accumulate in coastal food chains in eastern Canada.

Résumé

On connaît peu de choses sur l'état actuel de la population de phoques communs (*Phoca vitulina)* de Terre-Neuve et du Labrador étant donné que la dernière étude, et aussi la seule qui soit complète, a été menée dans les années 1970. Ainsi, selon un nombre limité de relevés de reconnaissance par bateau, de dénombrements opportunistes d'échoueries effectuées depuis le littoral et d'entrevues menées auprès de pêcheurs de 2001 à 2003, la répartition actuelle des phoques communs serait en général semblable à celle observée dans les années 1970. On dispose d'indices limités laissant entrevoir que l'abondance locale des phoques à certaines échoueries connues des régions les plus au sud de la province pourrait avoir augmenté, tandis que l'abondance aux emplacements plus au nord des régions de l'ouest et du nord-est de Terre-Neuve, et de la côte du Labrador, correspond de façon générale aux rapports des années 1970. Les analyses d'échantillons stomacaux prélevés de 1985 à 2003 indiquent que les phoques communs consomment une grande variété de poissons et d'invertébrés, mais que dix espèces de poissons représentent presque 95 % de la masse humide des proies consommées. La plie rouge, la morue polaire, le chaboisseau à épines courtes et la morue de l'Atlantique constituent la majeure partie des proies. On observe cependant des signes de variation régionale dans les régimes alimentaires des phoques échantillonnés sur les côtes sud, ouest et nord-est de Terre-Neuve et sur la côte du Labrador. Les phoques s'alimentent de poissons mesurant de 10,4 à 41,3 cm de longueur (moyenne = 18,8 cm, écart-type = 6,80). De 2001 à 2003, 66 échantillons de tissus de phoques communs ont été prélevés à l'échelle de la province. On a analysé ces échantillons pour déterminer les concentrations de mercure, d'éléments traces et les niveaux de polluants organiques persistants (POP). Les différences de concentrations de mercure et d'éléments traces constatées parmi les types de tissus analysés correspondaient aux valeurs indiquées dans la littérature publiée. La concentration moyenne d'éléments traces dans un même site d'échantillonnage et la plage de concentrations constatée aux sites de Terre-Neuve et du Labrador correspondent aux données sur les phoques communs d'Alaska et sur les pinnipèdes du Nord en général. Le mercure total, le sélénium (Se) et le cadmium (Cd) ont affiché la plus grande variabilité pour un même site d'échantillonnage et parmi l'ensemble des sites. Les changements dans la concentration rénale de cadmium selon la taille corporelle variaient selon le site, les concentrations plus élevées étant observées chez les phoques provenant des côtes sud et est de la province. La source de cadmium est inconnue à l'heure actuelle, mais pourrait se trouver dans la baie de Plaisance. Il est aussi possible que les contaminants soient transportés le long de la côte sud de la province et dans la baie de Plaisance par les eaux du Saint-Laurent. Selon la série de polluants organiques persistants (POP) examinée, les phoques communs prélevés dans les eaux de Terre-Neuve sont moins contaminés que ceux de la population de l'estuaire du Saint-Laurent et affichent en général une contamination semblable à celle des phoques du sud du golfe du Saint-Laurent. Les concentrations de mirex et de ΣBPC étaient de 5 à 10 fois plus élevées chez les individus de l'estuaire, tandis que celles de ΣDDT et de Σchlordanes étaient de 2 à 5 fois plus importantes que chez les phoques de Terre-Neuve. On a observé des profils de BPC et des proportions de POP semblables chez les phoques de Terre-Neuve appartenant à la même catégorie de sexe et d'âge, ce qui laisse entendre que les animaux ont probablement résidé en permanence dans une zone géographique limitée où ils ont absorbé les POP. Tel que prévu, les mâles adultes affichaient des concentrations de POP plus élevées que les femelles, mais aucune différence n'a été constatée entre les mâles et les femelles de l'année et les juvéniles. Ces nouvelles données sur la répartition générale, l'abondance locale, le régime alimentaire et les profils de contamination initiaux chez les phoques communs serviront de fondement à d'autres études écologiques et évaluations de la population, et à la recherche visant à comprendre le processus d'accumulation des contaminants dans les chaînes trophiques des régions côtières de l'est du Canada.

Introduction:

There are six species of pinnipeds in Newfoundland and Labrador waters including harp *(Pagophilus groenlandicus)*, hooded *(Cystophora cristata)*, harbour *(Phoca vitulina)*, grey *(Halichoerus grypus)*, ringed (*Phoca hispida)* and bearded seals *(Erignathus barbatus)*. Harp and hooded seals have received the most research attention from the Department of Fisheries and Oceans (DFO) because of the need to provide science advice for the management and conservation of these species and to better understand them as apex predators of fish resources in the northwest Atlantic marine ecosystem (e.g., Hammill and Stenson 2000). Much, less is known about the biology, ecology and abundance of the other four seal species. In the case of harbour seals, the only comprehensive study in Newfoundland and Labrador waters was conducted by Boulva and McLaren in 1979. These authors provided a wealth of information on local distribution and abundance, reproductive biology and behaviour, diet, growth and condition, and population dynamics. Since that time DFO has continued to collect harbour seal reproductive tracts and diet information but has not been able to process and analyse these data given other research priorities.

However, in recent years harbour seals have received more attention because of the Department's evolving Ocean Strategy. In 1997 the Oceans Act was passed and since that time DFO has moved towards developing an Oceans Action Plan that provides a framework for implementing coastal integrated management plans, marine protected areas, large ocean management areas and marine ecosystem health initiatives. In 2001, a comparative project was initiated to evaluate the harbour seal as an indicator species of marine ecosystem health in Placentia Bay and surrounding waters of Newfoundland. The objectives of the project were to: a) determine baseline contaminant profiles for harbour seals and their major prey species in Placentia Bay and the south coast of Newfoundland, b) collect the necessary harbour seal ecological data (including diet, reproductive status and age) to begin interpreting contaminant data from a marine ecosystem health perspective and evaluate whether harbour seals are an effective ecosystem indicator in coastal Newfoundland waters, and c) document the current and historical distribution, habitat use and relative abundance of harbour seals in key areas of Placentia Bay and surrounding areas with the goal of monitoring longer-term cumulative effects of future coastal developments related to offshore oil production. Some data analyses and considerable data interpretation and synthesis are still ongoing for each of the objectives. However, given that much of the information may be helpful for determining the status of harbour seals in Atlantic Canada we have compiled the most pertinent information from the ongoing project as well as include any accessible historical DFO data that may be important.

The information is presented under two general categories, ecology and contaminant profiles (total mercury, trace elements and persistent organic pollutants). The objectives of the ecology component were to provide an update on local abundance and distribution of seals in the vicinity of known haulout sites, estimate fertility and/or ovulation rates, summarize what is known about pupping times, and provide an overview of harbour seal diet in Newfoundland and Labrador. In terms of trace elements and total mercury (Hg) the primary objectives were to determine: the mean concentration of a suite of elements in the seal's muscle tissue, liver and kidneys; test the hypothesis that Hg and cadmium (Cd) were bioaccumulating; and, determine if sampling site was a significant factor in predicting the concentration of Hg and Cd in the various tissue. The study focused on these two contaminants because they are known to be toxic to mammals and are also known to bioaccumulate. Given harbour seals meet most of the conditions of a biomonitor (Rainbow and Phillips 1993), the species may be able to provide data on the geographic distribution and bioavailability of Hg and Cd around Newfoundland and Labrador. Levels of persistent organic pollutants (POPs) such as polychlorinated biphenyls (PCB) and p,p' dichlorodiphenyltrichloroethane (DDT) and its metabolites have never been thoroughly investigated in harbour seals inhabiting the coastal waters of Newfoundland and Labrador. Until now, only a preliminary study has reported levels of some POPs in blubber of 10 mature males (Lebeuf et al. 2003). In addition, very limited information exists on POPs in harbour seals throughout eastern Canada (Bernt et al. 1999; Lebeuf et al. 1999; Hobbs et al. 2002; Lebeuf et al. 2003). The objective of this study was to examine and compare concentrations and patterns of PCBs and organochlorinated pesticides (OCPs) such as DDTs, Chlordanes and related compounds, mirex, hexachlorocyclohexanes (HCHs), hexachlorobenzene (HCB), tris(4-chlorophenyl) methane (TCPMe) and tris(4-chlorophenyl) methanol (TCPMOH) in harbour seals from Newfoundland.

Materials and Methods:

Biological Sampling Program

Biological samples including stomachs, jaws and reproductive organs have been collected from all seal species in Newfoundland and Labrador waters since approximately 1985. Additional tissue/organ samples for contaminant or physiological studies have also been taken as required over the duration of the programme. The most intensively sampled species are harp and hooded seals taken during the late fall and early winter from the northeastern coast of Newfoundland. However, the Marine Mammal Section also has a significant amount of data from the other seal species, including harbour seals. Samples were obtained through an ongoing biological collection program involving 20–45 experienced seal hunters from around the province as well as technical and research personnel from the Department of Fisheries and Oceans (DFO). Many of the hunters have participated for numerous years and have provided continuity to the sampling programme. There are a total of 222 harbour seal samples taken from around the province primarily during the spring, summer and fall since 1985; a total of 66 seals were sampled from 2001-2003.

Reproductive Status and Ageing

The reproductive status of females was assessed by examining their ovaries and uterus (Fisher 1954; Bowen et al. 1981). Reproductive tracts were either preserved in 5% formalin or frozen; ovaries were cut into serial section 2.0 mm thick for examination. Females were considered immature if the ovaries were small and contained only inactive follicles with no corpus luteum (CL) or corpus albicans (CA). If there was evidence of a CL and/or CA in either ovary then the seal was considered to be mature. Mature females sampled in the late fall, winter and early spring were designated as pregnant or non-pregnant based on the presence or absence of a large, fully luteinized CL in one of the ovaries. Since 1990, the uterus was also examined to document either the presence of a developing foetus or evidence of enlarged size and ruggose texture that would indicate the female had recently given birth or aborted a foetus. Fertility rate was defined as the percentage of mature females pregnant at the time of sampling. Ovulation rate was defined as the percentage of mature females that had ovulated at the time of sampling.

Unfortunately, available teeth have not been aged so it was not possible to determine, age-specific contaminant profiles, age-specific pregnancy rates and mean age of sexual maturity. However, for a sub-set of more recently sampled seals (n=85), standard length, girth and total weight were available. Based on length/age relationships (Boulva and McLaren 1979; Markussen et al. 1989) these seals could be assigned into one of the following age categories: a) young of year (YOY), b) juvenile, or c) adult. Females 50–120 cm in length and males 50–130 cm were considered YOY. Females 121–135 cm and males 131–145 were considered juveniles; adult females were longer than 135 cm and adult males longer than 145 cm. These age classes were used for the contaminant analyses and for some of the diet analyses presented. Actual ages will be determined from sectioned teeth in the near future.

Diet

Contents of 222 stomachs were examined from harbour seals collected throughout the year from 1985-2003 in nearshore waters (described as within 30km of the coastline) around Newfoundland and Labrador. The stomachs were removed soon after death and frozen. In the laboratory, they were weighed and prey hard parts were removed following the steps described in Lawson et al. (1995), while whole prey were removed and measured separately. Prey species were identified by comparing recovered otoliths with a published otolith identification key (Härkonen 1986). An attempt was made to identify all prey items to the species level; however, when this was not possible, items were group by genus and considered a prey type.

The number of individual prey items in each stomach was calculated using recovered otoliths. If left and right otoliths could be matched, the side with the greater number was used to determine the minimum number of fish eaten, if not, the total number of otoliths was divided by two. When present, squid were identified using whole individuals. Upper beaks were compared with published descriptions (e.g., Dawe 1998; Lily and Osborne 1984) and the greater number of beak halves (upper or lower) was assumed to be equal to the number of squid consumed.

Prey size was estimated using otoliths with minimal or no erosion as described in Lawson et al. (1995). Otoliths were measured to the nearest 0.01mm and those shorter than 5 mm were measured using a Macintosh image analysis system; vernier calipers were used on otoliths longer than 5 mm. Length and mass of fish prey were estimated based on species-specific regression relationships to otolith dimensions. Estimated biomass and energy density for each prey type were also calculated as in Lawson et al. (1995). Prevalence was defined as the percentage of stomachs containing a particular prey species or prey type. Eroded otoliths were assumed to be originally the same size as uneroded otoliths from the same species, and estimated biomass was calculated by multiplying the number of eroded otoliths by the average mass of uneroded otoliths found in that stomach.

Samples were blocked into four geographic regions: Labrador (n=20), the northeast coast (n=82), the south coast (n=69), and the west coast (n=51). Given that annual data for some regions were sparse, they were combined into three year categories including: 1) 1985 -1989, 2) 1990 -1996 and 3)1997-2003. In some cases, the number of samples from the early time period was very low so these data were included in the 1990 -1996 year category. Statistical analyses were conducted using

Minitab 14 and data were examined using G-tests and one/two-way ANOVAs with alpha=0.05.

Surveys

Boat-based reconnaissance surveys of seven areas thought to be important for harbour seals in Newfoundland were conducted between May and September from 2001-2003. Dates and locations of areas surveyed are noted in Table 1 and on Figure 1a and Figure 2. Details of the survey route and coastal coverage are presented in Appendix 1. The surveys were planned to ensure that an entire haulout area/survey area could be covered during a 2–3 hr time period around low tide. Surveys were not attempted if visibility conditions (fog or rain) and sea state (winds > than 15 knots) were unfavourable for sighting seals. Small boats < 6.8 m were used at Merasheen Island and the Renews/Chance Cove area; a 13.9 m longliner was used to conduct the survey along the west coast of St. Mary's Bay. Opportunistic shore-based counts from an elevated viewing position (e.g., a bridge or high point of land) were done at Pt. May, St. Pauls Inlet and Southwest Arm, Marystown. Seals were identified to species using binoculars (boat surveys) and/or a spotting scope (shore-based counts). The positions of seals were documented using a GPS or by referencing to a nearby landmark. Aerial observations of the northern tip (the Ledges and The Bar) of the Port au Port Peninsula were made from a Cessna 337 flown at an altitude of 155 m and an air speed of approximately 105 knots. Counts were made visually by one of two observers seated on the left side of the aircraft during a single pass over the area. A haulout site was defined as an area where more than one seal was observed on successive surveys or counts. If more than one site was used regularly, the site frequented by higher numbers of seals was designated as the primary site and the other as the secondary haulout site.

