Status of harbour seals (*Phoca vitulina*) in Atlantic Canada

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ABSTRACT

Harbour seals are associated with small islets, reefs and rocks exposed at low tide and estuarine habitats throughout eastern Canada. Evidence of harvesting by indigenous people has been found in pre-European contact archaeological excavations. A bounty harvest as well as subsistence and commercial hunting probably lead to a decline in the population from 1949 to the early 1970s. The bounty was removed in 1976, and harbour seals, in the southern parts of their range have been protected since then. There is little information available on total abundance and current population trend. Mitochondrial and microsatellite DNA research has shown separation between Northeast and Northwest Atlantic harbour seals. Within Canada, the subspecies *Phoca vitulina* concolor shows some population sub-structure with three distinct units that could be separated into Hudson Bay, Gulf of St. Lawrence and Sable Island. Urban development resulting in habitat degradation is probably the most important factor affecting harbour seal populations in Atlantic Canada, although other factors such as incidental catches in commercial fisheries and competition with grey seals may also be important.

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INTRODUCTION

The harbour seal (*Phoca vitulina*) has the most extensive breeding distribution of any pinnipeds with breeding colonies distributed over 16,000 km from the Baltic Sea to Japan (Stanley *et al.* 1996). Five subspecies are recognized, with *P. v. richardii* and *P.v. stejnegeri* occurring in the eastern and western Pacific respectively, *P.v. vitulina* occurring in the Northeast Atlantic, *P.v. concolor* in the Northwest Atlantic, eastern Canadian Arctic and Hudson Bay, and *P.v. mellonae* confined to a few freshwater lakes in northern Quebec (Rice 1998).

In eastern Canada, harbour seals are also known as Kasigiak in Inuktitut, or ranger (young), dotard or doter (adult), bay, common and spotted seal in English (Mansfield 1967). In French they are known as phoque commun, loup-marin d'esprit, loup-marin de baie, loup-marin de batture, and loup-marin de grève (Comeau 1945, Mansfield 1967).

P.v. concolor has been reported throughout Hudson Bay, along the Baffin Island coast, Labrador, Newfoundland, the St. Lawrence River Estuary and Gulf of St. Lawrence, along the Nova Scotia coast, Sable Island, and in the

Bay of Fundy (Mansfield 1967). During the 1800s the species was also reported from as far west as Lake Champlain and Lake Ontario (Allen 1880). Harbour seals are also found along the northeastern United States coast (Katona *et al.* 1993). They are normally associated with coastal areas, isolated sandy beaches, small islets, rocks and reefs exposed at low tide (Boulva and McLaren 1979, Lesage *et al.*2004). Harbour seals are relatively sedentary, although at times extensive movement does occur (Lesage *et al.* 2004). Movements appear to be coastal, and harbour seals seem to avoid deep water (Lesage *et al.* 2004). In ice-covered regions, they are excluded from fast ice areas (Lesage *et al.* 2004).

BIOLOGY AND ECOLOGY

Biology

The first most extensive study of Atlantic harbour seals in Canada was carried out by Boulva and McLaren (1979). Field work was done at Sable Island, but questionnaires and interviews were used to gather regional information on the location and size of breeding colonies throughout eastern Canada. Males are sexually mature at 6 years of age, while the mean age of sexual maturity for females was 3-4 years old.

In the early 1970s on Sable Island, pupping began as early as 7 May and had finished by 10 June, with a mean date of pupping over three seasons of 25 May (Boulva 1975). During the late 1980s, the mean date of pupping occurred earlier (mean=22 May, SE=0.3, N=286), when the population was stable, but shifted to a later date in the early to mid-1990s (Mean=28 May, SE=0.3, N=390), coincident with a dramatic decline in the population (Bowen *et al.* 2003). Lactation lasts for 24 days (Bowen *et al.* 2003). Pup mortality prior to weaning is quite variable (12-21%), resulting in a mean survivorship for the pre-weaning period of 0.876. The sex ratio at birth is not significantly different from 1:1 and some pups are born with a white lanugo (12-25%). Birth mass of pups averages 10.9 kg (N=375) but increases with maternal age and maternal body mass. Pups of primiparous females were smaller at birth than those of multiparous females (Ellis *et al.* 2000). Pups gain

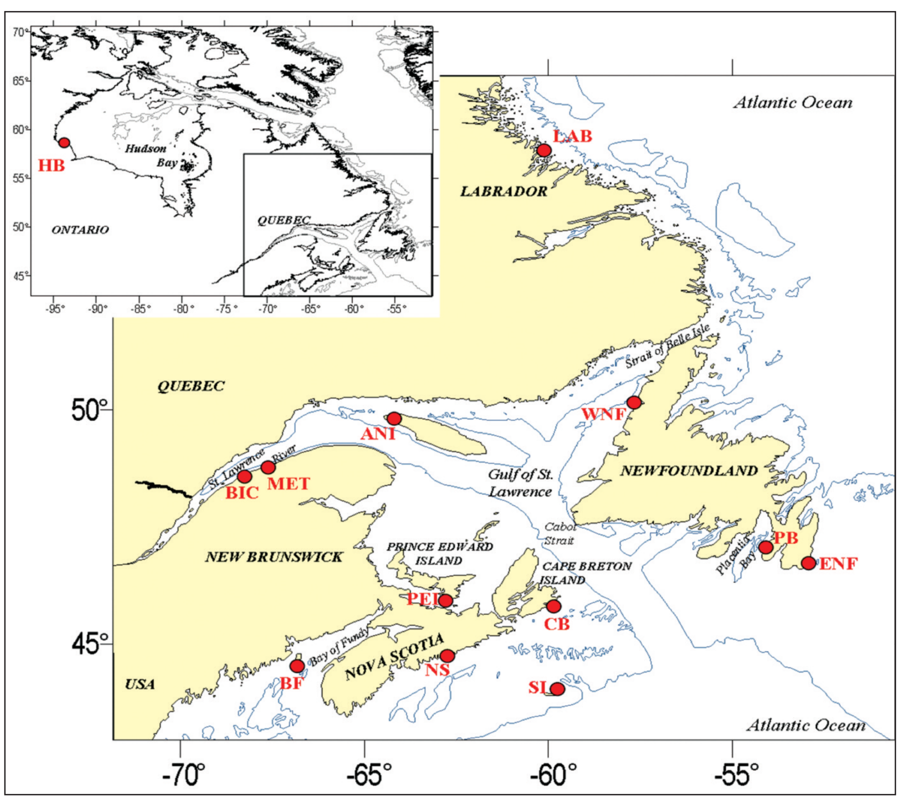

Fig. 1. *Map of eastern Canada showing areas mentioned in the text and the location of samples collected for genetic analyses (Picaud 2008). Locations are Bay of Fundy (BF), Nova Scotia (NS), Sable Island (SI), Cape Breton (CB), Eastern Newfoundland (ENF), Placentia Bay (PB), western Newfoundland (WNF), Labrador (LAB), Prince Edward Island (PEI), Anticosti Island (ANI), Bic (BIC) and Metis (MET) in the St. Lawrence River Estuary and western Hudson Bay (HB).*

