Hudson Bay Ringed Seal: Ecology in a Warming Climate

M. Chambellant

Abstract Ringed seals (*Phoca hispida*) have evolved to exploit snow covered sea-ice platforms for reproduction and survival and may face critical challenges with ongoing and predicted climate change. The Hudson Bay ecosystem is already showing signs of climate warming raising concerns for the ecological, economical, and culturally-significant ringed seals of Hudson Bay. This chapter summarizes the current knowledge on ringed seals in this subarctic region, including recent findings, and presents the data in regard to current climatic changes. In Hudson Bay, sandlance (*Ammodytes* sp.) is a major component of ringed seal fall diet, whereas Arctic cod (*Boreogadus saida*) representation in the diet is trivial, contrasting results from other Arctic locations. A comparison of density and demographic parameters between the 1990s and the 2000s suggests environmental conditions in the 1990s were not favourable for ringed seals, but improved in the 2000s. A decadal cycle in ringed seal numbers and reproductive performance may relate to variations in environmental conditions, particularly changes in the sea-ice regime. However, ringed seal pups are sensitive to snow cover and ice stability for survival. Thus, a long-term decline of ringed seal fitness in response to current and projected trends in Hudson Bay environmental variables may underlie the natural cycle. Long-term demographic studies of ringed seals at the southern limit of its range are needed to comprehend ringed seal population dynamics and its interaction with environmental variables.

Keywords Ringed seal • Sea ice • Sandlance • Arctic cod • Landfast ice • Diet • Polar bear • Euphausiid • Stable isotope • Capelin • Pregnancy rate • Demography • Range limit

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Introduction

Ringed seals (*Phoca hispida;* Order Carnivora; Family Phocidae; Picture 1) are among the smallest and more numerous seal species, and have a northern circumpolar distribution (Mansfield 1967; Frost and Lowry 1981). Sexually mature animals use primarily stable land-fast ice with sufficient snow cover to build sub-nivean birth lairs that are critical for pup survival (McLaren 1958; Smith and Stirling 1975; Hammill and Smith 1991). As a species adapted to exploit sea-ice habitat for reproduction and survival (Picture 2), the ringed seal may face critical challenges with predicted climate warming (IPCC [Intergovernmental Panel on Climate Change] 2007). Archaeological and historical studies have reported a decrease in ringed seals during warming/light-ice events (Woollett et al. 2000; see Laidre et al. 2008). More recently, the sensitivity of ringed seals to variations in their sea-ice habitat has also been reported. Early or late ice break-up, heavy/light ice conditions (Smith 1987; Kingsley and Byers 1998; Harwood et al. 2000) and unusual warm and/or rain events in the spring (Stirling and Smith 2004) can negatively affect

Picture 1 Ringed seal (**a**) on the ice (credit: John Moran) and (**b**) underwater (Credit: Jeremy Stewart-DFO)

Picture 2 Ringed seal winter habitat and breathing holes (*arrows*; Credit: Magaly Chambellant)

ringed seal reproduction and survival in the Arctic. In addition to the regular predation pressure by polar bears (*Ursus maritimus*) and Inuit, ringed seals in a warmer Arctic will likely suffer from habitat loss and shifts in prey availability and distribution. Expected shifts in species distribution could also bring new pressures on ringed seals such as predation by killer whales (*Orcinus orca*; Higdon and Ferguson 2009) or competition with invasive temperate seals such as harbour seals (*Phoca vitulina*; Stirling 2005). Effects of such changes on population health require long-term studies to assess and differentiate climate-induced changes from contemporaneous natural variations (Tynan and DeMaster 1997; Laidre et al. 2008).

In the Hudson Bay ecosystem, ringed seals are at the southern limit of the species' range (Frost and Lowry 1981), but, despite this fact, have seldom been studied in this region. In this chapter, I summarize current knowledge and recent findings on ringed seal population ecology in Hudson Bay and discuss their implications in the context of global warming.