Information on the distribution and relative abundance of harbour seals in areas not surveyed by boat, aircraft or shore - based counts, was collected from interviews with long-time coastal residents (particularly fishermen) and from discussions with experienced hunters participating in the biological collection programme. Whenever possible, two or three interviews were conducted in the same area so that reported observations could be validated. Those interviewed were asked to comment on the following: 1) how common harbour seals were in their area, 2) whether the distribution or relative abundance had changed in recent years, since 1990, or prior to 1990 and 3) did they know the location of any haulout sites, particularly those where pups were born, in their fishing/hunting area. This free-flow of information between fishermen/hunters and researchers has been facilitated by the biological collection program and encouraged by the Marine Mammal Section since the early stages of the collection programme.

Trace Elements and Total Mercury

Samples of tissue (muscle, liver and kidney) were obtained from 66 seals taken in Labrador (Sandy Island [site 212] n=6), the south coast (Placentia Bay [site 304] and Burgeo/Rose Blanche [site 301] n=30), the west coast (St. Pauls [site 402] n=25), and the east coast (Chance Cove [site 335] n=5; Figure 1a and b). They were shipped to the lab frozen and remained frozen at -20^{o}C until processed. Between 8 to 13 g of frozen tissue were lyophilized then re-weighed to obtain a dry weight. Samples were ground using an agate mortar and pestle. Ground samples were stored in plastic vials until sub-samples were taken for digestion. All digestion solutions were purchased as either certified trace clean or ultra-pure. In addition to total mercury (Hg), the suite of trace elements and heavy metals considered for analyses included phosphorus (P), magnesium (Mg), manganese (Mn), cobalt (Co), copper (Cu), zinc (Zn), arsenic (As), selenium (Se) and cadmium (Cd). For the purposes of this manuscript the term 'trace element' will include all analysed elements except Hg.

Digestion

Mercury - Approximately 5ml of concentrated nitric acid, 0.5 ml of concentrated hydrochloric acid, and a ^{201}Hg spike were added to either 0.1 grams of liver and kidney or 0.3 grams of muscle tissue. The tissue, acid, and spike mixture was held at room temperature for 2 hours then the temperature of the mixture was raised to 60°C and the solution covered and left to reflux at that temperature overnight. The next day an additional 2 ml of concentrated nitric acid was added to the sample and the mixture allowed to stand at 60°C for 2 hours. Three ml of hydrogen peroxide was then added and the mixture remained at 60°C for a further 2 hours. Samples were cooled and diluted to 15 ml with 18 MΩ water. Samples were centrifuged at 3000 rpm for 15 min., decanted and further diluted to a volume of 40ml with 18 MΩ water. Next 3ml of BrCl was added to the samples to oxidize all forms of Hg to Hg^{2+}. After 12 hours, if BrCl was still present in the sample, as evidenced by the appearance of a light yellow colour, then all Hg present was assumed to have been oxidized. If the solution was clear after 12 hours then additional BrCl was added and the sample was left to react for a further 12 hours. This was repeated until there was evidence of un-reacted BrCl in the sample. The un-reacted BrCl was neutralized by the addition of 1ml of hydroxylamine hydrochloride and diluted to a final volume of 50 ml with 18MΩ water. Aliquots were decanted into 15ml polyethylene tubes for analysis by isotope dilution inductively coupled plasma-mass spectrometry (ICP-MS)

Trace elements - Approximately 0.3 g of tissue was mixed with 5 ml of concentrated nitric acid and heated to 60°C for 2 hours. The temperature was then raised to 110°C and the sample digested for a further 4 hours. An additional 3ml of nitric acid was added and the temperature reduced to 60°C. The sample was covered and allowed to reflux overnight. The next day the temperature was increased to 110°C and the volume reduced to approximately 1ml. Samples were then diluted to a final volume of 50ml with 18 MΩ water. Aliquots were decanted into15ml polyethylene tubes for analysis by ICP-MS.

ICP-MS Analysis

Mercury concentrations were determined by isotope dilution ICP-MS. Analyses were carried out on a PE Sciex 6100 ICP-MS. Diluted samples were mixed on line with sodium borohydride to reduce the Hg^{2+} to Hg^{o}. The Hg vapour was separated in a liquid-gas separator and the Hg gas swept into the ICP-MS by a continuous flow of Ar. This produced a steady Hg signal from which the average count rate for ^{201}Hg and ^{202}Hg was measured. The total Hg concentration was determined using the equation of Smith (1993).

As with Hg, all trace elements were determined using a PE Sciex 6100 ICP-MS. However, the samples for trace element analyses were introduced to the plasma as a liquid. The instrument was operated in peak hop mode and concentrations were determined by comparison to a calibration curve. The calibration curve was generated by the analysis of a certified multi-element standard.

Persistent Organic Pollutants

Fifty-five harbour seals were sampled from the Pt. May/Marystown areas of Placentia Bay (site 304), St. Pauls Inlet (site 402) on the west coast and from Chance Cove/Renews (site 335) on the east coast (Figure 1a) from 2001-2003. Analyses on the available Labrador samples have not been completed yet. A block of blubber, from skin to muscle, was sampled from the back of each animal for POP analysis. Seals were grouped based on sex and their age/maturity category rather than by sampling site location. Given that ages were not available from sectioned teeth, standard body length was used to assign seals into pup (YOY), juvenile and adult age categories. A total of 22 males were sampled of which 12 were mature, two were juveniles and eight were pups (YOY); 15 of the 33 females were matures, six were juveniles and 12 were pups (YOY).

POPs were extracted and cleaned as described by Hobbs et al. (2002). Briefly, skinless blubber samples, extending from the entire depth of the blubber, were chemically dried, spiked with a mixture of $^{13}C_{12}$ PCBs and labelled pesticides and column extracted. A portion of each extract was used for gravimetric lipid determination. Lipids were removed from the remaining extract by gel permeation chromatography and cleaned-up using a multiple layer silica column. Extracts were concentrated and spiked with an instrument performance solution containing two additional $^{13}C_{12}$ PCBs. The PCB congeners and OCPs were quantified using a gas chromatograph equipped with an ion trap detector operated in the MS/MS mode. The final concentration of the native compounds was corrected on the basis of the recovery of the labelled surrogate compounds. Concentrations were quantified for 43 PCB congeners; 8, 15,18, 28, 31, 33, 37, 40, 44, 49, 52, 66, 70, 74, 87, 90, 95, 99, 101, 105, 110, 118, 123,128, 138, 149, 151, 153, 156, 170, 171, 177, 180, 183, 187, 191, 194, 195, 199, 205, 206, 208, 209 and 16 OCPs (2,4’- and 4,4’-DDE, 2,4’- and 4,4’-DDD, 2,4’- and 4,4’-DDT, α- and γ-Chlordane, *cis*- and *trans*-nonachlor, α- and γ-HCH, HCB, mirex, TCPMe and TCPMOH). The precision and the accuracy of the analysis of PCB congeners and OCPs was validated by repeated analysis (n=6) of the certified external standards SRM1945 (NIST, 1994).

PCB results were reported as 43 individual congeners, as the sum of those congeners (ΣPCB) and by homologue groups (tri- to decachlorinated biphenyls). Concentrations of PCB homologue groups were determined by summing the concentrations of all specific congeners having the same number of chlorine atoms. DDT group pesticides (ΣDDT) were calculated as the sum of the concentrations of 2,4’-DDE, 4,4’-DDE, 2,4’-DDD, 4,4’-DDD, 2,4’-DDT and 4,4’-DDT. Chlordane-related compounds (ΣChlordanes) were calculated as the sum of α-chlordane, γ-chlordane, *cis*-nonachlor and *trans*-nonachlor. Concentrations of HCH compounds (ΣHCH) were calculated as the sum of α-HCH and γ-HCH whereas concentrations of TCPM compounds (ΣTCPM) were calculated as the sum of TCPMe and TCPMOH. Concentrations of mirex and HCB were reported individually. Contaminant concentrations were reported on an extractable lipid basis (ng/g lipid).

Differences in contaminant levels among the different age categories of seals were assessed by analysis of variance (ANOVA) on logarithmic transformed data, followed by a Bonferroni’s post-hoc comparisons test. Differences in the proportion of PCBs and OCPs relative to the sum of POPs as well as PCB homologue groups relative to the

ΣPCBs among seal groups were assessed by analysis of variance (ANOVA), followed by a Bonferroni's post-hoc comparisons test. Statistical analyses were conducted using SYSTAT for Windows (version 7.0, SPSS Inc., 1997). Statistical significance was set at p=0.05.

Results:

Distribution and Local Abundance

Boulva and McLaren (1979) provided harbour seal abundance data for ten localized areas of Newfoundland and St. Pierre et Miquelon. Updated information for four of these areas including the Chance Cove area on the east coast, Placentia Bay on the south coast, the Port au Port Peninsula area on the west coast and St. Pauls Inlet on the west coast are presented in Table 1 and in Figure1a and 2. In addition to these sites, information for the Pass Island and Pt. May areas on the south coast has also been provided. The location of primary and secondary haulout sites in each area as well as information on observation points and coastal survey coverage is presented in Appendix 1.

The Chance Cove area is well known to researchers and local residents and appears to have been occupied by harbour seals on a long-term basis. During 2002 and 2003, three small boat surveys were conducted from Renews to Chance Cove Provincial Park; the maximum count of harbour seals was 164 (Figure 1a and 2). Placentia Bay and St. Mary's Bay are both large bodies of water so only certain segments of the coastline were surveyed given the logistic constraints. A total of 269 harbour seals were counted between Bull Island Pt. and Red Head on the west coast of St. Mary's Bay during a single boat (longliner) survey. In Placentia Bay surveys were conducted in the vicinity of Merasheen Island (small boat) and Southwest Arm in the Marystown area (primarily shore-based counts); a maximum of 14 seals were observed in the vicinity of Merasheen Island and 13 in Southwest Arm for a total of 296 in the surveyed areas of St. Mary's and Placentia Bays. The maximum number of seals seen at Pt. May was 46. A total of 24 harbour seals were observed on Pass Island during a single small boat survey; 30 adult grey seals were also present. During a single opportunistic aerial assessment of the area known as the Ledges north of the Port au Port Peninsula there were 40 seals counted; this represents a minimum count since there was evidence of animals entering the water in advance of the aircraft over-flight. During 2003 and 2004 there were five shore-based surveys in the St. Pauls Inlet area and a maximum of 88 harbour seals were counted.

In recent years fishermen and hunters have reported that, in general, harbour seals are uncommon and rarely observed in the coastal water of the Northern Peninsula, including the Port au Choix and St. Anthony areas (Figure1a and 2). Similarly, the eastern portion of Notre Dame Bay in the vicinity of Twillingate and Fogo Island is reported to have very low number of harbour seals. Presently there is little known about the distribution of seals in Bonavista Bay. Hunters and fishermen participating in the biological collection program have confirmed that a significant number of harbour seals still frequent the area around Burgeo on the south coast of the Island. In recent years they have reported that the numbers of seals appear to have remained fairly stable and YOY have been observed. And finally, there is little information available for harbour seals in Georges Bay.

Little is known about the current distribution and relative abundance of harbour seals along the coast of Labrador. Although it is likely that the highest densities are found along the coast south of Cartwright (Figure 1b), there has been relatively little seal research conducted in the area to substantiate this. The Paradise River near Cartwright in central Labrador may have one of the larger breeding colonies of harbour seals in the region according to reports from five local hunters; as many as 100 seals may inhabit the river system and estuary. Hunters from the community of Rigolet consider harbour seals common in certain areas, most notably Double Mer Lake and an area near Cape Harrison along the coast north of Groswater Bay. Harbour seals are seen in the bays near Hopedale but three hunters from that community were of the opinion that the species is generally uncommon with numbers remaining stable or slightly increasing since the mid 1980s. Few hunt this species, but those who do indicated that the only reliable site where harbour seals can be found in any number is the Sandy Island area near Natuashish where as many as 40-50 animals have been observed. In the Nain area the species is considered uncommon but can be seen in river mouths, estuaries, riffle areas in nearshore areas and on rock ledges of some of the seaward islands. There was no consensus among the four hunters on the current status of harbour seal abundance; one hunter had no comment and the others felt that the population had increased, decreased or remained stable since the mid 1980s. The two hunters who have spent the most time out on the water in recent years felt the population was either decreasing or had remained stable. The only commonly acknowledged pupping area near Nain was the Spracklins Island. Farther north, harbour seals are seen in Port Manver, Okak Bay and Saglek Fjord. Hunters along the coast of Labrador usually observe seals during the spring and summer and few knew specific details on where seals overwintered. However, all commented on the use of riffle areas in the larger river systems, tickles and runs in nearshore areas (i.e. open areas kept free of sea ice by tides, currents and winds) hinge ice along shorelines (particularly in Double Mer Lake), and seasonal migrations to the nearest ice edge.

Diets

Approximately 40 prey species or prey types were identified in food containing harbour seal stomachs sampled from nearshore areas of Newfoundland and Labrador (n=147; Table 2). Thirty-two were fish species with Atlantic cod (*Gadus morhua*), sand lance (*Ammodytes dubius*), capelin (*Mallotus villosus*), and herring (*Clupea harengus*) being the most prevalent. Of the 18 invertebrate species identified, various squid and shrimp species, and Hyperid amphipods were the most prevalent (Table 2). Ten fish species accounted for almost 95% of the wet mass of food consumed based on reconstructed sizes of prey. Winter flounder (*Pseudopleuronectes americanus)*, Arctic cod *(Boreogadus saida)*, shorthorn sculpin (*Myoxocephalus scorpius*), and Atlantic cod *(Gadus morhua)* were the most important in terms of wet mass contribution. Approximately 60% of available energy was contributed by winter flounder, herring, shorthorn sculpin and Arctic cod (Table 2). Although both sandlance and capelin were prevalent in the diet, neither was as important to the overall diet in terms of wet mass and energy contribution. Herring contributed only moderately to the diet in terms of wet mass consumed, but was significant in terms of overall energy contribution.