600 g per day during an average lactation period of 24 d and are weaned at an average body mass of 24.9 kg (N=52, Muelbert and Bowen 1993). During the initial post-weaning period pups loose body mass, but gain lean tissue mass indicating continued skeletal growth. Heavier pups were also relatively fatter than light pups (*i.e.* those below the median mass) and had significantly greater total body energy to sustain them during the transition to nutritional independence (Muelbert *et al.* 2003).

In the St Lawrence Estuary, pupping begins as early as 12 May and finishes by 21 June, with a mean date of pupping over three seasons of 26 May (Dubé *et al.* 2003). This is earlier than predicted by Temte *et al.* (1991), suggesting latitude may be less important along the Atlantic coast of North America, than along the Pacific coast where a latitudinal gradient has been found. Pup survival prior to weaning is quite variable (0.5-0.9), but survival is high during the 2 months following weaning (0.8-1.0) (Dubé 2002). The sex ratio at birth is not significantly different from 1:1 and, as elsewhere, some pups are born with a white lanugo (3-12%). Pups gained on average 544 (SE=141, N=110) g per day; and 50% of the pups were weaned after 33 (SE=1.8) days (Dubé *et al.* 2003). This is almost 10 days longer than that which has been reported in other studies, and is likely the result of the indirect method used to estimate duration of lactation (Dubé *et al.* 2003).

Harbour seal pups are capable of entering the water soon after birth to follow the female but their ability to follow and dive with their mother is limited in early lactation (Bowen *et al.* 1999). However, blood oxygen stores and ability to control heart rate develop quickly, although development of oxygen stores in muscle myoglobin continues after weaning (Lapierre *et al.* 2004, Greaves *et al.* 2004, 2005, Clark *et al.* 2006, Clark *et al.* 2007). Bowen *et al.* (2001a, b) examined factors affecting pup development among harbour seals on Sable Island. They found that females expended a constant proportion of stored energy reserves, rather than a constant amount of energy. Females supported the costs of lactation from stored reserves early in lactation, but diving activity increased as lactation progressed as females foraged more to support lactation (also see Boness *et al.* 1994). The fraction of total energy expenditure that was derived from food intake during lactation was inversely proportional to maternal body mass, indicating that larger females were better prepared to support lactation than smaller females (Bowen *et al.* 2001a, b). The duration of lactation was related to the rate of mass gain and weaning mass. Pups that grew faster had shorter lactation periods, while pups with larger weaning mass suckled for longer periods. Pups of older females grew faster than did pups of younger females, at least early in lactation. Lighter females had lighter pups at birth, their pups grew more slowly and these females invested relatively more in lactation than did heavier females. Pups from heavy females had higher survival than pups of light females.

Mating occurs in the water, during late May or June, during late lactation. The mating system appears to be more of a lek-type than a territorial or female-defence system observed among land- or ice-breeding pinnipeds (Boness *et al.* 2006). Boness *et al.* (2006) simultaneously used animal-borne video cameras, radio telemetry, time-depth recorders and DNA paternity analysis to describe the tactic used by males to secure mating. Males decreased time offshore feeding and increased time near shore during late lactation. Concomitantly they reduce foraging effort and food intake (Coltman *et al.* 1997, 1998a) and increased display behaviour and threats to other males. A multivariate analysis of phenotype and paternity showed that the most successful males were of moderate body size, were rarely sighted alone and were associated with many different groups of females (Coltman *et al.* 1998b). DNA paternities also suggested that females selected as mates were females that were fertilized less often than expected by males adjacent to their haulout location in the colony (Boness *et al.* 2006).

Diet and foraging behaviour

As in most pinnipeds, harbour seals consume a wide variety of prey. Species composition and importance show temporal and spatial variation. In an early sample made up of animals from the Bay of Fundy, Sable Island and southeastern Cape Breton Island, Atlantic herring *(Clupea* *harengus)*, squid *(Illex illecebrosus)*, flounder *(Pleuronectidae)*, alewife *(Alosa psuedo-harengus)*, hake *(Merluccius* sp. and *Urophycis* sp.*)*, smelt *(Osmerus mordax)* and mackerel *(Scomber scombrus)* accounted for 78% of the diet by percent occurrence. Cod *(Gadus morhua)*, capelin *(Mallotus villosus)* and sand lance *(Ammodytes* sp.*)* were also consumed, but each accounted for less than 3% of the diet (% occurrence) (Boulva and McLaren 1979). In a more recent study, involving animals collected in the Bay of Fundy, the Eastern shore of Nova Scotia and Cape Breton Island (Bowen and Harrison 1996), Atlantic herring, squid, Atlantic cod, pollock *(Pollachius virens)* and hake accounted for 54% and 61% of the diet by % occurrence and % mass respectively. Alewife, flounder and capelin each accounted for less than 3% of the diet. In Newfoundland and Labrador waters winter flounder *(Pseudopleuronectes americanus)*, Arctic cod *(Boreogadus saida)*, shorthorn sculpin *(Myoxocephalus scorpius)*, Atlantic cod and Atlantic herring accounted for 83.8% of the diet based on mass. However the key prey species consumed by seals varied regionally within the province (Sjare *et al.* 2005). In the St Lawrence Estuary, trophic relationships of harbour seals, harp seals *(Phoca groenlandica)*, hooded seals *(Cystophora cristata)*, grey seals (*Halichoerus grypus*) and beluga *(Delphinapterus leucas)* have been examined (Lesage *et al.* 2001). Harbour seals along with hooded seals occupied the highest trophic position. Limited diet information indicate that harbour seals in the estuary feed on capelin, sand lance, herring, some sculpins (Cottidae) and flatfish (Lesage *et al.* 2001).