Distribution and Density

Until recently, published information on density and distribution of ringed seals in Hudson Bay has been limited to estimates obtained by aerial surveys conducted in 1974 over the coastal areas of James Bay and southern and western sides of Hudson Bay (Smith 1975); 1978 over the coastal areas of southeastern Hudson Bay (Breton-Provencher 1979); and 1994–1995 over western Hudson Bay (Lunn et al.

1997). In 2007 and 2008, Fisheries and Oceans Canada (DFO) conducted aerial surveys over western Hudson Bay. The resulting data in combination with that collected by Environment Canada (EC) over the period 1995–2000, provide the first time-series for ringed seal density in Hudson Bay.

Both the DFO and EC studies were designed as systematic, strip-transect surveys following Lunn et al. (1997). Ten east-west transects (transects 7–16 of Lunn et al. 1997) were flown at intervals of 15’ of north latitude between Churchill, MB (58°47' N; 94°10' W) in the south and Arviat, NU (61°6' N; 94°4' W) in the north, the west coast of Hudson Bay in the west, and 89°W longitude in the east (Fig. 1). Surveys were flown in late spring (26 May–6 June) during the annual moult when ringed seals haul out on the ice to bask in the sun (McLaren 1958; Smith 1973; Picture 3).

In western Hudson Bay, ringed seals favoured the land-fast ice as a prime habitat to haul-out in late spring (density: 1.3–3.4 seals/km^2). When hauled out on pack ice, ringed seals were found in lower densities (0.2–1.8 seals/km^2) and preferred regions of high ice coverage with small cracks. The inclination of ringed seals to use stable and high-ice covered, cracking platforms has already been observed in Hudson Bay (Smith 1975; Lunn et al. 1997) and across the Arctic (Stirling et al. 1977; Kingsley et al. 1985; Kingsley and Stirling 1991).

Ringed seal density estimates varied considerably from year-to-year (0.5–1.6 seals/km^2; Fig. 2) but were in the range of previous estimates (Smith 1975;

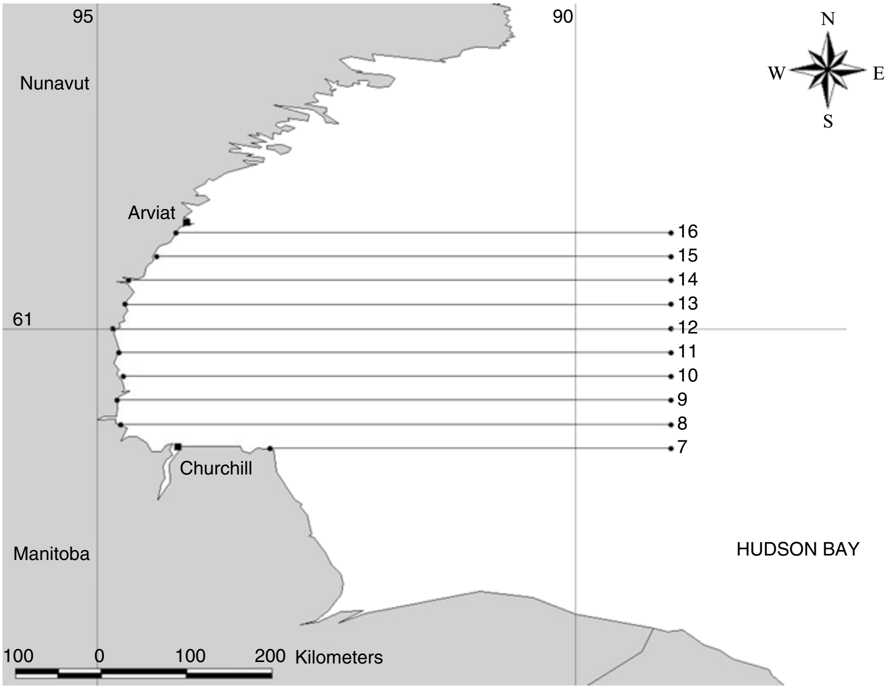


Fig. 1 Study area and transects flown during aerial surveys in western Hudson Bay, 1995–2008. Transect numbers (7–16) refer to Lunn et al. (1997)