A summary of regional trends in diet composition are presented in Table 3. Arctic cod was by far the most important prey species in terms of wet mass (85%) along the Labrador coast. Shorthorned sculpin (28%) and winter flounder (26%) were most important along the northeast coast of Newfoundland while Atlantic cod (27%) was the greatest contributor along the south coast. On the west coast of Newfoundland, winter flounder, Atlantic cod and herring were all important. The proportion of empty stomachs from Labrador (10%; n=20), the northeast coast (42%; n=82), the south coast (41%; n=69) and the west coast (22%; n=51) varied significantly (G=13.328, df=3, p=0.004).

Although harbour seals had a diverse and varied diet, there were relatively few prey species found in each stomach (overall mean=2.2, SD=1.45). The mean number of prey types consumed in a meal by seals from the Labrador coast (2.4 items), the northeast and west coasts (2.4 items) and the south coast(1.8) did not differ ($F_{3,132}$ = 1.23, p=0.300). There were also no differences ($F_{1,128}$=2.21, df=1, p=0.140) in the mean number of prey types consumed by males (2.3 items, SD = 1.70) and females (1.9 items, SD=1.10). Seals fed on fish prey that was 10.4–41.3 cm in length. There was no difference ($F_{1,93}$= 1.6, df=1, p= 0.29) between the mean length of prey consumed from 1985 -1996 (18.4 cm, SD=6.80) and 1987-2003 (19.06cm, SD=9.70). However, the mean length of species consumed along the Labrador coast (13.6 cm, SD=4.56), the northeast coast (21.4 cm, SD=9.81), the south coast(15.9 cm, SD=7.12), and the west coast (19.73 cm, SD=5.8) differed significantly ($F_{3,93}$= 5.31, df=3, p= 0.002).

Reproductive Status:

There were 73 (54 immature and 19 mature) female harbour seals collected from 1988–2004; all of the mature seals had either a developing or fully developed CL that indicated they were pregnant. Only 15 animals (13 immature; 2 mature) were taken October through April so it would not be possible to gain further insight on overall fertility rate based on a late-term samples even if data on non-pregnant individuals had been present in the database. The majority of females were sampled during the delayed implantation phase of their reproductive cycle. Age of sexual maturity was not estimated given the lack of known ages. The earliest born pups were observed in the Marystown area on May 5, 2002 (Table 1). The presence of pregnant females on May 27, 2003 at Marystown, on June 1, 2003 at Pt. May, and on June 8, 2003 in St. Pauls Inlet was evidence that pupping continued through to at least early June in at least some areas of Newfoundland. There was also a very young pup observed on June 5, 2001 in the Merasheen Island area. The relatively high proportion of females and pups as well as pregnant females observed in Southwest Arm in the vicinity of Marystown suggested that some sex and age structuring existed at the site. The observation of lone pups on July 22, 2003 at the Chance Cove haulout suggested that the weaning of pups may have occurred or was ongoing at the site.

Contaminants:

Mean trace element concentrations for muscle, liver and kidney samples are given in Table 4. At all but one site, hepatic tissue had the highest concentrations of P, Mn, Cu, Zn, As, Se, and total Hg (total Hg at site 301 was the exception). Renal tissue had the highest concentrations of Co and Cd, while muscle tissue contained the highest concentration of Mg. With the exception of Se, Cd, and Hg, there was little difference in mean elemental concentrations among sites within tissue types. However, the concentrations of Se, Cd, and Hg were dependent on seal length. There was a log-linear relationship between total Hg in the hepatic tissue and seal length (Figure 3). As well, there was a very strong correlation between hepatic Hg and Se (Figure 4), which is believed to indicate the presence of tiemannite (HgSe), a mineral that acts to detoxify Hg

(Wagemann et al. 1998). However, on a molar basis there appears to be an excess of Se (molar ratio < 1) in smaller, younger seals (Figure 5).

Cadmium concentrations in renal tissue were also related to the size of the animal (Figure 6). However, the sites seemed to fall into two groups. Samples from the south and east coast (sites 301, 304 335) seemed to have a more rapid increase in Cd concentration with length compared to samples from St. Pauls (site 402) on the west coast of the island and the Labrador site (site 212).

Almost every single PCB congeners analysed in seal blubber samples were above detection limits (Table 5). The sum of the 43 congeners analysed (ΣPCBs) represents at least 75% of the total concentration of PCBs in seals (Hobbs et al. 2002). Congeners 99, 138, 153, and 180 were the main contributors, accounting for more than 70% of the ΣPCBs.

The mean ΣPCB concentration was higher in mature male harbour seals than in mature females, male and female pups. Levels of ΣPCBs in pups and juveniles were not statistically different between genders (Table 5). The same observations were made for the penta to octa chlorinated PCB homologue groups. For each seal group, the hexa chlorinated PCB homologue group represented about 50% of the ΣPCBs. Very similar overall PCB patterns were observed in the seals examined (Figure 7). Nevertheless, tri, tetra and nona/deca chlorinated PCB homologue groups, which represent altogether less than 10% of the Σ PCBs, showed different mean concentration predominance's among seal groups. For instance, the mean concentration of tri-PCBs was highest in male pups whereas the mean concentrations of nona/deca-PCBs were not different in mature males and females.

OCPs were systematically detected in Newfoundland harbour seals (Table 6). ΣDDTs, mainly represented by its metabolite 4,4'-DDE, had the highest mean concentrations in the seals examined. Σ Chlordanes, dominated by trans-Nonachlor, was also predominant in the examined seals with mean concentrations exceeding 150 ng/g lip for each seal group. Mean concentrations of both Σ DDTs and ΣChlordanes were, similarly to Σ PCBs, higher in mature males than in females whereas levels in pups and juveniles were not statistically different between genders. The highest mean concentration of Mirex was found in mature males whereas there was no difference in mirex levels among the other seal groups. ΣTCPMs mean concentrations were not different among the seal groups except that mean concentration in mature males were higher than in mature and juvenile females. For HCB and ΣHCHs, mean concentrations were not significantly different between mature males and females and were generally equal or even lower than those of juveniles and pups.

The main contributors, mainly ΣPCBs, ΣDDTs and ΣChlordanes, represent about 55, 30 and 10% of the sum of POPs, respectively, exhibiting very similar proportion for each seal group (Figure 8). It is interesting to note that the proportion of mirex is the lowest in both male and female pups, and no significant difference was observed among the other seal groups.

Discussion

Distribution and Local Abundance

Throughout its range, harbour seal population abundance is difficult to assess because the species is small, cryptic, often widely distributed and tends to be less gregarious during the pupping and mating period than other land breeding pinnipeds (P. Olesiuk pers. comm.). Systematic aerial surveys are the only feasible and scientifically rigorous way to assess population abundance and trends over a large geographic area such as Newfoundland and Labrador (e.g., Olesiuk 1993). Unfortunately, it is very unlikely that these data will become available in the foreseeable future. The recent interviews and boat/shore-based haulout surveys reported here were conducted with the objective of providing minimum estimates of local abundance in the vicinity of several well known haulout sites. Although, this approach is not a valid way of quantitatively assessing harbour seal population abundance or monitoring population trends in Newfoundland and Labrador, these data are useful for the planning and design of any future aerial surveys, confirming that seals still frequent known haulout sites, and for making some crude comparisons of abundance at specific haulout sites in the future.

The boat/shore-based survey information presented here has several limitations and caveats. It is not known what proportion of the population was documented in each of the surveys; additional systematic effort at the peak of the pupping and moulting periods would be required to develop realistic corrections for the fraction of the population hauled out (e.g., Olesiuk et al.1990). There is also no doubt that disturbance caused by hunting influenced the survey results at St. Pauls Inlet, Pt. May and Southwest Arm and would also confound any attempt to correct counts for those haulout sites even though multiple surveys were conducted. To partially mitigate this problem in these areas, surveys were conducted before any hunting activity took place or they were conducted at least two days after any hunting activity. However, even when the numbers of animals sampled were accounted for, maximum counts were often obtained on the first survey of the season. There was no, or only minimal, disturbance created during the St. Mary's Bay survey or the surveys of the Chance Cove and Merasheen Island areas so these counts may reflect minimum local abundance more reasonably.

Boulva and McLaren (1979) estimated there were a total of 2010 seals in Newfoundland and provided local abundance estimates for ten areas based on questionnaires, the distribution of bounty returns and informal interviews with fishermen. Although caution must be used in comparing these results with current observations because the counting methodologies were different, the reconnaissance survey results presented here suggest that seal numbers may have increased at two of the sites (i.e. Chance Cove and St. Pauls Inlet) and have at least remained stable in others (e.g. the Port au Port Peninsula area). The Chance Cove area and St. Pauls Inlet showed the largest increases relative to Boulva and McLaren's (1979) numbers. Both of these haulout sites are long-term, localized and well known making comparisons to the earlier data less problematic and more insightful in terms of evaluating changes in local abundance. There is a possibility that a small proportion of the 164 seals observed in the Chance Cove area were misidentified grey seals. However, an experienced marine mammal observer conducted the survey so this should not have been the case. The Ledges area of the Port au Port Peninsula is another well known, long-term haulout site. The minimum estimate of 40 seals presented here is somewhat lower, but consistent, with the one provided by Boulva and McLaren (1979). The large number of animals entering the water in advance of the aircraft suggests that 40 seals is an underestimate, and if this is true, more animals may be using the site than in the late 1970s. However, it is also possible that some of these unidentified animals in the water were grey seals since on mixed haulout sites this type of startle reaction is common for grey seals (Hammill pers. comm.). In recent years fishermen have occasionally reported the presence of harbour seals in St. George's Bay, but follow-up interviews to confirm the reports have not been conducted in the area.

It is difficult to draw any conclusions about changes in local abundance in Placentia Bay and St. Mary's Bay because Boulva and McLaren (1979) did not provide any numbers for known haulout sites. However, the current observations in both areas, particularly in St. Mary's, indicate that the area is still frequented by a higher number of seals than in other areas of the province. An attempt was made through the biological collecting program to have harbour seals sampled for diets and reproductive status in the Port au Choix area, St. Anthony and Twillingate area. However, the hunters reported that there were so few animals in these local areas that it was not worth the effort to hunt them suggesting that numbers had not increased in recent years. Thus, there is also limited information suggesting that the general patterns of local distribution observed in Newfoundland during this study are still consistent with Boulva and McLaren (1979). There is also an indication that abundance at some well known haulout sites in the more southern portions of the province may have increased while abundance at sites in more northern areas and the northeast coast still remain low relative to the early 1980s. However, a better understanding of annual and seasonal seal movement patterns as well as diel haulout behaviour is needed before any conclusions on site specific and local abundance trends can be to made.

Historic traditional knowledge on the distribution, relative abundance and movement patterns of harbour seals in Labrador has been generally summarized by Brice-Bennett (1977) as follows. Prior to the 1960s relatively large numbers were common in bays in the vicinity of Cape Harrison (the Hopedale area), around Spracklins Island (Nain), and in localized areas of Double Mer Lake and Back Bay (Rigolet). From 1960-977 there was thought to be a widespread decline in the number of harbour seals and a possible shift in their distribution to the seaward islands in most areas. Local hunters claimed that intensive hunting in the late 1950s and early 1960s may have been responsible for some of these changes. Current reports, from hunters in the above mentioned communities presented here, confirmed that the same areas are still important habitat for the species and that local seal numbers are relatively low and have not changed notably during the 1980s, 1990s and more recent years.

There has been no attempt to conduct wider-scale surveys to estimate the total population of harbour seals in Newfoundland and Labrador since the study of Boulva and McLaren (1979). However, Hammill and Stenson (2000) estimated that in 1996 the total population of harbour seals in eastern Canada was approximately 32,000 with 5,120 in Newfoundland and Labrador (based on observation that 16% of the 1973 estimate was attributed to the province). This total estimate was derived using a Leslie matrix population model based on data provided in Boulva and McLaren (1979) and then projected forward until the proportional age composition stabilized; the reconstructed population increased at a rate of 5.6% per year. Unfortunately, the model was data deficient and no further research has been conducted to validate and/or improve these estimates.

Diets

The diet of harbour seals has been well studied throughout much of its range, and as Boulva and McLaren (1979) generally noted, the most common prey items found in the stomach are herring, flatfish, and either gadoids or cephalopods. Certainly in broad terms, the diet of harbour seals in Newfoundland and Labrador is consistent with this observation. In addition to data presented here, there have been only two studies of harbour seal diets in eastern Canada and both were conducted in Nova Scotian waters (Boulva and McLaren, 1979; Bowen and Harrison 1996). The most prevalent prey items from seals sampled off Sable Island and the Bay of Fundy were herring (24%), squid (21%), and flounder (14%; Boulva and McLaren, 1979). Results were comparable for seals taken from the northeast coast of Nova Scotia and the Bay of Fundy approximately 15 years later with herring (20%), squid (17.0%), Atlantic cod (8%), and pollock (8%) being the most prevalent species (Bowen and Harrison 1996). Boulva and McLaren (1979) did not reconstruct the stomach contents of the seals sampled, but Bowen and Harrison (1996) reported that the two most prevalent species also contributed most significantly in terms of wet mass (i.e. herring 24% and squid 15%). In comparison, this study showed that pelagic forage fish such as Arctic cod and capelin as well as shorthorned sculpin were generally more prevalent and contributed more in terms of wet mass in the diet of Newfoundland and Labrador seals while squid was considerably less important. The contribution in terms of both prevalence and wet mass of flounder and Atlantic cod is generally notable in all three studies. The differences in species composition of seal diets between Newfoundland and Labrador and the Scotian shelf may in part be explained by prey availability given the different oceanographic conditions in the two regions (Bowen and Harrison 1996). For example squid, red and white hake *(Urophcis chuss* and *tenuis* respectively*)*, pollock *(Pollachius virens)* and alewife *(Alosa pseudoharengus)* are all species more characteristic of warmer Scotian Shelf waters compared to Arctic cod, capelin and herring which are usually associated with colder water.