Although relatively little is known about the foraging behaviour of pinnipeds, animal-borne video cameras have provided some insight into the tactics used by adult male harbour seals during the breeding season (Bowen *et al.* 2002). Foraging tactics used by males differed with prey type. Swim speed and handling time differed with prey type with the result that profitability of prey (*i.e.*, the net energy gain per unit prey mass) also varies by prey type and prey size.

Dive shape analysis revealed temporal changes in the foraging behaviour and food intake of harbour seal adults during the breeding season and young of the year during the first month post-weaning (Baechler *et al.* 2002). Estimates of food intake form water turnover studies were positively correlated with the proportion of flat bottomed dives suggesting that such dives are predominately used during foraging.

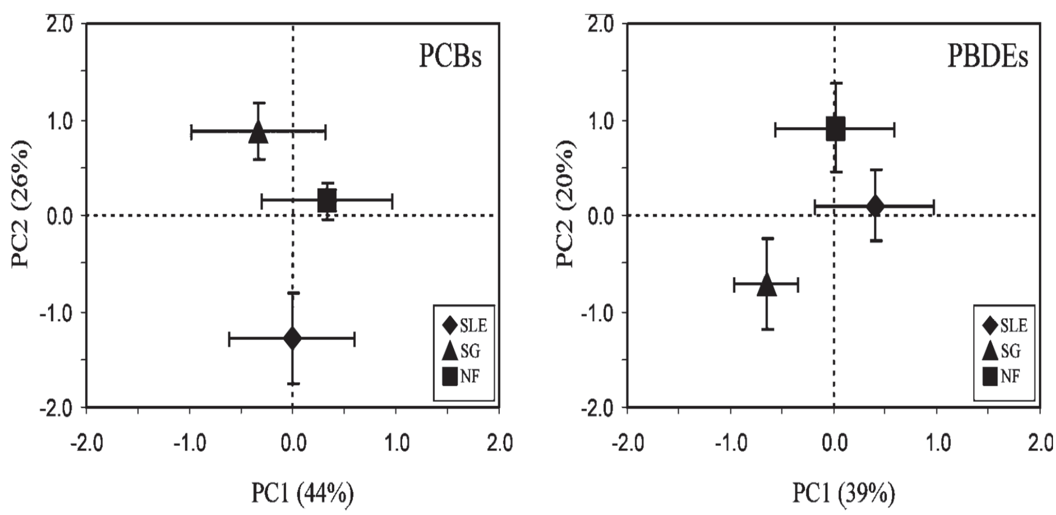

Fig. 2. *Principal component mean scores (±95% confidence interval) of PCBs and PBDEs in blubber of harbour seals from the St. Lawrence Estuary (SLE) , southern Gulf of St. Lawrence (SG) and Newfoundland (NF) (Lebeuf et al. 2003).*

POPULATION SIZE AND STRUCTURE

Abundance

Little effort has been undertaken to determine harbour seal abundance in Atlantic Canada. Available estimates are from regional studies that have addressed specific concerns. These studies have used different methods and methods used within studies have changed over time.

Early work by Fisher (1949, cited in Boulva and McLaren 1979) suggested that the population of harbour seals in the Maritimes (excluding Sable Island) was around 10,000-15,000 animals. In 1973, there were an estimated 5,500 in the same area (Boulva and McLaren 1979). However, estimates from both studies must be viewed cautiously. Estimates from Boulva and McLaren (1979) were based upon interviews, bounty reports and questionnaires sent to local fisheries officers, which according to the authors were more thorough than the earlier study by Fisher (1949), but nonetheless were not the result of actual counts. The estimated total population for Newfoundland, the Maritimes, the Gulf and estuary of the St. Lawrence from the study by Boulva and McLaren (1979) was around 12,700 in 1973. Throughout the 1970s the perception was that the Atlantic harbour seal population was declining and the population was projected to number as few as 4,000 by 1979 (Boulva 1973, McLaren 1977).

Count and tagging data are available for the number of pups (1970-2002), parturient females (1987-1996) and juveniles, adult males and females (1991-1998) on Sable Island (Boulva and McLaren 1979, Lucas and Stobo 2000, Bowen *et al.* 2003). Using the number of pups as an index of abundance, pup production numbered around 350 animals in the early 1970's. The number of pups increased beginning in 1978 reaching a maximum of just over 600 pups by 1989, then declined to around a dozen pups or less by 2002 (Bowen *et al.* 2003). A decline in the number of juveniles and adults did not occur immediately, but a decline was observed in these age classes as a result of the reduced number of pups moving into the older age classes. This decline appears to result from a combination of shark-inflicted mortality, on both pups and adult females and inter-specific competition with the much more abundant grey seal *(Halichoerus grypus)* for food resources (Bowen *et al.* 2003).

Elsewhere, a series of coastal aerial surveys were flown over parts of the Bay of Fundy and southwestern Nova Scotia during 1985, 1986, 1987, 1991 and 1992. Surveys were flown during the pupping season (1985) and also during the moult (July-August, 1986-1992) (Stobo and Fowler 1994). The study design called for surveys to be flown within a 4 h window centred on a mid-morning to mid-afternoon low tide, but for various reasons this was not always possible to achieve. Total counts of hauled-out animals from these areas varied from 731 in 1985 to 3,534 in 1992. Although the authors concluded that the harbour seal population in this area was likely increasing, interannual differences in survey conditions and areas covered did not allow for this change to be quantified.