Picture 3 Ringed seals hauled-out on the ice (**a**) along a crack and (**b**) around a hole during the spring moult (Credit: Blair Dunn-DFO)

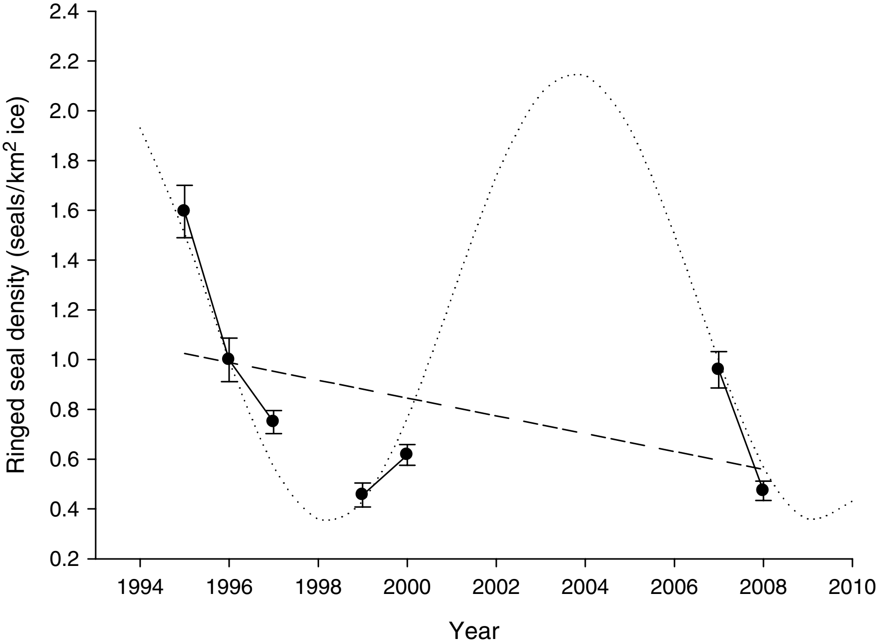


Fig. 2 Ringed seal density in western Hudson Bay estimated by aerial strip survey over the period 1995–2008. Seal density estimates ± standard error. A linear regression (*dashed line*) and a sine function (*dotted line*) were fitted to the data as $y = -0.036x + 72.41$ and $y = 0.9 * \sin((2\pi/11) * (x - 1990)) + 1.25$, respectively

Breton-Provencher 1979; Lunn et al. 1997). The overall apparent declining trend was not statistically significant (Fig. 2). However, the decline in estimated density observed from 1995 to 1999 was supported by observations of low pregnancy rates and low percentages of pups in the harvest in the 1990s from the same area (Holst et al. 1999; Stirling 2005). Ferguson et al. (2005) confirmed low pup survival in the 1990s compared to the 1980s, and suggested the existence of a decadal pattern in ringed seal recruitment that reflected environmental cycles. In this study, an 11 year period sine function was a better fit to the density estimates than the linear regression (Residual Sum of Squares $(\mathrm{RSS})_{\mathrm{sine}} = 0.08$ versus $\mathrm{RSS}_{\mathrm{linear}} = 0.75$), suggesting that the number of ringed seals in western Hudson Bay may have followed a decadal cycle that could mirrored environmental changes, rather than a linear trend (Fig. 2). The age structure of ringed seals collected in the 2000s (Fig. 3), showing a high proportion of pups and juveniles, is typical of a growing population and would support the increasing number of ringed seals in the early 2000s suggested by the cycle. However, our ability to detect a trend in ringed seal density estimates is limited by the absence of survey data over a 6-year period (2001–2006) and strong interannual variations. Long time series are required to confirm, or not, the decadal cycle and/or the declining trend hypotheses.