The preliminary diet composition data presented in this manuscript is based on prey-containing stomachs from all age classes of seals. Young-of-the-year and juvenile seals could not be considered separately due to a lack of tooth-derived ages. Boulva and McLaren (1979) reported that two pups approximately five weeks of age had consumed primarily amphipods and shrimp. Bowen and Harrison (1996) found that pups < 1 year old fed primarily on pelagic prey (herring and squid), while older seals consumed greater quantities of demersal and benthic prey (cod and flatfishes). These findings suggest that the diet composition as currently presented may underestimate the importance of some larger fish prey items in the adult seal diet. This potential bias will be addressed as soon as ages for the seals sampled are available.

The regional differences observed in the diets of seals sampled from the Labrador, northeast, south and west coasts of the province are interesting but not unusual for harbour seals (e.g., Payne and Selzer 1989; Olesiuk et al. 1990; Olesiuk 1993; Bowen and Harrison 1996; Hall et al. 1998). Payne and Selzer (1989) and Olesiuk et al. (1990) found that annual and/or regional variations in the diet of seals were often related to changes in the abundance of the prey species in question as well as the type of habitat. Of particular importance was bottom substrate and water depth; e.g. species like sandlance tend to dominate shallow sandy bottom areas while flounder, herring and gadoids are more dominant in areas with deeper water and rocky bottoms. Bowen and Harrison (1996) were able to attribute differences in diets of seals sampled from the Bay of Fundy and Scotian Shelf to the distribution and availability of several key prey species in the region. Although the analysis of regional diet trends in Newfoundland and Labrador are still preliminary, the importance of prey distribution and availability is evident. For example, Arctic cod is distributed widely throughout Labrador and it is also the most abundant gadoid species in nearshore waters (Lilly and Carscadden 2002); not surprisingly this is reflected in its role as the most important prey species for seals in that area of the province. There is a similar relationship between the presence of Atlantic cod in the diet of harbour seals and the distribution and relative abundance of cod. Abundance of Atlantic cod is low along the Labrador and northeast coasts compared to the south and west coasts where there are still limited commercial fisheries; this is generally reflected in the diet both from prevalence and wet mass perspective. Once these regional data have been comprehensively analysed and checked more carefully for possible sample collection biases, it is quite likely similar patterns will emerge for other key species such as flounder, herring and shorthorned sculpin. It should also be noted that seasonal sampling biases can have a strong effect on the interpretation of regional diet data (Bowen and Harrison 1996); the preliminary analyses presented here have not examined possible seasonal effects.

The relatively low mean number of prey types found in the stomach of harbour seals found in this study coupled with the importance of schooling forage fish in the diet are consistent with what is known about the foraging behaviour of the species. The consumption of small, relatively energy rich prey usually encountered in schools prey maximizes foraging efficiency by increasing capture rates and minimizing searching and handling time (Bowen and Harrison 1996). There is a substantial body of literature providing evidence that small, abundant, schooling fish species are the primary prey for numerous species of pinnipeds as they are for harbour seals (e.g., Frost and Lowery 1986; Bowen et al. 1993; Olesiuk *et al*. 1990; Lawson et al. 1995).

Reproductive Status

Boulva and McLaren (1979) estimated the fertility rate of females seven years of age and older at 95% which is consistent with more current studies in Europe and Norway (e.g., Härkonen and Heide-Jorgensen 1990). The estimate presented by Boulva and McLaren (1979) was based on samples taken from October to the whelping period (i.e., late-term) ensuring that potential biases related to pseudo-pregnancies and mid-term abortions did not affect the estimate (Bowen et al. 1981). This approach was not possible with the small numbers of samples taken during the late-term period in this study. Therefore, having to determine reproductive status based on corpora luteum development and structure before implantation of the embryo has most certainly biased the fertility rate estimate upward. There is little quantitative information on the occurrence of pseudo-pregnancies and mid-term abortions in harbour seals so it is difficult to know how inflated the estimate might be. However, the small sample size is a more serious problem and it hampers any definitive conclusions about fertility rate – except that it appears to be high in Newfoundland and Labrador. Until there is more late term pregnancy information available, it is more appropriate to consider data presented here as an estimate of ovulation rate rather than fertility rate.

Boulva and McLaren (1979) estimated mean pupping date on Sable Island to be May 25 with most of the pups being weaned 30 days later. Observations of females and pups and of pregnant females at the haulout sites surveyed in this study are consistent with these earlier observations. They also match the pattern seen at the harbour seal breeding colony on the French Island of Miquelion (J. Lawson, DFO pers. comm.). It is difficult to interpret the single observation of lone pups at the Chance Cove haulout site given the females changing attendance pattern as the pups get older, but again, it is consistent with weaning times on Sable Island.

It has been well documented that harbour seals in some areas of their range exhibit strong age and sex segregation at haulout sites during the breeding season. For example, Kovacs et al. (1990) studied two haulout sites in New Brunswick and found that one group contained mostly males and no pups while the other had approximately equal numbers of males and females with pups. The reasons for segregation by age and/or sex are not clear; it may be related to breeding behaviour and mating tactics or perhaps by the availability of haulout space or other environmental factors (Kovacs et al. 1990). The high proportion of females and pups at the Marystown haulout area suggests that at least in some locations in Newfoundland and Labrador sex segregation may occur. Patterns of female/pup clumping may become apparent at other haulout sites once there is a closer examination of the GPS locations of surveyed seals in the future.

Contaminants

The mean within site concentrations of trace elements, and the range among sites around Newfoundland and Labrador (Table 4) are consistent with the concentrations found in harbour seals from Alaska (Miles et al 1992) and in northern pinnipeds in general (Fant et al. 2001, Julshamn and Grahl-Nielsen 2000, Yeats et al. 1999, Wagemann et al. 1998). Relative differences in concentrations of trace elements among tissue types are also similar to the results of the studies mentioned above. Various multivariate analyses were conducted to determine if trace metal concentrations could be used to differentiate sample sites, but there were no significant trends. Therefore, the discussion will focus on Hg, Se, and Cd values which exhibited the greatest variability within and among sites.

The correlation of total Hg in hepatic tissue with length (Figure 3) is an indication of the bioaccumulative nature of Hg. However, Wageman et al. (1998) suggested that the Se-Hg correlation (Figure 4) was an indication of the presence of tiemannite, a mineral that may result in the detoxification of Hg. On a molar basis (Figure 5) there appears to be an excess of Se in smaller and presumably younger seals. Outridge et al. (2000) suggested that the less than 1:1 molar ratio between Hg and Se in smaller, younger belugas may indicate a greater ability of the liver to detoxify Hg. If this is also true for harbour seals, older animals may lose their ability to remove MeHg from other organs as they age.

The change in renal cadmium concentration with size was dependent on sample site (Figure 6). The slope of the regression line through the data from St. Pauls was significantly different from the Placentia Bay regression. The data from the Labrador sample plotted along the St. Pauls regression line whereas the data from Renews aligned with the Placentia Bay data. These differences suggest that there are different sources of Cd for seals from the different areas of the province. The source of cadmium is unknown at this time but it is possible that Placentia Bay is the source, or that contaminants are being transported along the south coast of the Island and into Placentia Bay from the St. Lawrence River. The small number of seals and limited lengths of the Burgeo/Rose Blanche sample made it difficult to assign the Cd data to either regression. .This is an interesting site because it lies to the west of the entrance to Placentia Bay and it would not likely be impacted by contaminants from Placentia Bay. It could, however, be influenced by contaminants form the St. Lawrence River.

POPs were present in all examined harbour seals, but some significant differences in levels of contamination were observed among sex and age categories. For most of the POPs investigated, levels were higher in mature males than in females. This observation is explained by the transfer of contaminant loads from the mother to her pup during gestation and lactation. Although the elimination of POPs by mature females represents an efficient process for most chemicals, some are not as readily eliminated by females. For instance, the mean concentration of nona/deca chlorinated PCB homologue group is similar in both mature males and females. For other POPs such as HCB and HCHs, which are characterised by relatively high water solubility, bioaccumulation levels are generally similar in all seals groups. Although sex has a significant influence on the levels of POPs in mature seals, both male and female pups and juveniles exhibit very similar levels. The similar proportion of some POPs among sex and age categories suggests that seals are likely long-term residents of a particular geographic area where they are exposed to POPs, possibly through diet. Fish prey species from Placentia Bay and St. Pauls Inlet were collected during the study but have not been analysed for POP contaminant levels. Until this research can be completed it will be difficult to begin understanding the complex relationship between the contaminant profile of harbour seals and their prey relative to both regional and longer-range sources of toxic substances in eastern Canada (e.g., Cullon et al. 2005; Gouteux et al. 2005; Lebeuf et al. 2003; Ross et al. 2004).

The Newfoundland harbour seal population is less contaminated by most POPs relative to seals from the St Lawrence Estuary (SLE) population (Bernt et al. 1999, Hobbs et al. 2002). Most notably, ΣPCBs and Mirex exhibit the largest difference in contamination between the two populations, being 5-10 times higher in the SLE population, independent of seal groups. These observations are in agreement with the origin of the sources of PCBs in the SLE (Lebeuf and Nunes, 2005). For ΣDDTs and ΣChlordanes, concentrations are 2-5 times higher in the SLE population while HCB and ΣHCHs are at comparable levels in both seal populations. These observations are also in agreement with the expected behaviour of these chemicals, characterised by physico-chemical properties favouring their atmospheric distribution. Levels of ΣPCBs in mature male harbour seals from the southern Gulf of St Lawrence (SG) have also been reported and were found to be similar to those from the Newfoundland population (Lebeuf et al. 2003).

Harbour seals from the Newfoundland population have also been analysed for polybrominated diphenyl ethers (PBDEs), a group of chemicals used as flame retardants. PBDEs are becoming of great concern due to their rapid increase in biota, including marine mammals, in North America. Recently, Lebeuf et al. (2004) reported that the levels of PBDEs in beluga whales from the SLE doubled every three years between 1988 and 1999. PBDE levels in 10 mature male harbour seals from the Newfoundland population were in the range of 230-320 ng/g lipid, apparently 2-3 times lower than those found in SLE and SG populations (Lebeuf et al. 2003).

Summary Comments

This manuscript provides a preliminary summary of new data, and in some cases, the only information on the general distribution, local abundance, diet and baseline contaminant profiles of harbour seals in Newfoundland and Labrador. These data will provide a basis for future ecological studies and aerial population assessments as well as improve our understanding of how contaminants accumulate in coastal food chains in eastern Canada. Once seal ages are available, additional analyses on age-specific contaminant profiles, reproductive status, and diet studies can be completed and reported in the primary literature. Members of the research team are currently working on three manuscripts that comprehensively address each of the components presented and discussed here. It is hoped that the final interpretation of these findings will provide the initial basis for evaluating the harbour seal as a sentinel of higher-trophic-level health in coastal marine environments of eastern Canada. One of the general goals of our original study was to compliment existing and ongoing harbour seal research by DFO scientists and their colleagues in Pacific Region. Ross et al. (2004) has recently shown that knowledge of contaminant profiles and burdens in harbour seals is useful in terms of understanding how these compounds accumulate in coastal food chains and can also provide insight into the relative importance of regional versus international sources of persistent, bioaccumulative, and toxic substances. Throughout many parts of their range harbour seals are increasingly being viewed as a species that can provide an integrated measure of the contamination of coastal environments (e.g., Ross 2000; Ross et al. 2004), and from this comparative perspective, there is a need for baseline data on many aspects of the biology and ecology of harbour seals in Newfoundland and Labrador.

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Figure 1a. Study area map of Newfoundland. In 2001-2003, samples for contaminant, diet and reproductive analyses were collected at Chance Cove/Renews (site 335), Marystown (site 304), Pt. May (site 304), St. Pauls Inlet (sited 402), Burgeo/Rose Blanche (site 301).