Helicopter surveys have also been flown to count hauled-out animals along the coast and around small islands in parts of the Gulf of St. Lawrence and the St Lawrence estuary at an altitude of 152.4 m, and a distance of 300 m offshore to minimize disturbance. In the estuary, surveys were flown during June 1995, 1996, and 1997, and in August during 1994, 1995, 1996 and 1997, and in different parts of the Gulf during June 1996 and 2001 (Robillard *et al.* 2005). Trends in counts at 9 sites that were surveyed in June and in August under similar conditions revealed, that although all slopes were positive, only one was significant. Overall, the June surveys resulted in an average of 469 (SD=60, N=3) hauled-out animals, which is only slightly lower than a count of 621 (SD=41, N=3) hauled-out animals flown under similar conditions in August. Aerial surveys in the Gulf of St. Lawrence resulted in counts of 467 animals in 1996 and 423 animals in 2001 for a different area (Robillard *et al.* 2005). If the hauled-out counts are corrected for animals in the water at the time the surveys are flown, and the densities from the surveyed areas are extrapolated to include the areas not surveyed in the Gulf of St. Lawrence, then there were about 4,000-5,000 harbour seals in the St Lawrence

Table 1. Bounty claims in the Maritime region of Atlantic Canada between 1950 and 1971 (Boulva 1973). Numbers have not been correct for struck and loss as presented in Boulva (1973).

Year	Adults	Pups	Year	Adults	Pups
1950	219	1120	1961	177	430
1951	325	1030	1962	149	550
1952	410	935	1963	179	408
1953	310	870	1964	65	291
1954	271	765	1965	101	349
1955	260	760	1966	82	370
1956	184	458	1967	48	199
1957	260	602	1968	120	323
1958	299	521	1969	169	414
1959	214	518	1970	205	375
1960	158	394	1971	163	276

River Estuary and the Gulf of St. Lawrence (Robillard *et al.*2005).

In Newfoundland, Boulva and McLaren (1979) estimated a total of 2,010 seals in Newfoundland, from their questionnaire survey. Since then, as in other regions there has been little attempt to determine harbour seal abundance. Local boat and aerial surveys and interviews with fishermen were completed during May-September 2001-2003 to obtain more information on harbour seals in the province. Surveys were timed to be completed within 2-3 h of low tide (Sjare *et al.* 2005). Although direct comparisons with the earlier study (Boulva and McLaren 1979) are not possible because the methods differed, the impression was that distribution had changed little and that numbers at some haulout sites in the south and south-western part of the province may have increased, while abundance at some haulout sites in the northern and north-eastern part of the province have remained stable or may have declined (Sjare *et al.* 2005). Recent reports from hunters along the Labrador coast suggest that there has been little change in general the

Table 2. Estimates of 217 adult harbour seals killed by hunters and recovered (Boulva 1973). NS stands for the province of Nova Scotia and NB stands for the province of New Brunswick (see Fig. 1).

Hunter	Locality	Shot	Recovered	% Lost
1	Fourchu, NS	10	5	0.50
2	Canso, NS	10	5	0.50
3	Ecum Secum, NS	25	24	0.96
4	Sheet Harbour, NS	10	2	0.20
5	Fort Mouton, NS	32	27	0.84
6	Jordan Bay, NS	10	5	0.50
7	Port Clyde, NS	10	10	1.00
8	Penfield, NB	30	25	0.83
9	Beaver Harbour, NB	10	7	0.70
10	Campobello, NB	50	38	0.76
11	Grand Manan Island, NB	10	5	0.50
12	Grand Manan Island, NB	10	5	0.50

Table 3. Geographical origins, acronyms, sample size and collection dates of the samples analysed for microsatellite and mitochondrial DNA variability of harbour seal (Picaud, 2008).

Sampling site	Acronym	Sample size microsatellite	Sample size mitochondrial DNA	Collection dates
Bic	BIC	48	38	2001-2002
Métis	MET	21	15	2002
Anticosti Island	ANI	16	17	1994; 2004
Prince Edward Island	PEI	29	23	2001-2004
West Newfoundland	WNF	25	20	2002-2003
Placentia Bay	PB	24	21	2002
East Newfoundland	ENF	4	4	2002-2003
Cape Breton	CB	5	5	1992
Nova Scotia	NS	8	7	1992
Bay of Fundy	BF	24	17	1988-1989
Sable Island	SI	30	27	1989
Labrador	LAB	6	6	2003
Hudson Bay	HB	19	17	2001-2002
Total Northwest Atlantic		259	217	
Skagerrak Strait (Sweden)	SW	31	31	2002

distribution, habitat use and relative abundance of seals since the early 1980s (Sjare *et al.* 2005). Assuming 4,000-5,000 harbour seals in the Gulf and estuary of the St Lawrence, and an estimate of 4,000 to 7,000 animals for the Bay of Fundy (3,534 from Stobo and Fowler (1994) corrected for animals in the water by multiplying by 1.2-1.9 and rounding to the nearest thousand) results in an index of 8,000 to 12,000 harbour seals in Atlantic Canada, excluding Newfoundland. This is probably a minimum estimate because the surveys are dated, and large areas have not been surveyed, but the degree of bias is not known. With the exception of Sable Island, where harbour seal abundance has increased and then declined since the 1970s, it is not possible to evaluate trend among harbour seals in Atlantic Canada. A comparison of recent geographic distribution, with that observed in the 1970s suggests that there has been little change (Boulva and McLaren 1979).

Stock structure

Harbour seals in eastern Canada are generally found in small, apparently isolated populations (Boulva and McLaren 1979). Tagging and telemetry data, as well as variability in pelage patterns and the number of post-canine teeth have been used to support the hypothesis that harbour seals tend to be sedentary and the small groups are semi-isolated, (Boulva and McLaren1979, Thompson 1993, Lesage *et al.* 2004). This relatively sedentary nature would also suggest that a degree of segregation could be detected using genetic markers either by examining the degree of separation through maternally inherited mitochondrial DNA or using microsatellite DNA analyses. Analyses of mitochondrial DNA show clear separation between harbour seals from the East Atlantic *(P.v. vitulina)* and the West Atlantic *(P.v. concolor)*, and in the West Atlantic between samples from western Hudson Bay and the French island of Miquelon off the south coast of Newfoundland and Sable Island, but no differences were observed between animals sampled from Sable Island and Miquelon (Stanley *et al.* 1996). In a recent study, skin samples (N=290) were obtained from harbour seals in the St. Lawrence Estuary, the northern Gulf of St. Lawrence

Table 4. A comparison of mean PCB and OC pesticide blubber concentrations (ng/g lipid) in adult male harbour, grey, harp and hooded seals from the North Atlantic and Arctic Oceans since 1988 (Hobbs et al. 2002).