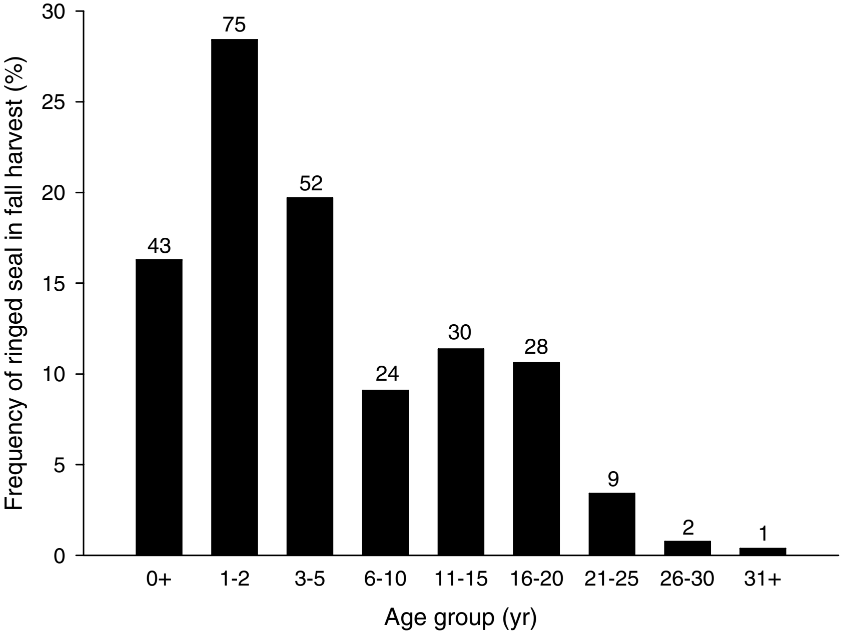


Fig. 3 Age distribution of ringed seals collected in western Hudson Bay from 2003 to 2006. Sample size for each age-class is presented on top of the bars

Growth, Body Condition, and Sexual Maturity

As part of a community-based monitoring program established by DFO Winnipeg, in several Hudson Bay communities, ringed seal samples and measurements were collected by Inuit hunters during their fall subsistence harvest in Arviat, Nunavut, from 2003 to 2006. Ringed seals were aged by reading growth layer groups in the cementum of decalcified, stained, thin canine tooth sections (Stirling et al. 1977). Ovaries and testes were frozen upon collection and later thawed to be weighed to the nearest 0.1 g.

Of the 262 seals examined over the 4-year study, 49.6% were females and 50.4% were males. The sex ratio was not different from unity as reported previously in Hudson Bay (Breton-Provencher 1979; Holst et al. 1999) and elsewhere in the Arctic (Smith 1973; Lydersen and Gjertz 1987; Smith 1987). Mean age of females was higher than that of males (Table 1), a result different from Holst et al. (1999). Maximum ages for females and males were 35 and 27 years, respectively. The relatively low mean population age could be explained by the fact that adults (≥6 years old) represented only 36% of the collection (48% juveniles and 16% pups; Fig. 3). This is a typical age class distribution for ringed seals during the open-water/fall period, when the mating season is over and juveniles are not excluded by adults (McLaren 1958; Smith 1987; Holst et al. 1999). The mean age of ringed seal females collected in the 2000s was not different from females collected in the early 1990s at the same location (Holst et al. 1999), but males were significantly younger in the 2000s ($t_{176} = 3.27$, $P = 0.0013$).

Growth in length (Fig. 4) and mass (Fig. 5) of male and female ringed seals were estimated by Gompertz growth curves with three parameters. There was no sexual dimorphism in length, mass or body condition (fat depth) in western Hudson Bay ringed seals (Table 1). But, since the females were significantly older, the males may be slightly larger at a given age (Breton-Provencher 1979; McLaren 1993). Compared with other locations in the Arctic, ringed seals in Hudson Bay were

Table 1 Age of ringed seals, and standard length, mass and fat depth of adult (≥6 years) male and female ringed seals collected in western Hudson Bay from 2003 to 2006. Mean ± SD (n) [range]