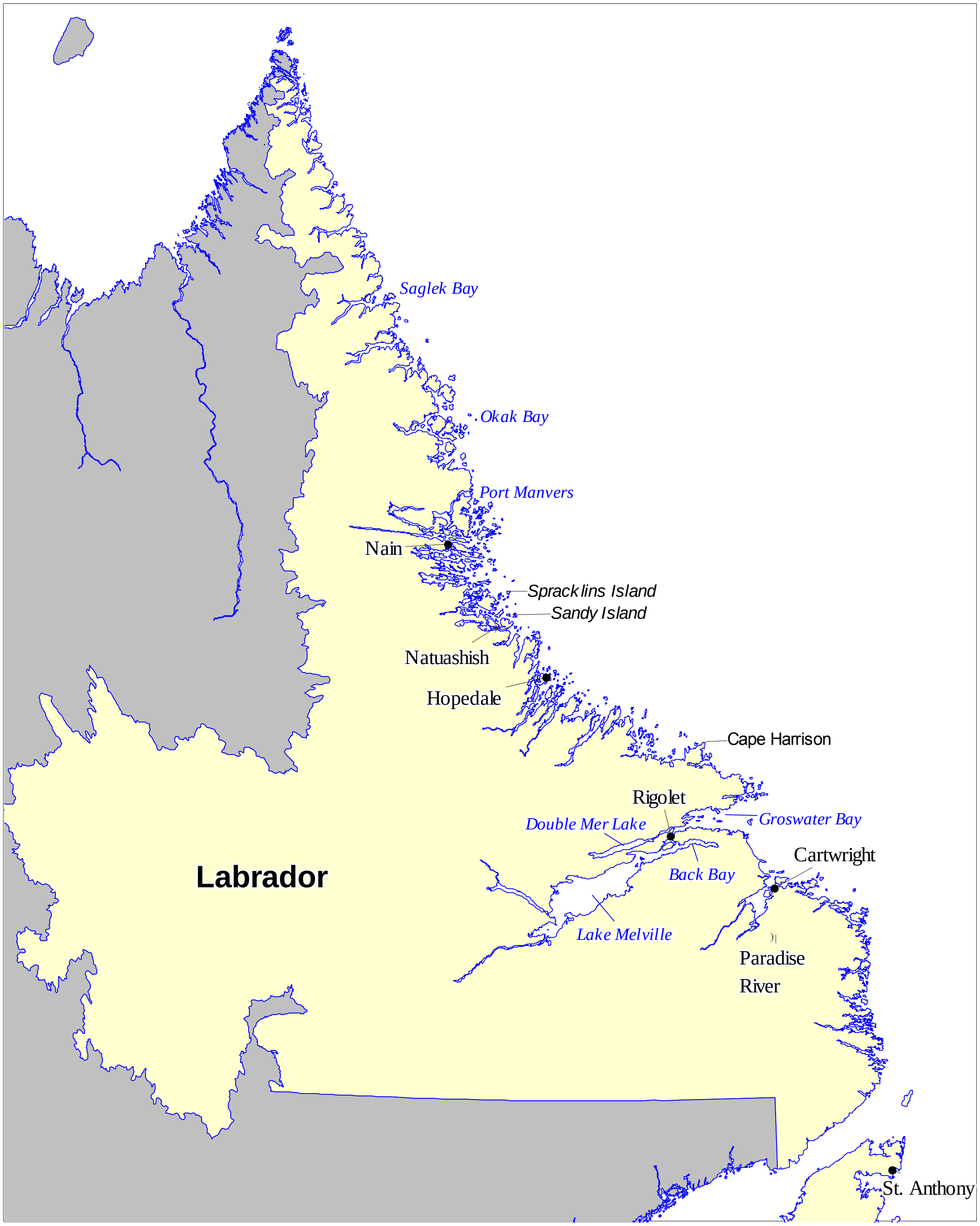

Figure 1b. Study area map of Labrador. Contaminant samples were collected from Sandy Island near Natuashish (site 212).

Figure 2. Current and historical evidence of local distribution and abundance of harbour seals in Newfoundland. Grey shading indicates occurrence. The 1973 estimated number of seals in each area is given with a trend arrow for that time period: stable (horizontal); declining (downward); increasing (upward) (Boulva and McLaren 1979). Current (2002 and 2003) estimations are shown in parentheses. (NS) indicates no survey and/or no new data. Coastal areas marked in black indicate the areas surveyed by small boat and/or shore-based counts. The coastal area from Bull Island Pt. to Red Head in St. Mary's Bay was surveyed from a longliner.

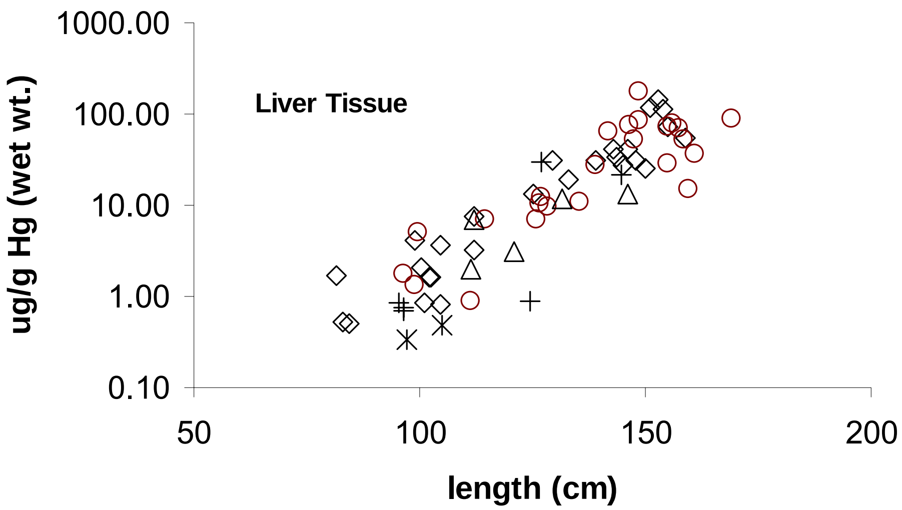

Figure 3. Relationship between length of individual seals and the total Hg concentration in the hepatic tissue. Each symbol represents a different sampling site. Site 212 Labrador (+), 301 Rose Blanche/Burgeo ((), 304 Placentia Bay (◊), 335 Chance Cove/Renews (Δ), 402 St. Pauls (○).

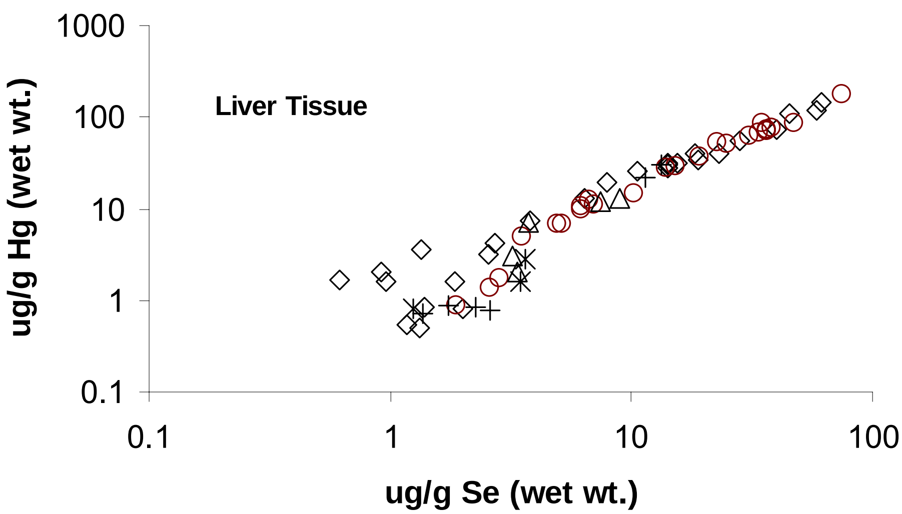

Figure 4. Relationship between the concentrations of Se and total Hg in the hepatic tissue of individual seals. . Each symbol represents a different site. Site 212 Labrador (+), 301 Burgeo/Rose Blanche ((), 304 Placentia Bay (◊), 335 Chance Cove/Renews (Δ), 402 St. Pauls (○).

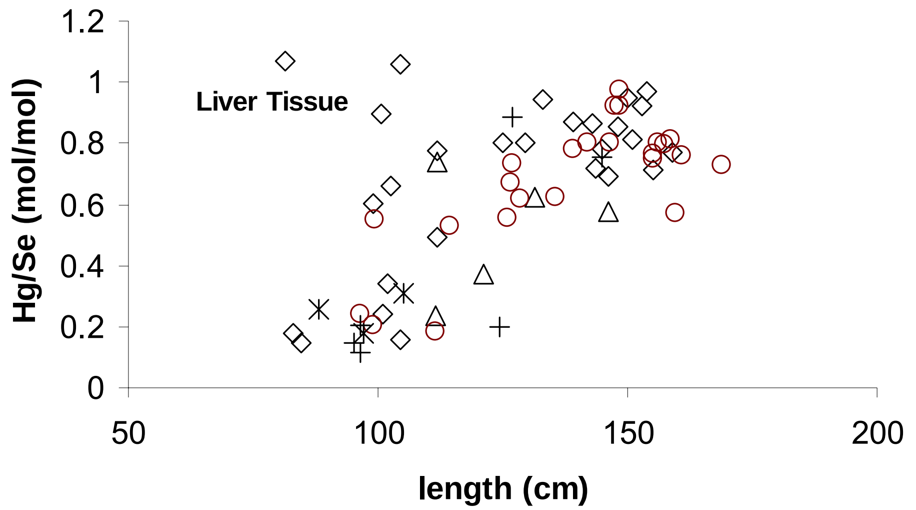

Figure 5. Relationship between seal length and Hg/Se molar ratio. Each symbol represents a different site. Site 212 Labrador (+), 301 Burgeo/Rose Blanche ((), 304 Placentia Bay (◊), 335 Chance Cove/Renews (Δ), 402 St. Pauls (○).

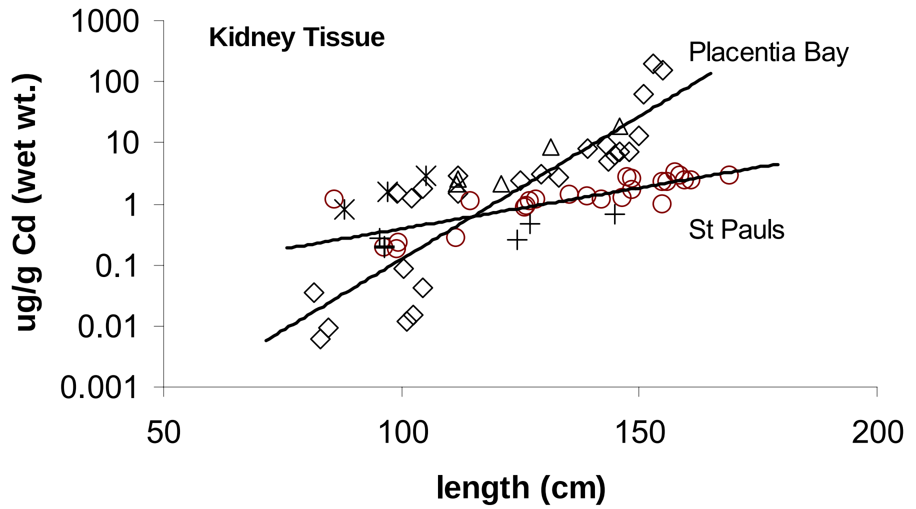

Figure 6. Relationship between seal length and cadmium concentration. Solid lines were obtained using the Placentia Bay and St. Pauls data. Each symbol represents a different site. Site 212 Labrador (+), 301 Burgeo/Rose Blanche ((), 304 Placentia Bay (◊), 335 Chance Cove/Renews (Δ), 402 St. Pauls (○).

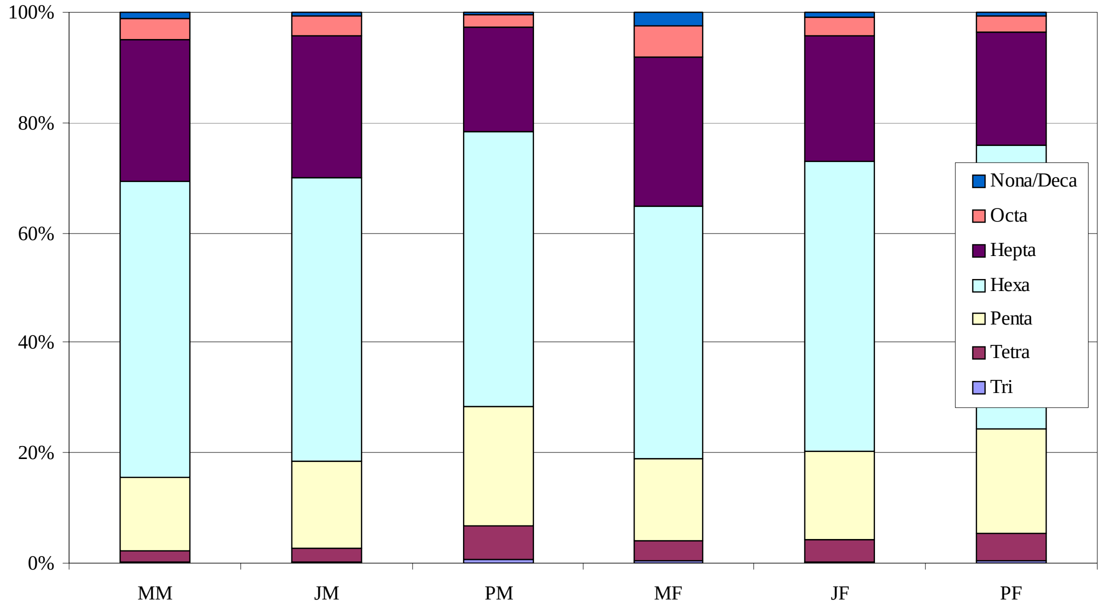

Figure 7. Relative contribution (%) of individual PCB homologue groups (tri to decachlorinated biphenyls) to the SPCBs in mature males (MM), juvenile males (JM), pup males (PM), mature females (MF), juvenile females (JF) and pup females (PF) from the harbour seal population of Newfoundland.

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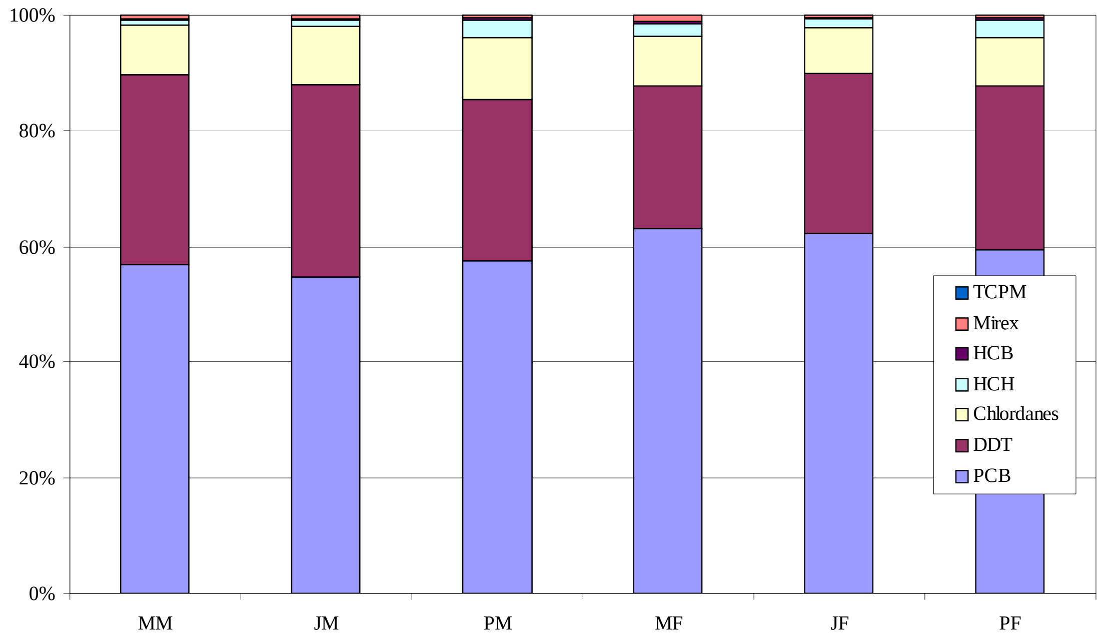


Figure 8. Relative contribution (%) of individual POP groups relative to the sum of POPs in mature males (MM), juvenile males (JM), pup males (PM), mature females (MF), juvenile females (JF) and pup females (PF) from the harbour seal population of Newfoundland.