Species	Location	Date(mo/yr)	n	Age (yrs)	ΣPCB[a]	ΣDDT[b]	ΣCHLOR[c]	HCB	ΣHCH[d]	Mirex
	Western Atlantic									
Harbour seals	St Lawrence Estuary (Métis & Bic)	05/1990 & 06,08/1996	5	9.5±4.0[e] (5-16)	40,700±28,100 (5,140-82,100)	6,360±2,850 (3,180-11,200)	2,240±1,580 (857-5,300)	11.8±9.51 (0.01-25)	63.6±21.7 (32.8-93.4)	343±213 (60-527)
	St Lawrence Estuary (Métis & Bic)	05-09/1995	5	5.8±1.2 (5-8)	27,100±24,200 (10,100-75,000)	7,180±3,190 (3,700-13,100)	1,620±807 (848-3,160)	10.7±1.40 (nd-12.8)	96.0±22.4 (76.9-139)	201±137 (67.5-459)
Hooded seals	Gulf of St Lawrence (Magdalen Islands)	03/1990 & 1996	12	10±1.6[f] (7-12)	11,300±5,720 (2,070-22,700)	13,200±6,300 (3,320-22,400)	2,240±836 (39.4-336)	20.6±7.02 (12.3-35.7)	29.2±8.72 (21.6-48.9)	99.3±50.9 (27.1-194)
Grey seals	Gulf of St Lawrence (Port Hood & Amet Isl)	01/1996 & 06/1997	9	8.1±4.4 (5-19)	7,030±3,250 (1,570-12,300)	3,650±1,230 (1,200-5,920)	611±214 (313-1,030)	54.1±43.7 (20.3-155)	73.3±25.2 (20.1-118)	51.7±19.2 (28.5-93.1)
	St Lawrence Estuary (Bic)	07/1995	1	11	15,800	4,210	775	nd	603	116
Harp seals	Gulf of St Lawrence (Magdalen Islands)	03/1995 & 1996	11	10.4 (6-16)	1,830±1,050 (799-3,850)	1,320±642 (660-2,450)	708±291 (435-1,350)	82.2±60.3 (22.5-236)	97.8±26.7 (54.3-149)	12.7±8.99 (4.40-29.9)
	St Lawrence Estuary (Escoumins)	12/1988 - 02/1989	13	10±2.7 (7-16)	2,490±2,350[g]	2,130±2,620[h]	1,590±930[i]	see ΣCHLOR	see ΣCHLOR	-
	St Lawrence Estuary (Escoumins)	04/1989	1	16	20,001	1,290[h]	1,160[i]	see ΣCHLOR	see ΣCHLOR	-
	Gulf of St Lawrence (Harrington Harbour)	12/1989	2	10±2 (8-12)	1,770±212[g]	878±197[h]	1,290±685[i]	see ΣCHLOR	see ΣCHLOR	-
	Arctic									
Harbour seals	West Iceland	1990	1	8	1,840[j]	2,950[h]	1,370[k]	5	7[m]	-

Species	Location	Date(mo/yr)	n	Age (yrs)	ΣPCB[a]	ΣDDT[b]	ΣCHLOR[c]	HCB	ΣHCH[d]	Mirex
Grey seals	West Iceland	1990	1	26	3,470[j]	3,030[h]	1,480[k]	10	5[m]	-
Harp seals	Hudson Strait (Salluit)	10/1989	1	15	1,930[g]	2,330[h]	857[i]	see ΣCHLOR	see ΣCHLOR	-
	East Ice (White/Barents Seas)	03-04/1993	9	10 (7-18)	2,550[n] (790-5,300)	1,850[p] (630-4,280)	340?[q] (420-2,980)	80 (40-200)	80[r] (60-120)	-
	East Ice (White/Barents Seas)	04-05/1993	7	14 (9-26)	4,420[n] (750-9,810)	3,270[p] (550-7,870)	2,290[q] (350-5,250)	260 (50-640)	110[r] (70-190)	-
	West Ice (Greenland Sea)	04-05/1991	7	12 (6-18)[e]	971 ± 770[s]	1,240 ± 1,050[t]	-	145±98.9	46.4±11.6[r]	-
	Eastern Atlantic									
Harbour seals	Eastern England	08-12/1988	1	13	25,500[u]	3,640[t]	-	-	-	-
	Eastern Scotland	08-12/1988	1	10	7,620[u]	1,970[t]	-	-	-	-
	Western Scotland	08-12/1988	1	9	28,500[u]	3,040[t]	-	-	-	-
Grey seals	Swedish Baltic Sea	1988	10	adult (pooled)	103,000[u] (66,000-180,000)	36,000[t] (11,000-100,000)	-	-	-	-
	Swedish Baltic Sea	1982-88	15	? (9-22)	82,000[v]	-	-	-	-	-

Data provided as means ± standard deviation or ranges. "-" indicates that data were not available.

[a]Σof 25 congeners; [b]2,4'+4,4'-DDE+2,4'+4,4'-DDD+2,4v+4,4v-DDT; [c]α+γ-chlordane+*cis*+*trans*-nonachlor+heptachlor; [d]α-HCH+γ-HCH; [e]one seal of unknown age; [f]4 seals of unknown age; [g]Σ of 15 congeners; [h]Σ 4,4'-DDT+4,4'-DDE; [i]HCH+HCB+*trans*-nonachlor+heptachlor epoxide; [j]Σ of 5 congeners; [k]α+γ-chlordane+*cis*+*trans*-nonachlor+oxychlordane; [m]α-HCH only; [n]Σ of 21 congeners; [p]4,4'-DDE+2,4'+4,4v-DDD+2,4v+4,4v-DDT; [q]also includes oxychlordane; [r]α+β+γ-HCH; [s]Σ of 9 congeners; [t]4,4'-DDE+4,4'-DDD+4,4'-DDT; [u]Σ PCB as Aroclor 1254; [v]Σ of 7 congeners.