	Male	Female	*P*
Age (year)	5.4 ± 6.5 (128) [0 – 27]	7.6 ± 7.9 (127) [0 – 35]	0.027[a]
Standard length (cm)	120.2 ± 12.5 (40) [86 – 144.8]	120.4 ± 13 (49) [86.4 – 147.3]	0.94[b]
Mass (kg)	46.7 ± 17.5 (15) [22 – 75]	48.8 ± 12.6 (24) [21 – 72]	0.67[b]
Fat depth (cm)	5.6 ± 1.2 (38) [2.5 – 9.3]	5.4 ± 1.5 (50) [2 – 8]	0.57[b]

[a] *P* value from Mann–Whitney test.

[b] *P* value from 2-tail t-test.

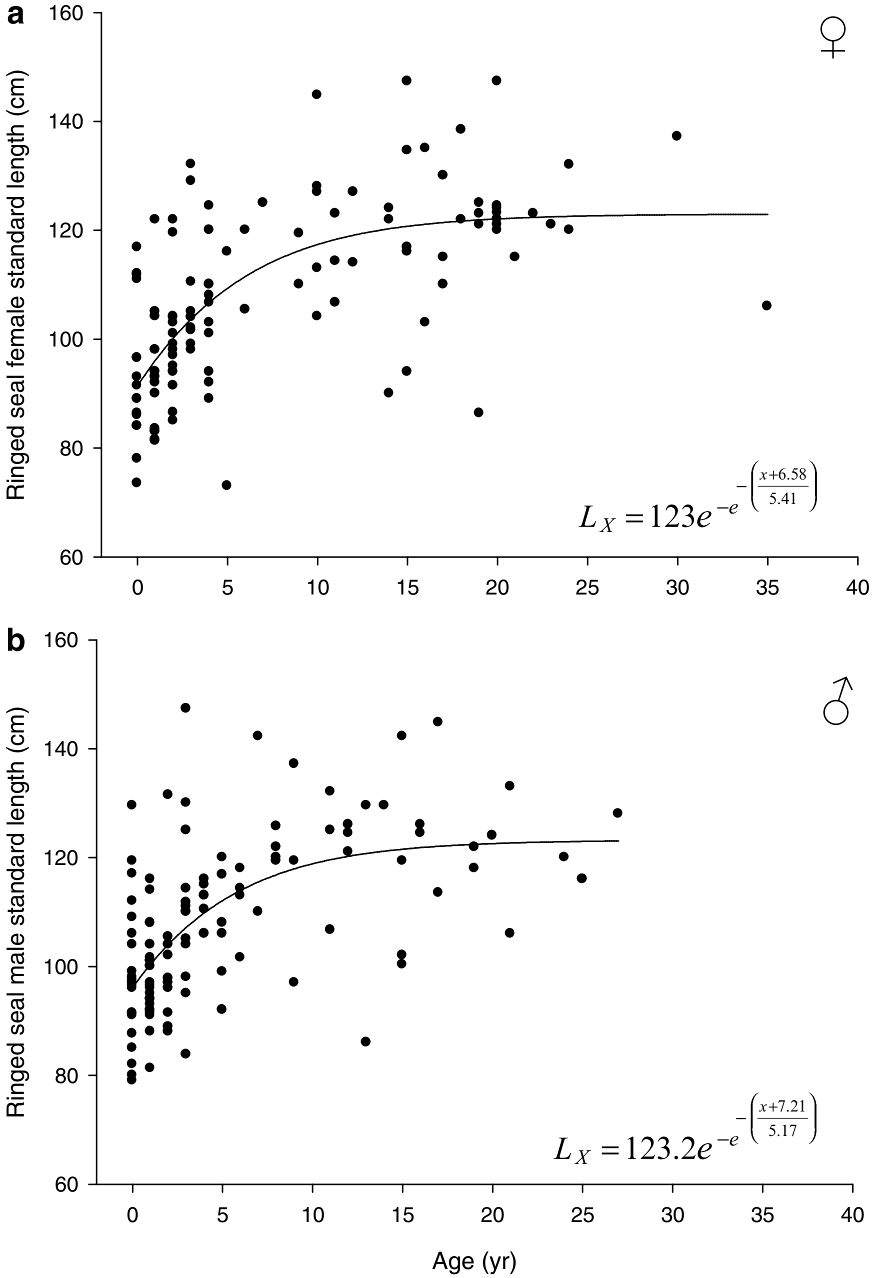


Fig. 4 Growth in length of (**a**) female ($r^2 = 0.46$) and (**b**) male ($r^2 = 0.39$) ringed seals collected in western Hudson Bay from 2003 to 2006