Table 1. Summary of local abundance estimates for harbour seals in Newfoundland based on small boat surveys, shore-based counts and aerial observations survey from 2001-2003 (B=boat survey; SB=shore based; A=aircraft).

Date dd/mm/yy	Location and Survey Method	No. of Harbour Seals	Comments on Age Structure	Main area (s) of Concentration
27/8/2002	Renews/Chance Cove (B)	104		Chance Cove area
18/9/2002	Renews/Chance Cove (B)	164		Chance Cove area
22/7/2003	Renews/Chance Cove (B)	94	6 pups	Chance Cove area
5/6/2001	Merasheen/King Is. (B)	14	Female/young pup	southern King Island
29/5/2003	Merasheen/King Is. (B)	7		southern King Island
13/8/2003	W. coast St. Mary's Bay (B)	269		Bull Island Pt. to Red Head
5/5/2002	Marystown (SB)	6	1 female/pup pr	Southwest Arm
4/6/2002	Marystown (SB)	13	3 female/pups pr	Southwest Arm
6/6/2002	Marystown (SB)	9	2 female/pup pr	Southwest Arm
7/6/2002	Marystown (SB)	7	3 female/pup pr	Southwest Arm
27/5/2003	Marystown (SB)	9	3 preg females; 1 pup	Southwest Arm
31/5/2003	Marystown (SB)	10		Southwest Arm
1/6/2003	Marystown (SB)	11	1 female/pup pr	Southwest Arm
5/6/2003	Marystown (SB)	11	1 female/pup pr	Southwest Arm
5/6/2002	Pt. May (SB)	46	5 female/pup pr	Point May Pond & slipway
8/6/2002	Pt. May (SB)	30		Point May Pond
28/5/2003	Pt. May (SB)	43	1 female/pup pr	Point May Pond
1/6/2003	Pt. May (SB)	20	8 preg females	Point May Pond
5/6/2003	Pt. May (SB)	24		Point May Pond;
18/6/2003	Pt. May (SB)	17	1 female/pup pr	Point May Pond;
25/9/2003	Seal Cove/Pass Is (B)	24		Pass Is; 30 grey seals
20/9/2003	Port au Port Peninsula (A)	40		the Ledges
24/9/2002	St. Pauls Inlet (SB)	88		St. Pauls Bridge;
27/9/2002	St. Pauls Inlet (SB)	24		St. Pauls Bridge;
8/6/2003	St. Pauls Inlet (SB)	64	6 female/pup pr; 1preg female	St. Pauls Bridge;
21/9/2003	St. Pauls Inlet (SB)	31	2 pups; 2 juv	St. Pauls Bridge
22/9/2003	St. Pauls Inlet (SB)	37		St. Pauls Bridge

Table 2. Estimated numbers, prevalence, wet mass (kg), and energy (kcal) of vertebrate and invertebrates in harbour seal stomachs containing prey (N=147) collected from 1985-2003 in nearshore waters.

Prey Species	No. of Prey Items	Prevalence[a]	Wet mass[b]	Energy[b]
Vertebrates				
Atlantic Herring (*Clupea harengus*)	82	13.6	12.8 (8.5)	28776.4 (15.8)
Capelin (*Mallotus villosus*)	284	14.3	2.6 (1.7)	5218.8 (2.9)
Smelt (Osmeridae)	40	4.1		
Atlantic Mackerel	1	0.7		
Stickleback sp.	1	0.7		
Threespine Stickleback (*Gasterosteus aculeatus*)	1	0.7		
Gadoid sp.	3	1.4		
Gadus sp.	184	10.2	10.5 (7.0)	10638.6 (5.8)
Atlantic Cod (*Gadus morhua*)	265	25.9	16.0 (10.7)	16189.7 (8.9)
Rock Cod (*Gadus ogac*)	98	8.8	13.4 (8.9)	13527.7 (7.4)
White Hake (*Urophycis tenuis*)	2	1.4		
Arctic Cod (*Boreogadus saida*)	432	7.5	21.6 (14.4)	24888.0 (13.6)
Sand Lance (*Ammodytes dubius*)	1268	23.8	7.7 (5.1)	8110.9 (4.4)
Daubed Shanny (*Lumpenus maculatus*)	1	0.7		
Eelpout sp. (Zoarcidae)	3	0.7		
Newfoundland Eelpout	1	0.7		
Vahl's Eelpout	2	0.7		
Ocean Pout	1	0.7		
Redfish sp.(*Sebastes*)	226	8.2	7.4 (4.9)	9727.1 (5.3)
Sculpin sp. (Cottidae)	6	2.7		
Shorthorn Sculpin (*Myoxocephalus scorpius*)	85	8.8	19.9 (13.2)	25636.5 (14.1)
Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*)	1	0.7		
Mailed Sculpin	1	0.7		
Liparis sp.	2	1.4		
Lumpfish sp.	1	0.7		
Pollock	7	2		
Prickleback sp.	22	0.7		
Cunner	38	3.4		
Sea Lamprey	1	0.7		
American Plaice (*Hippoglossoides platessoides*)	24	0.7		
Unidentified Fish	205	11.6		
Winter Flounder	108	8.8	31.7 (21.1)	32297.6 (17.7)
Wolffish sp.	2	1.4		
Total	3398		150.3[c]	182374.4[c]

Table 2. Continued

Prey Species	No. of Prey Items	Prevalence	Wet mass[b]	Energy[b]
	Invertebrates			
Brachyura (Crab)	1	0.7		
Chionoecetes opilio (Snow Crab)	1	0.7		
Hyas sp. (Crab)	6	2		
Amphipoda	1	0.7		
Euphausiacea (Euphausiid)	2	1.4		
Gammaridea (Gammarid Amphipod)	2	0.7		
Hyperidae (Hyperiid Amphipod)	17	2		
Illex illecebrosus	37	3.4	0.6 (0.4)	869.7 (0.5)
Teuthoidea (Squid)	36	4.8		
Mollusca	1	0.7		
Polychaeta	2	1.4		
Mysidae (mysid)	6	2		
Eualus fabricii (Shrimp)	1	1.4		
Eualus sp. (Shrimp)	2	0.7		
Natantia (Shrimp)	15	2.7		
Pandalus borealis (Shrimp)	15	1.4		
Pandalus montagui (Shrimp)	18	2		
Pandalus sp. (Shrimp)	5	1.4		

Note: Numbers in parentheses are percentages

[a] As a percentage of the total number of prey-containing stomachs for each region.
[b] For vertebrates, prey accounting for at least 95% of total mass and energy; values calculated using all prey recovered.
[c] Values are calculated using all prey recovered
Seaweed and stone were recovered in 2 prey containing stomachs.

Table 3. Prevalence[a], estimated wet mass (kg), and total prey energy (kcal) of prey species accounting for at least 95% of total reconstructed wet mass of prey containing stomachs of harbour seals recovered in nearshore areas from 1985-2004.

	Labrador			Northeast Coast			South Coast			West Coast		
Prey Species	Prevalence	Mass	Energy	Prevalence	Mass	Energy	Prevalence	Mass	Energy	Prevalence	Mass	Energy
Arctic cod	11.1	20.3 (84.5)	23388.6 (86.2)	16.7	0.3 (0.5)	378.6 (0.5)	2.4	1.0 (6.6)	1120.7 (7.1)			
Atlantic cod				8.3	1.0 (1.6)	1035.6 (1.4)	34.1	3.9 (26.6)	3975.4 (25.1)	47.5	11.1 (24.3)	11178.5 (18.5)
Atlantic herring				2.1	0.9 (1.5)	2195.9 (3.1)	7.3	1.7 (11.4)	3776.0 (23.8)	40	10.2 (22.3)	22804.4 (37.8)
Capelin				12.5	0.6 (0.9)	1246.5 (1.7)	19.5	1.1 (7.4)	2209.6 (13.9)	12.5	0.9 (1.9)	1762.6 (2.9)
Gadus sp.	16.7	0.03 (0.1)	33.4 (0.1)	20.8	9.9 (15.0)	9970.0 (13.9)	0.2	0.2 (1.3)	187.6 (1.2)	2.5	0.4 (1.0)	447.3 (0.7)
Redfish							12.2	0.9 (6.0)	1170.9 (7.4)	17.5	6.5 (14.2)	8556.1 (14.2)
Rock cod	16.7	0.1 (5.2)	1257.8 (4.6)	16.7	11.8 (17.8)	11873.6 (16.6)				2.5	0.4 (1.0)	396.2 (0.7)
Sand lance	44.4	1.8 (7.4)	1881.7 (6.9)	27.1	3.5 (5.3)	3680.6 (5.1)	14.6	1.5 (9.8)	1539.1 (9.7)	20	1.0 (2.1)	1009.33 (1.7)
Shorthorn sculpin	5.6	0.4 (1.8)	567.8 (2.1)	20.8	18.4 (27.9)	23726.7 (33.1)	2.4	0.4 (2.8)	535.9 (3.4)	2.5	0.6 (1.4)	806.0 (1.3)
Winter flounder				8.3	17.2 (26.0)	17507.4 (24.4)	7.3	1.3 (9.0)	1349.9 (8.5)	15	13.2 (28.9)	13440.1 (22.3)
Total		24.0	27129.4		65.9	71615.4		14.8	15865.4		45.6	60401.0
Total no. of stomachs	18			48			41			40		

Note: Numbers in parentheses are percentages.
[a] As a percentage of the total number of prey-containing stomachs for each region.

Table 4. Mean seal length and mean elemental concentrations (ug/g wet wt.) for seal tissue from 5 sites in Newfoundland and Labrador.

Site (n)	Tissue	length	P	Mg	Mn	Co	Cu	Zn	As	Se	Cd	Total Hg
212 (6)	muscle	114	2510	249	0.17	0.004	1.89	24.13	0.11	0.51	0.003	0.35
(6)	liver	114	3110	205	4.16	0.015	11.46	34.68	0.21	5.47	0.146	9.20
(6)	kidney	114	2465	147	0.86	0.016	6.86	18.15	0.13	2.11	0.341	1.09
301 (2)	muscle	101	3589	264	0.16	0.005	1.28	22.77	0.14	0.50	-0.003	0.41
(3)	liver	97	4028	192	3.02	0.017	11.51	28.47	0.38	2.78	0.178	1.75
(3)	kidney	97	3507	142	0.87	0.025	7.12	20.48	0.35	3.55	0.251	1.84
304 (27)	muscle	124	3242	258	0.18	0.004	1.49	21.40	0.16	0.56	0.032	0.61
(27)	liver	124	3757	188	4.30	0.014	17.44	49.25	0.73	14.68	9.595	30.52
(27)	kidney	122	3148	145	0.94	0.017	6.80	26.83	0.36	3.62	20.252	2.33
335 (5)	muscle	124	3413	268	0.14	0.004	1.46	16.89	0.08	0.40	0.009	0.38
(5)	liver	124	4134	204	4.01	0.014	18.96	40.38	0.29	5.34	1.604	7.41
(5)	kidney	124	3538	138	0.93	0.019	9.94	24.90	0.20	3.84	6.816	2.71
402 (25)	muscle	136	2808	247	0.13	0.004	1.42	19.77	0.14	0.61	0.006	0.75
(25)	liver	136	3636	197	4.64	0.023	18.72	42.74	0.95	19.76	0.629	39.44
(25)	kidney	136	2651	134	0.96	0.024	5.42	19.87	0.39	4.97	1.563	2.39

Site locations: 212 Labrador; 301 Burgeo/Rose Blanche; 304 Placentia Bay; 335 Chance Cove/Renews; 402 St. Pauls

Table 5. Mean concentrations (ng/g lipid) of PCB congeners in male and female harbour seals collected from nearshore water in Newfoundland.