(Anticosti Island), the west coast of Newfoundland, Prince Edward Island, the east coast of Cape Breton Island, Nova Scotia, the Bay of Fundy, Placentia Bay (Newfoundland), east coast of Newfoundland, Labrador and western Hudson Bay. Another 31 samples were obtained from the northeast Atlantic (Skagerrak Strait, Sweden). Mitochondrial and microsatellite DNA analyses were undertaken to examine possible structure among colonies from the different areas (Picaud 2008). These analyses supported findings that there are significant differences between Northeast and Northwest Atlantic populations (Stanley *et al.* 1996), and also point to significant sub-structure with three distinct units that could be separated into Hudson Bay, Sable Island and the Gulf of St. Lawrence. Little differentiation was observed between populations of the Gulf of St. Lawrence, Newfoundland and coastal Nova Scotia, including the Bay of Fundy, indicating significant gene flow at this scale.

Analyses of patterns and overall persistent organic pollutant levels in marine mammal tissues reflect contaminant levels in areas where animals are foraging. Comparisons of contaminant burdens between areas might also provide insights into possible population structure. Polychlorinated biphenyl (PCB), and polybrominated diphenylether (PBDE) levels were examined in 8 harbour seals from the St Lawrence estuary, 10 harbour seals from the southern Gulf of St Lawrence and 10 harbour seals from the south, southeast coast of Newfoundland (Lebeuf *et al.* 2003). Ninety percent of animals could be separated correctly into three groups (Fig. 2). Three animals were not correctly assigned to their sampling area, including a seal from the estuary that was assigned to the southern Gulf, a seal from Newfoundland that was assigned to the southern Gulf and a seal from the southern Gulf that was assigned to Newfoundland.

INTERACTIONS WITH MAN

Exploitation

Harbour seals were harvested for subsistence throughout the Maritime Provinces prior to the arrival of Europeans. Skeletal or tooth remains have been identified from the Bay of Fundy dating from the Woodland period, during 3000 BC-1500 CE (Black 2003). In the north-eastern part of the Gulf of St. Lawrence, near the Strait of Belle Isle, and along the north shore of Quebec and in the St Lawrence Estuary, seals were an extremely important resource to Amerindian groups during the Archaic (8500-3500 BC) and Woodland (3000 BC-400 BC) periods, but this harvesting seems to have concentrated on harp seals, during the spring, while harbour seals were much less important and were likely hunted in late spring or early summer (Pintal 2003, Plourde and St. Pierre 2003). There is some documentation of commercial harvesting of seals in the St Lawrence beginning in the 1700s. Initially, harvesting was for both the oil and the skin. Harp seals again seem to be the most important resource, but harbour seals continued to be taken into the 1900s for both food and for commercial reasons (Castonguay 2003, Comtois 2003). Harvesting was concentrated during spring and early summer when animals were hauled-out near shore and likely when young seals were available. Harvesting of harbour seals for their pelts continued into the early 1970s. In 1927, a bounty was placed on harbour seals in eastern Canada to reduce conflicts with inshore fishermen. Initially payments were for submission of harbour seal snouts. However, it was discovered that grey seals and some other animals were sometimes submitted, so the system was changed in 1949 to payments for jaws only (McLaren 1977). Some statistics are available for early harvests. In Nova Scotia and New Brunswick, a total of 16,326 bounty kills were recorded between 1950 and 1971, approximately 73% of these were pups (Table 1). The estimates of numbers of adults killed are likely underestimated, because some animals killed were likely not recovered. Boulva (1973) estimated that on average only 65% (SD=24, CV=36.5) of adults killed are recovered (Table 2). Taking into account the number of animals struck and lost, increases the number of adults estimated to have been killed from 4,368 to 6,723 and total kills to 18,681. Animals were also killed by hunters from the province of Quebec, but species were not recorded separately so it is not possible to distinguish the number of harbour seals killed from the other seal species taken. The bounty was removed in 1976 owing to concerns about declines in harbour seal abundance.

Legislation

Marine mammal management and conservation in Canada are the responsibility of the Department of Fisheries and Oceans, which manages marine mammal activities under the Marine Mammal Regulations of the Fisheries Act. In cases of particular conservation concern, marine mammals may also be protected under the Species At Risk Act. Under the Marine Mammal Regulations, the hunting of harbour seals is prohibited along the Atlantic coast of Canada from near the northern tip of Labrador, south to the Bay of Fundy and including the Gulf of St. Lawrence and the waters surrounding Sable Island off the east coast of Nova Scotia (Fig. 1).

Interactions with fisheries

Seals interact with fisheries in a variety of ways that have both positive (feeding on predators of commercially valuable species) and negative (feeding on target species or their prey; damage to gear) impacts (Hammill and Stenson 2000, Morissette *et al.* 2006). Compared to harp, hooded and grey seals, harbour seals are thought to be only minor consumers in the Atlantic Canada ecosystem, owing to their low abundance (Hammill and Stenson 2000), but as outlined elsewhere, there is considerable uncertainty regarding harbour seal abundance in eastern Canadian waters. Harbour seals have been identified as problematic to salmon aquaculture operations in the Bay of Fundy, but this impact has not been quantified. Harbour seals have been implicated in the loss of catches and gear damage in small coastal fisheries for smelt *(Osmerus mordax)* and gaspereau *(Alosa pseudoharengus)*, but these impacts have not been separated from the impacts of grey seals (Cairns *et al.* 2000). Harbour seals are also caught in fishing gear, primarily small trap nets deployed in coastal fisheries, but incidental catch levels have not been quantified.

Limiting Factors

A significant decline in harbour seals has been observed on Sable Island. This decline has been associated with high mortality from shark predation and possibly competition with the much larger and more abundant grey seal for prey resources (Bowen *et al.* 2003). The large number of grey seals on this offshore island is likely what attracts sharks to the area, and harbour seals are likely secondary prey. Elsewhere, habitat loss is likely an important factor limiting harbour seals. Coastal development and shoreline activity has resulted in harbour seals abandoning certain beach areas (Lavigne 1978), and throughout much of their range, haulouts are limited to offshore islets, reefs and rocks and small isolated points. Harbour seals are taken incidentally in coastal fishing gear, but this is not likely to have large scale population impacts. High contaminant levels have been documented among harbour seals in the St. Lawrence Estuary (Table 4) (Bernt *et al.* 1999, Hobbs *et al.* 2002), but this is not likely to be a factor limiting the population.

REFERENCES:

Allen, J.A. 1880. *History of North American pinnipeds.* Washington, U.S. Geol. Geogr. Surv. Terr. Misc. Publ 12:xvi + 785 p.