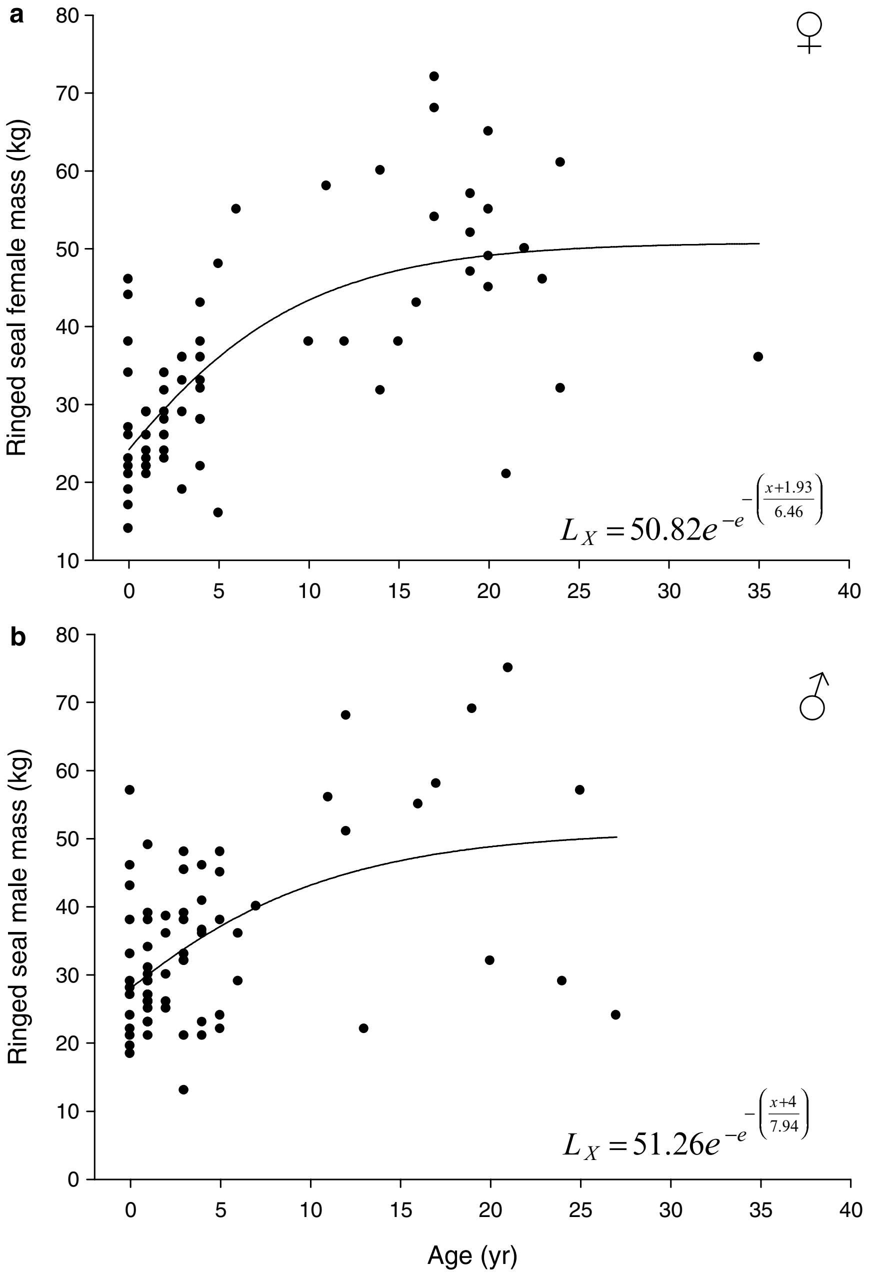


Fig. 5 Growth in mass of (**a**) female ($r^2 = 0.49$) and (**b**) male ($r^2 = 0.26$) ringed seals collected in western Hudson Bay from 2003 to 2006

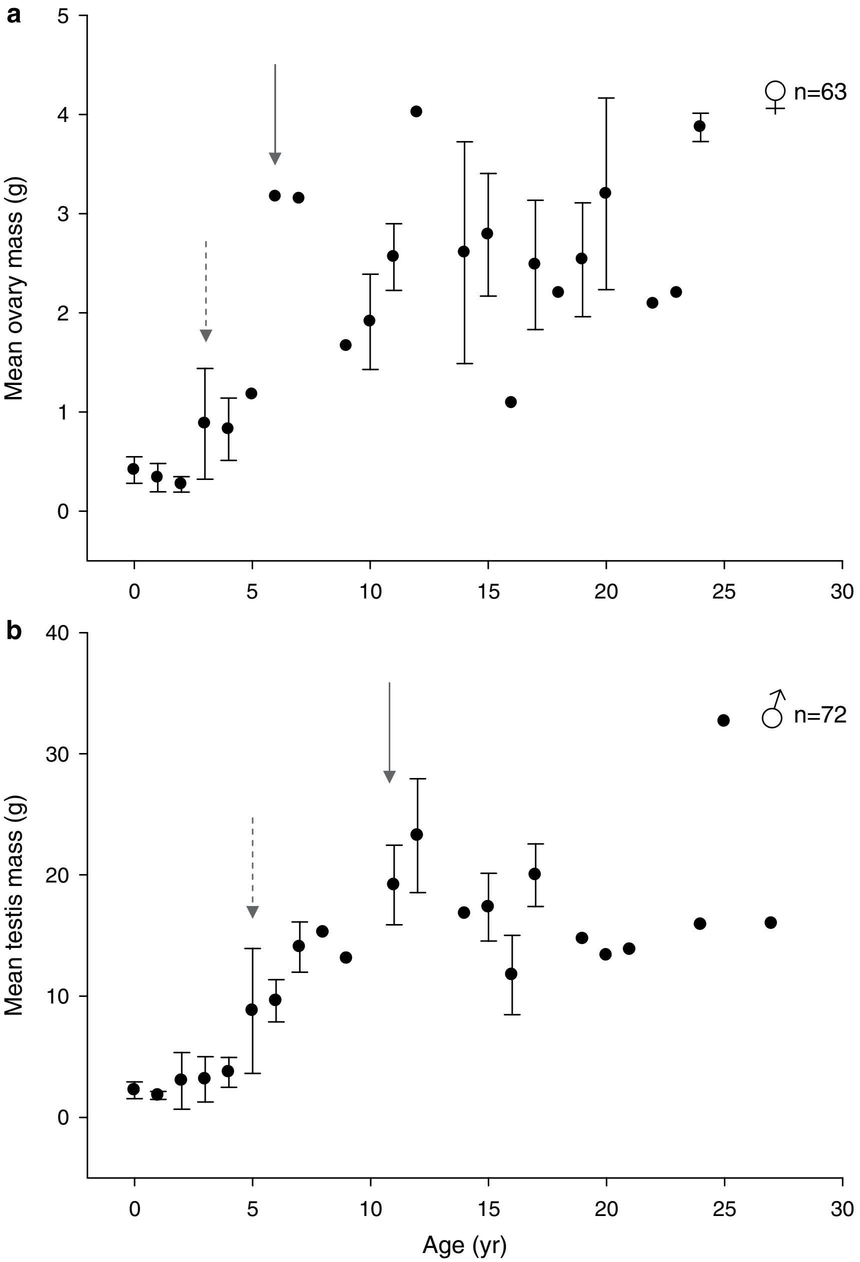


Fig. 6 Change over time in mass of (**a**) ovaries and (**b**) testes of ringed seals collected in western Hudson Bay from 2003 to 2006. Mean ± SD. The dashed-line arrow indicates physiological sexual maturity and the solid-line arrow indicates the behavioural sexual maturity