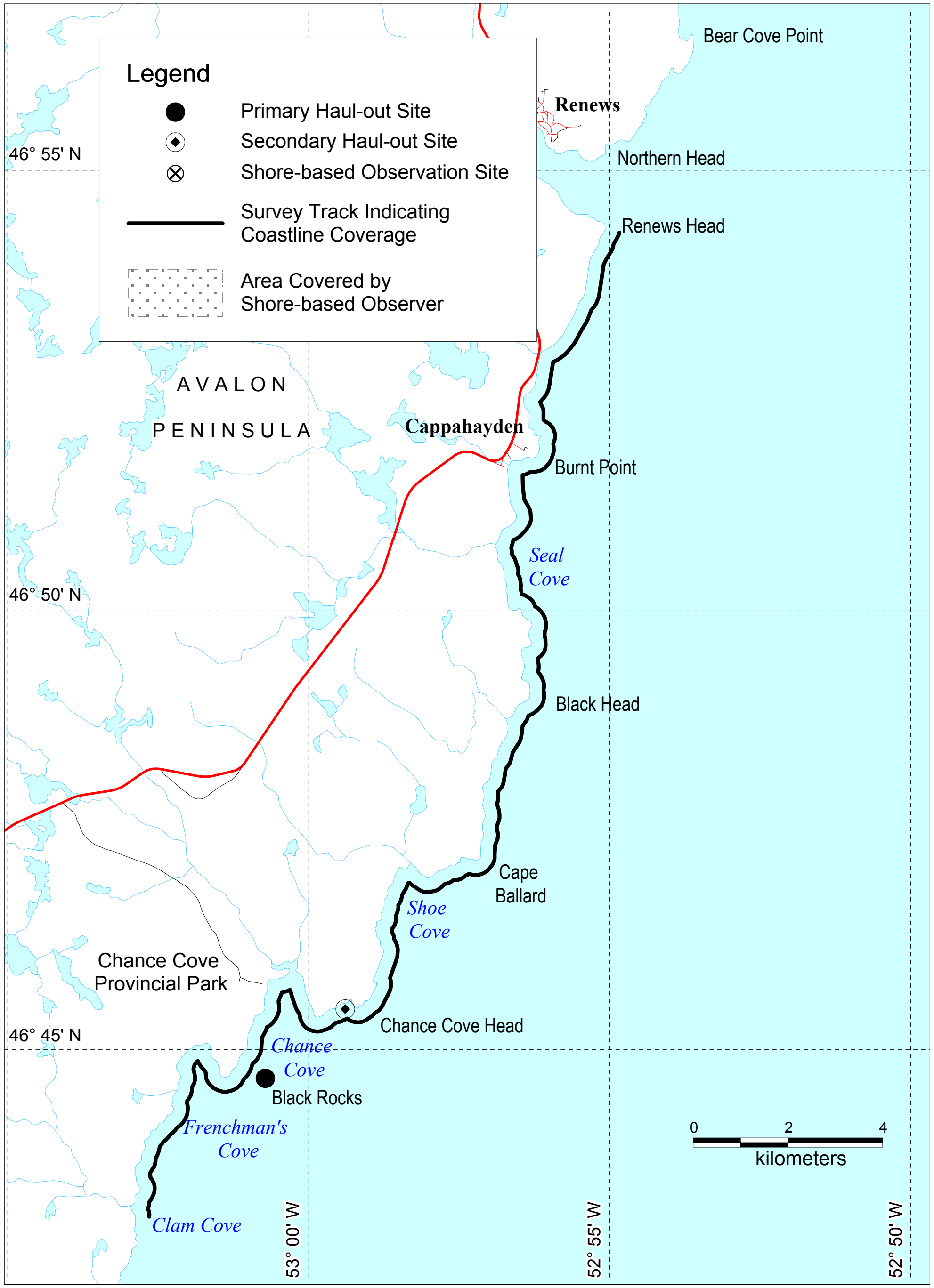
	Mature		Juvenile		Pup	
	(ng/g lip.)	95%CI	(ng/g lip.)	95%CI	(ng/g lip.)	95%CI
Male	(n=12)		(n=2)		(n=8)	
ΣPCB	5854	2694	3433	450	1613	633
Female	(n=15)		(n=6)		(n=12)	
ΣPCB	1465	397	2656	1270	1743	416

Table 6. Mean concentration (ng/g lipid) of OCPs in male and female harbour seal collected from nearshore areas of Newfoundland.

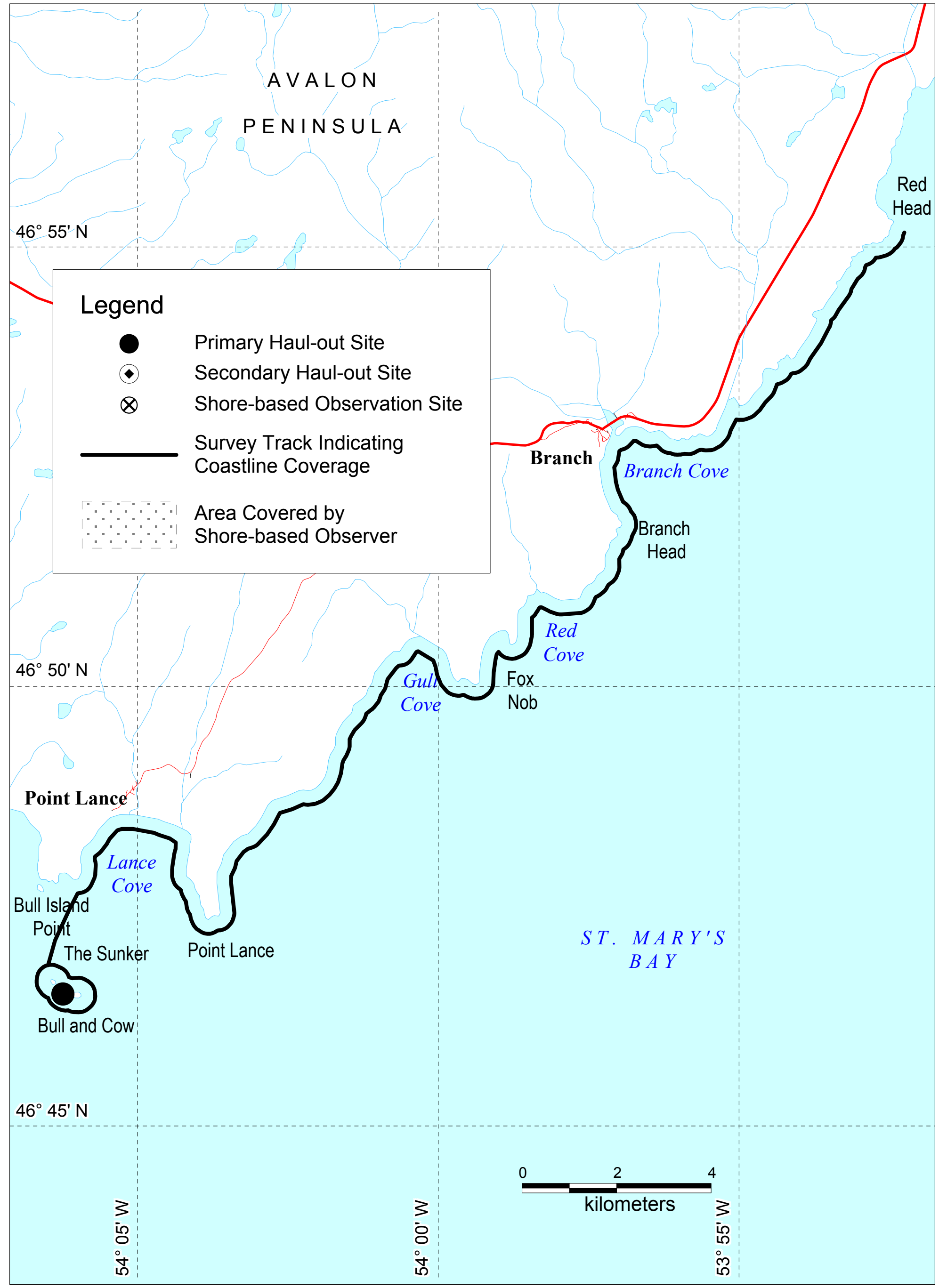
	Mature		Juvenile		Pup	
	(ng/g lip.)	95%CI	(ng/g lip.)	95%CI	(ng/g lip.)	95%CI
Male	(n=12)		(n=2)		(n=8)	
HCB	10.2	1.8	15.1	3.0	10.9	2.3
Mirex	80.0	55.1	32.8	4.8	8.3	2.7
ΣDT	3295	1492	2071	209	759	227
ΣChlordane	800	270	623	16.8	289	81.6
ΣHCH	57.8	6.3	73.1	12.9	74.3	18.9
ΣTCPM	10.7	7.1	3.0	0.2	2.9	1.1
Female	(n=15)		(n=6)		(n=12)	
HCB	7.5	1.1	7.1	1.5	10.7	1.3
Mirex	20.9	6.5	18.1	10.8	11.9	3.8
ΣDDT	567	140	1144	732	873	318
ΣChlordane	185	37.4	331	242	250	76.6
ΣHCH	43.6	6.9	52.7	5.9	79.5	10.7
ΣTCPM	1.8	0.6	1.4	0.6	2.8	1.4

Appendix 1

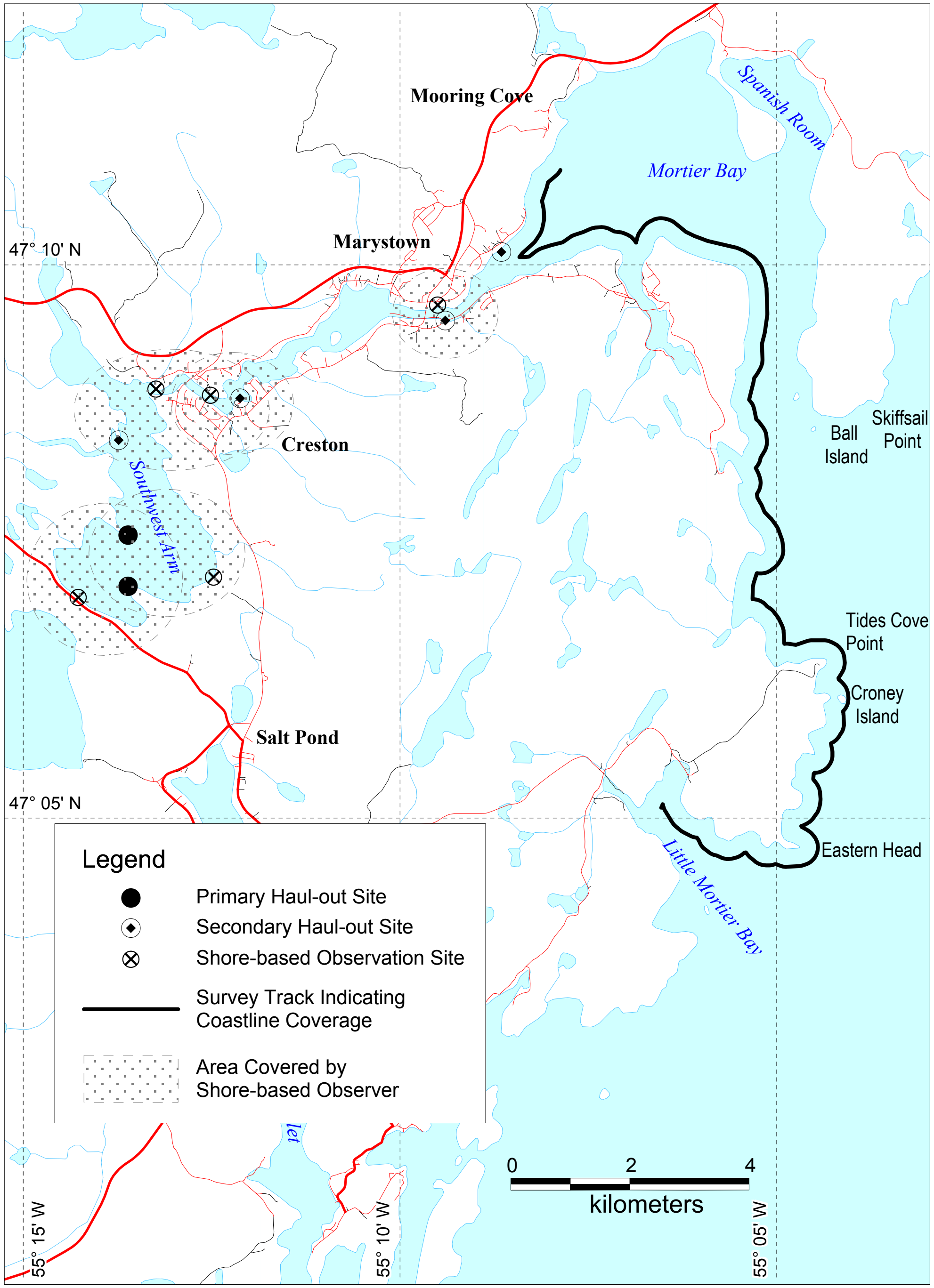
Appendix 1a. Small boat survey route from Renews to Chance Cove showing the primary haulout site near Black Rock. Individual seals were observed both in the shallow water and on the shore along the route.



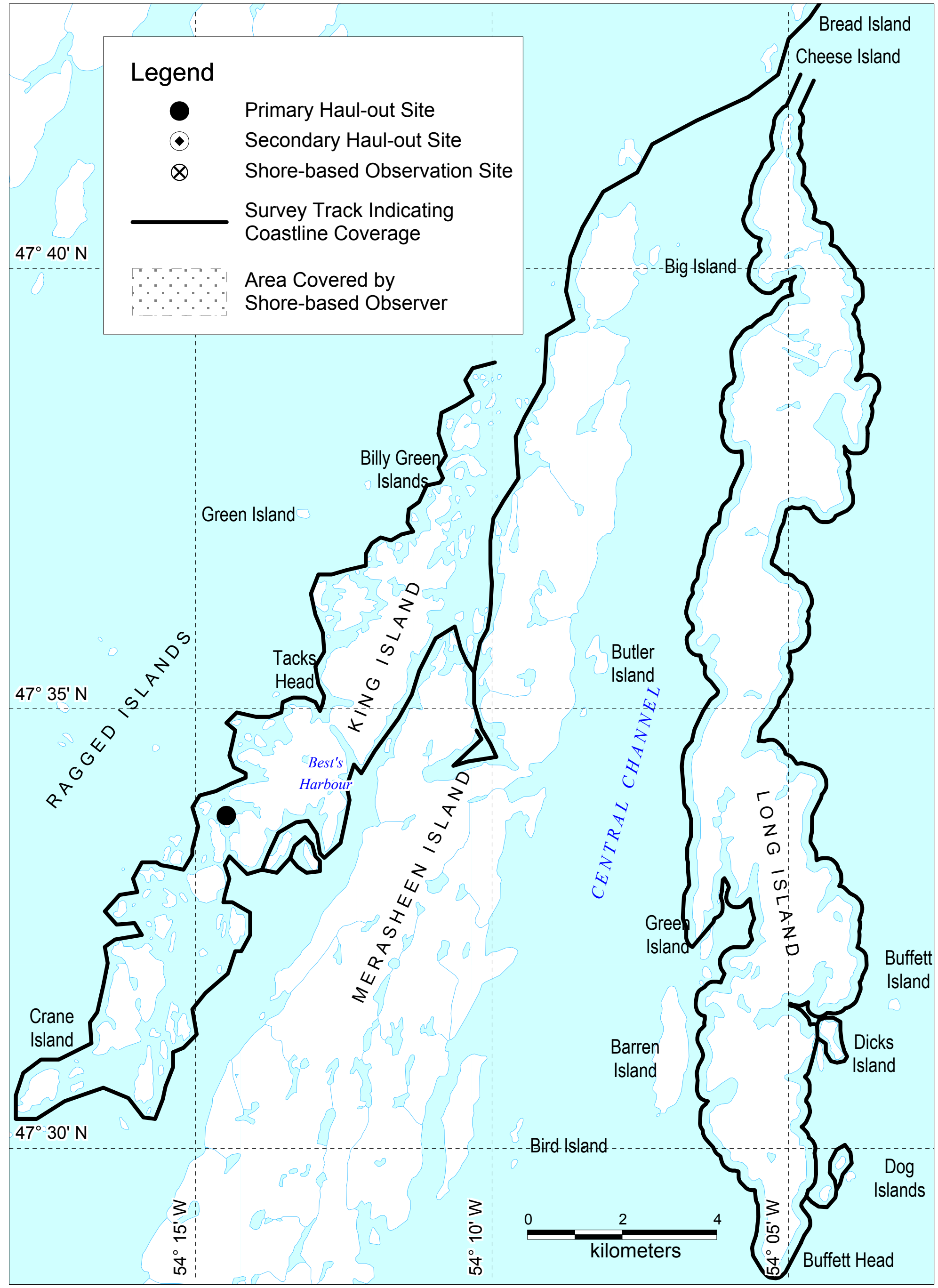
Appendix 1b. Longliner survey route from Bull Island Pt. to Red Head in St. Mary's Bay. The primary haulout site was Bull and Cow Island, but individual seals and small groups of seals were seen along the entire route.