Baechler, J., Beck, C.A. and Bowen, W.D. 2002. Dive shapes reveal temporal changes in the foraging behaviour of different age and sex classes of harbour seals *(Phoca vitulina). Can. J. Zool.* 80:1569-1577.

Bernt, K.E., Hammill, M.O., Lebeuf M. and Kovacs, K.M. 1999. Levels and patterns of PCBs and OC pesticides in harbour and grey seals from the St Lawrence Estuary, Canada. *Sci. Total Environ.* 243/244:243-262.

Black, D.W. 2003. L'importance du phoque dans l'alimentation des populations sylvicoles de la région de Quoddy (Nouveau-Brunswick). In: P. Charest, P. and Plourde, M. (eds.). *La chasse au phoque, une activité multimillénaire*. Recherches amerindiennes au Québec 33:21-34.

Boness, D.J., Bowen, W.D. and Oftedal, O.T. 1994. Evidence of a maternal foraging cycle resembling that of otariid seals in a small phocid, the harbour seal. *Behav. Ecol. Sociobiol.* 34:95-104.

Boness, D.J., Bowen, W.D., Bulheier, B.M. and Marshall, G.J. 2006. Mating tactics and mating system of an aquatic-mating pinniped: the harbour seal, *Phoca vitulina. Behav. Ecol. Sociobiol.* 61:119-130.

Boulva, J. (MS) 1973. The harbour seal, *Phoca vitulina concolor*, in eastern Canada. [PhD thesis]. Dalhousie University, Halifax, NS Canada. 151 pp.

Boulva, J. 1975. Temporal variations in birth period and characteristics of newborn harbour seals. *Rapp. P. -v. Réun. Cons. perm. int. Explor. Mer.* 169:405-408.

Boulva, J. and McLaren, I.A. 1979. Biology of the harbour seal, *Phoca vitulina*, in Eastern Canada. *Bull. Fish. Res. Bd Can.* No 200:25 pp.

Bowen, W.D. and Harrison, G.D. 1996. Comparison of harbour seal diets in two inshore habitats of Atlantic Canada. *Can. J. Zool.* 74:125-135.

Bowen, W.D., Boness, D.J. and Iverson, S.J. 1999. Dive behaviour of lactating harbour seals and their pups during maternal foraging trips. *Can. J. Zool.* 77:978-988.

Bowen, W.D., Iverson, S.J., Boness, D.J. and Oftedal, O.T. 2001a. Foraging effort, food intake and lactation performance depend on maternal mass in a small phocid. *Funct. Ecol.* 15:325-334.

Bowen, W.D., Ellis, S.L., Iverson, S.J. and Boness, D.J. 2001b. Maternal effects on offspring growth rate and weaning mass in harbour seals. *Can. J. Zool.* 79:1088-1101.

Bowen, W.D., Tully, D., Boness, D., Bulheier, B. and Marshall, G. 2002. Prey-dependent foraging tactics and prey profitability in a marine mammal. *Mar. Ecol. Prog. Ser.* 244:235-245.

Bowen, WD, Ellis, S.L., Iverson, S.J. and Boness, D.J. 2003. Maternal and newborn life-history traits during periods of contrasting population trends: implications for explaining the decline of harbour seals *(Phoca vitulina),* on Sable Island. *J. Zool.* 261:155-163.

Cairns, D.K, Keen, D.M., Daoust, P-Y, Gillis, D.J. and Hammill, M.O. 2000. *Conflicts between seals and fishing gear on Prince Edward Island.* Can. Tech. Rep. Fish. Aquat. Sci. No 2333. 39 pp.

Castonguay, D. 2003. L´exploitation du loup-marin et son incidence sur l´occupation de la côte par les Montagnais de la traite de Tadoussac, au xviiie siècle. In P. Charest and Plourde, M. (eds.). *La chasse au phoque, une activité multimillénaire*. Recherches amerindiennes au Québec 33:61-72.

Clark, C.A., Burns, J.M., Schreer, J. F. and Hammill, M.O. 2006. Erythropoietin levels in developing harbour seals *(Phoca vitulina). Gen. Comp. Endocrinol*. 147:262-267.

Clark, C.A., Burns, J.M., Schreer, J.F. and Hammill, M.O. 2007. A Longitudinal And Cross-Sectional Analysis Of Total Body Oxygen Store Development In Nursing Harbour Seals *(Phoca vitulina). J. Comp. Physiol*. *B* 177:217-227.

Coltman, D.W., Bowen, W.D., Boness, D.J. and Iverson, S.J. 1997. Balancing foraging and reproduction in male harbour seals: an aquatically mating pinniped. *Anim. Behav*. 54:663-678.

Coltman, D., Bowen, W.D., Iverson, S.J. and Boness, S.J. 1998a. The energetics of male reproduction in an aquatically mating pinniped, the harbour seal. *Physiol. Zool*. 71:387-399.

Coltman, D., Bowen, W.D. and Wright, J. 1998b. Male mating success in an aquatically mating pinniped, the harbour seal *(Phoca vitulina)*, assessed by microsatellite DNA markers. *Mol. Ecol.* 7:627-638.

Comeau, N-A. 1945. *La vie et le sport sur la côte nord du bas Saint-Laurent et du Golfe*. Éditions Garneau, Québec. 372 pp.

Comtois, R. 2003. La chasse au phoque par les Innus d´Ekuanitshit (Mingan) de 1900 à 1950. In: Charest, P. and Plourde, M. (eds.). *La chasse au phoque, une activité multimillénaire.* Recherches amerindiennes au Québec 33:73-88.

Dubé,Y. 2002. Estimation de la saison des naissances, de la croissance et de la survie des chiots du phoque commun, *Phoca vitulina concolor*, à deux sites d'échoueries situés dans l'Estuaire du Saint-Laurent, Canada . MSC Thesis Université Laval Québec, 101 Pp.

Dubé,Y., Hammill, M.O. and Barrette, C. 2003. Pup development and timing of pupping in Harbour Seals in the St. Lawrence River estuary, Canada. *Can. J. Zool*. 81:188-194.

Ellis, S.L., Bowen, W.D., Boness, D.J. and Iverson, S.J. 2000. Maternal effects on offspring mass and stage of development at birth in the harbour seal, *Phoca vitulina. J. Mammal.* 81:1143-1156.