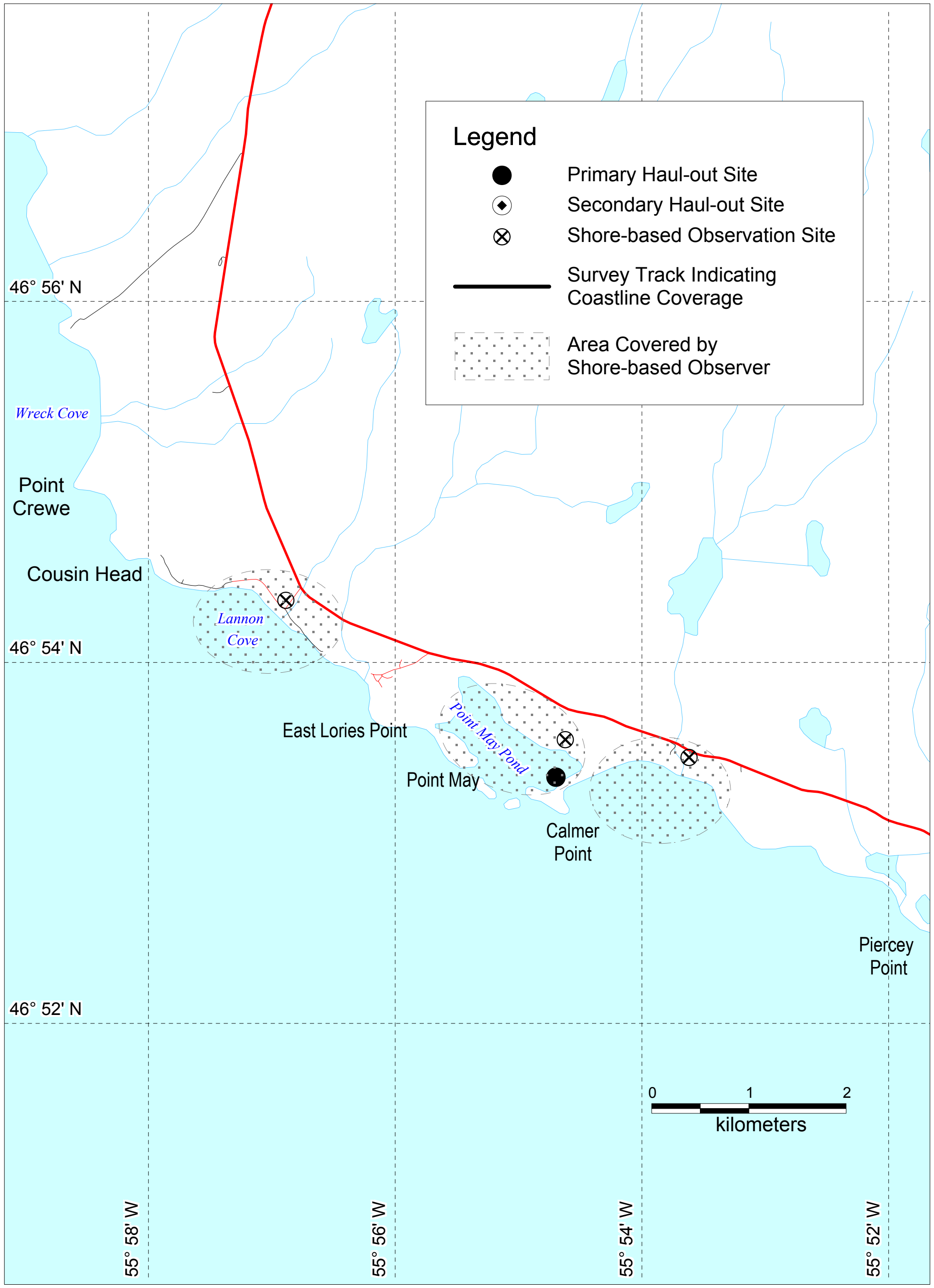
Appendix 1c. Shore-based observations of harbour seals in Southwest Arm near Marystown. There are two primary and three secondary haulout sites frequented by small groups of seals.



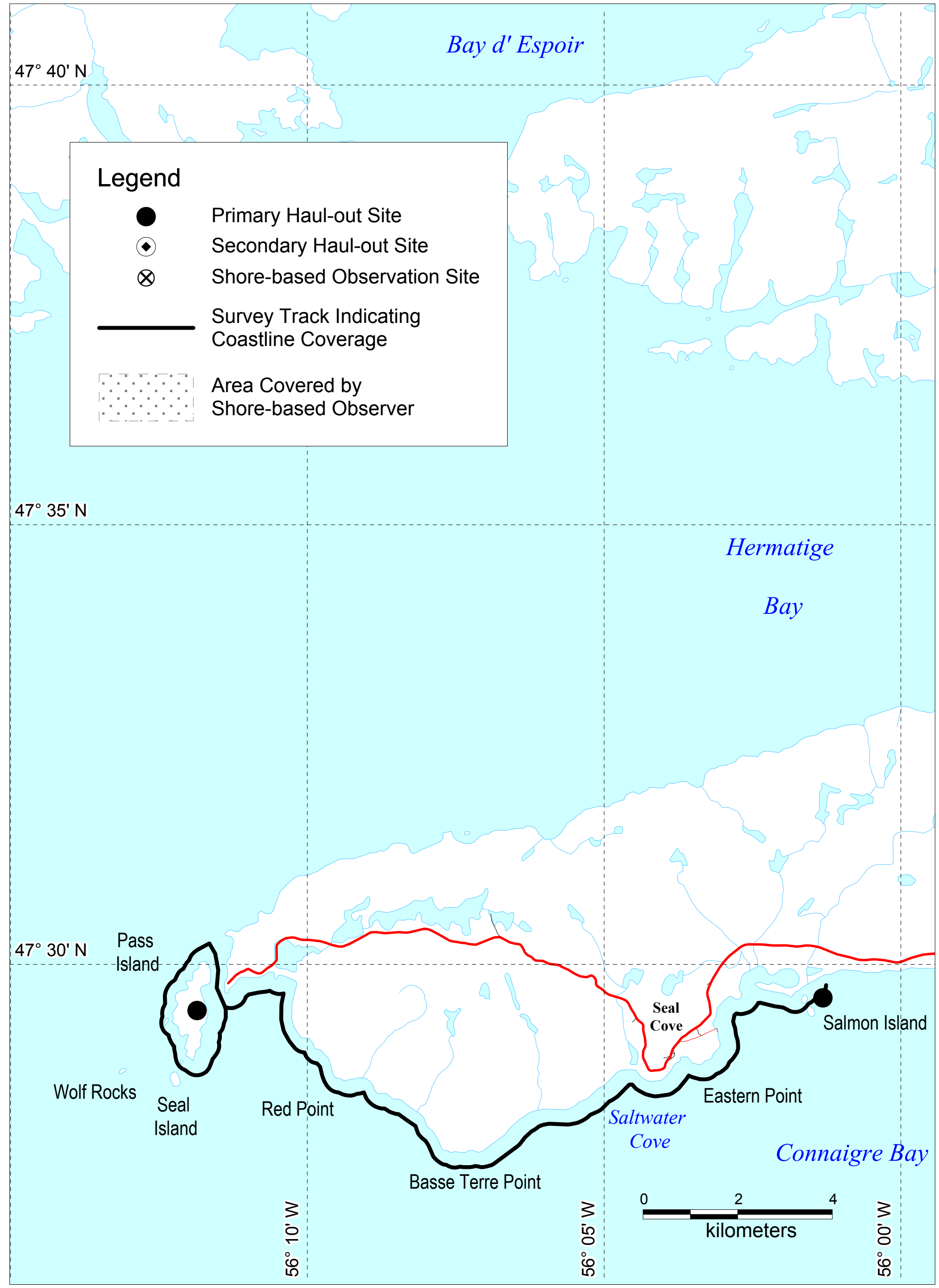
Appendix 1d. Small boat survey routes around the Merasheen, King and Long Island area. The primary haulout site was located on the southern portion of King Island. The majority of seals seen were located in the vicinity of this haulout site.



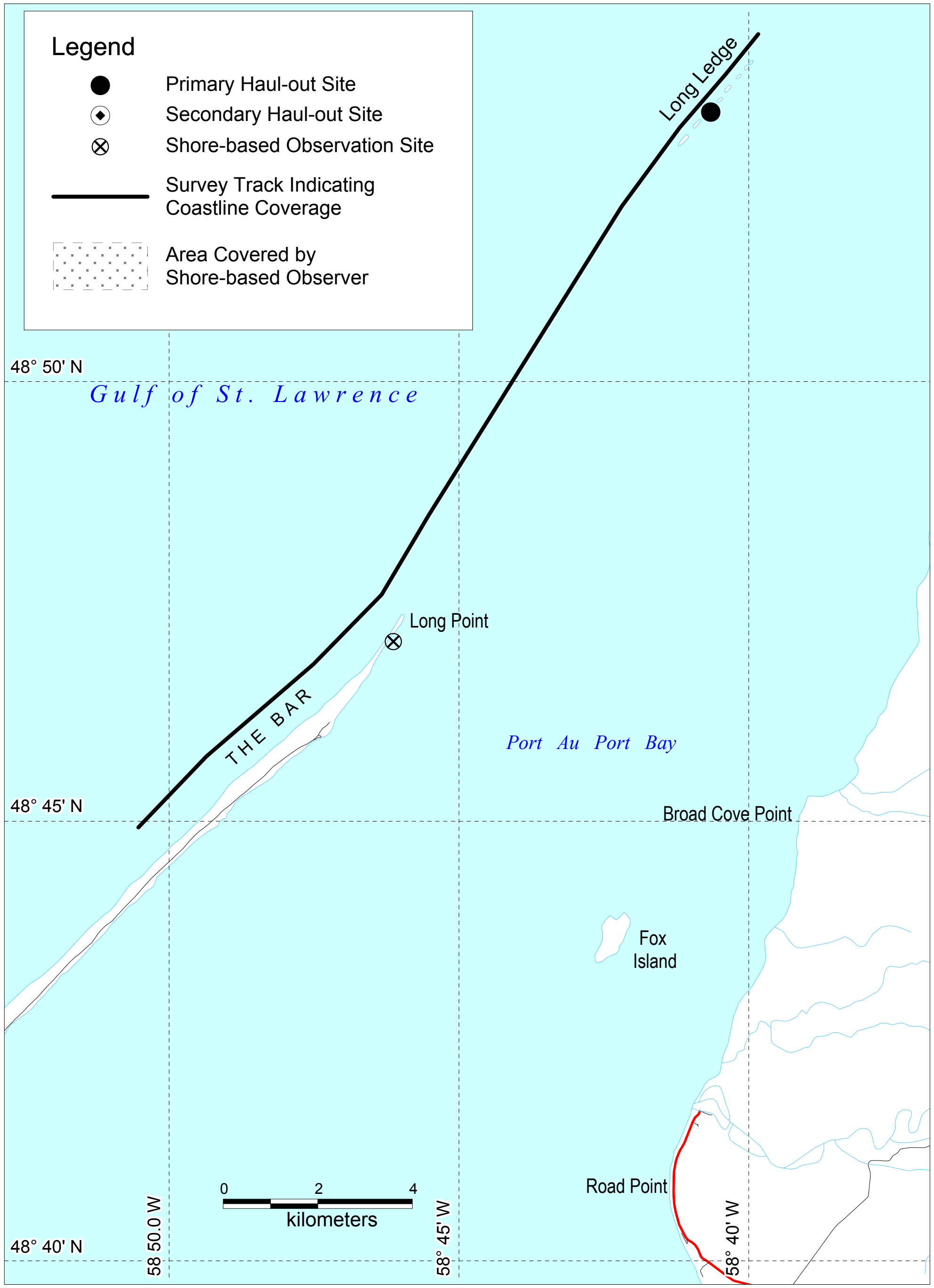
Appendix 1e. Shore-based observations at Pt. May. The primary haulout site was at Pt. May pond.



Appendix 1f. The small boat survey route in the Pass Island area. The primary haulout sites were located on Pass Island and on Salmon Island.



Appendix 1g. The flight route over the Ledges and Bar region of the Port au Port Peninsula. The primary haulout site was on the Ledges.



Appendix 1h. Shore-based observations at St. Pauls Inlet. Although boat surveys were made of the area, all the of haulout counts were made from shore locations.