Fisher, H.D. 1949. Harbour seals. *Fish. Res. Bd.* Can. *Atl. Biol. Stn. Annu. Rep*. 1949:104-106.

Greaves, D.K., Hughson, R.L., Topor, Z., Schreer, J.F., Burns, J.M. and Hammill, M.O. 2004. Changes in heart rate variability during diving in young harbour seals, *Phoca vitulina. Mar. Mamm. Sci.* 20:861-871.

Greaves, D.K., Schreer, J.F., Hammill, M.O. and Burns, J.M. 2005. Diving heart rate development in postnatal harbour seals, *Phoca vitulina. Physiol. Biochem. Zool*. 78(1):9-17.

Hammill, M.O. and Stenson, G.B. 2000. Estimated prey consumption by harp seals *(Phoca groenlandica)*, grey seals *(Halichoerus grypus),* Harbour seals *(Phoca vitulina)* and hooded seals *(Cystophora cristata). J. Northw. Atl. Fish. Sci.* 26:1-23.

Hobbs, K.E., Lebeuf, M. and Hammill, M.O. 2002. PCBs and OCPs in male harbour, grey, harp and hooded seals from the Estuary and Gulf of St. Lawrence, Canada. *Sci. Total Environ.* 296:1-18.

Katona, S.K., Rough, V. and Richardson, D.T. 1993. *A field guide to whales, porpoises and seals from Cape Cod to Newfoundland.* Smithsonian Institution Press, Washington. 316 pp.

Lapierre, J.L., Schreer, J.F., Burns, J.M. and Hammill, M.O. 2004. Developmental changes in cardiorespiratory patterns associated with terrestrial apnoeas in harbour seal pups. *J. Exp. Biol.* 207:3891-3898.

Lavigne, P-J. 1978. *La chasse estivale du phoque dans le Saint Laurent.* Rapport Préliminaire non-publié. 54 pp + tables.

Lebeuf, M, Hammill, M. and Sjare, B. 2003. Using POPs to distinguish harbour seal *(Phoca vitulina)* colonies of Atlantic Canada. *Organohalogen Compd.* 62:236-239.

Lesage, V, Hammill, M.O. and Kovacs, K.M. 2001. Marine mammals and the community structure of the estuary and Gulf of St Lawrence, Canada: evidence from stable isotope analysis. *Mar. Ecol. Prog. Ser.* 210:203-221.

Lesage, V., Hammill, M.O. and Kovacs, K.M. 2004. Long-distance movements of harbour seals *(Phoca vitulina)* from a seasonally ice-covered area, the St. Lawrence River estuary, Canada. *Can. J. Zool.* 82:1070-1081.

Lucas, Z. and Stobo, W.T. 2000. Shark-inflicted mortality on a population of harbour seals *(Phoca vitulina)* at Sable Island Nova Scotia. *J. Zool.* 252:405-414.

Mansfield, A.W. 1967. Seals of Arctic and eastern Canada. *Fish. Res. Board Can. Bull.* 137. 35 pp.

McLaren, I.A. 1977. The status of seals in Canada. In: Mosquin. T. and Suchal, C. (eds.); *Proceedings of the Symposium on Canada's threatened species and habitats,* May 20-24, 1976. Ottawa.

Muelbert, M.M.C. and Bowen, W.D. 1993. Duration of lactation and postweaning changes in mass and body composition of harbour seal, *Phoca vitulina,* pups. *Can. J. Zool*. 71:1405-1414.

Muelbert, M.M.C., Bowen, W.D. and Iverson, S.J. 2003. Weaning mass affects changes in body composition and food intake in harbour seal pups during the first month of independence. *Physiol. Biochem. Zool.* 76:418-427.

Morissette, L., Hammill, M.O. and Savenkoff, C. 2006. The trophic role of marine mammals in the northern Gulf of St. Lawrence. *Mar. Mamm. Sci*. 22:74-103.

Picaud, D. (MS) 2008. Population structure of the harbour seal *(Phoca vitulina concolor)* in the Northwest Atlantic based on microsatellite and mitochondrial DNA analyses. [MSc thesis]. University of Quebec at Rimouski.

Pintal, J-Y. 2003. Préhistoire de la chasse au phoque dans le détroit de Belle-Isle. In: Charest, P. and Plourde, M. (eds.); *La chasse au phoque, une activité multimillénaire.* Recherches amerindiennes au Québec 33:35-43.

Plourde, M. and Saint-Pierre, C.G. 2003. Les phocidés du secteur de l´embouchure du Saguenay : Modalités d´exploitation au Sylvicole supérieur. In: Charest, P. and Plourde, M. (eds.); *La chasse au phoque, une activité multimillénaire.* Recherches amerindiennes au Québec 33:45-60.

Rice, D.W. 1998*. Marine mammals of the world-Systematics and distribution.* Special publication No 4, The Society for Marine Mammalogy, Lawrence, KS. 231 pp.

Robillard, A., Lesage, V. and Hammill, M.O. 2005. Distribution and abundance of harbour seals *(Phoca vitulina)* and grey seals *(Halichoerus grypus)* in the estuary and Gulf of St Lawrence, 1994-2001. *Can. Tech. Rep. Fish. Aquat. Sci.* 2613:152 pp.

Sjare, B., Lebeuf, M. and Veinott, V. 2005. Harbour seals in Newfoundland and Labrador: a preliminary summary of new data on aspects of biology, ecology and contaminant profiles. *CSAS Res. Doc*. 2005/030. 38 pp.

Stanley, H.F., Casey, S., Carnahan, J.M., Goodman, S., Harwood, J. and Wayne, R.K. 1996. Worldwide patterns of mitochondrial DNA differentiation in the harbour seal. *Mol. Biol. Evol.* 13:368-382.

Stobo, W.T. and Fowler, G.M. 1994. Aerial surveys of seals in the Bay of Fundy and off southwest Nova Scotia. *Can. Tech. Rep. Fish. Aquat. Sci*. 1943:57 pp.

Temte, J.L., Bigg, M.A. and Wiig, Ø. 1991. Clines revisited: the timing of pupping in the harbour seal *(Phoca vitulina). J. Zool.* 224:617-632.

Thompson, P.M. 1993. Harbour seal movement patterns. *Symp. Zool. Soc. Lond.* 66:225-239.