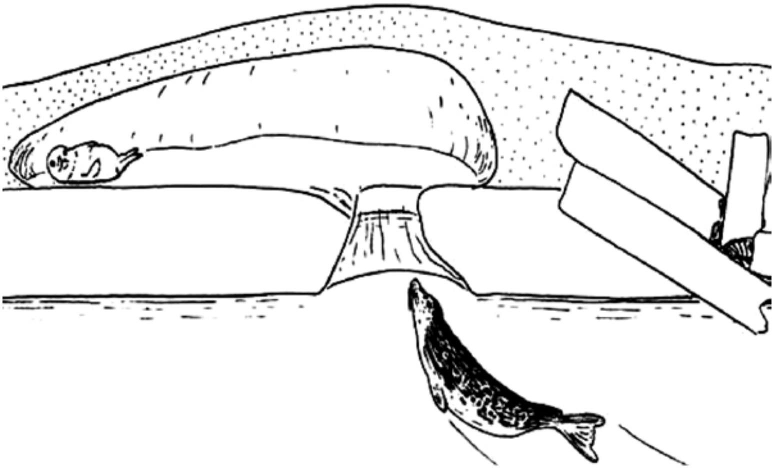
smaller both in length and mass supporting the hypothesis of latitudinal size differences (McLaren 1993; Holst and Stirling 2002; Krafft et al. 2006).

Body condition, measured by fat depth (cm), of ringed seals collected from 2003 to 2006 (5.5 ± 1.4 cm, $n = 88$) was similar to that reported in the 1990s from the same location (Stirling 2005).

In Hudson Bay, ovary mass increased dramatically around the age of 6 years but, increases could be detected as early as 3 years of age (Fig. 6a). Male ringed seals seemed to reach sexual maturity around 5 years of age, but testes mass continued to increase until 10–11 years of age (Fig. 6b). Both sexes appear to mature physically before they reach behavioural sexual maturity. The ages at maturity are in accordance with those of other ringed seals in Hudson Bay (Breton-Provencher 1979; Holst et al. 1999) and in the rest of the Arctic (Kingsley and Byers 1998; Holst and Stirling 2002; Krafft et al. 2006), albeit at the lower end of the spectrum.

Reproduction and Survival

The reproductive cycle of ringed seals in Hudson Bay has yet to be described but is likely similar to other Arctic locations. Pups are born on land-fast or stable pack ice in sub-nivean lairs that require a snow depth on the ground of 20 cm or more (Smith and Stirling 1975; Furgal et al. 1996; Ferguson et al. 2005) to provide sufficient protection against Arctic weather and predators (Smith and Stirling 1975; Hammill and Smith 1991; Smith et al. 1991; Picture 4). Nominal birth date for pups is set on the 1st of April but the pupping period could be spread over several weeks (McLaren 1958; Smith 1973, 1987). In Hudson Bay,



Picture 4 Ringed seal female and pup in birth lair (from Mansfield 1967)

traditional knowledge and recent data converge to an earlier pupping period, starting in February and peaking around mid-March (McDonald et al. 1997; Cleator 2001; M. Chambellant 2009). This supports the hypothesis of a latitudinal gradient of pupping suggested by McLaren (1958) and Smith (1987). Pups are weaned before break-up, after nursing for 5–7 weeks (Hammill et al. 1991; Lydersen and Hammill 1993).

Mating is thought to take place underwater around the time of weaning (Smith 1987). Breton-Provencher (1979) reported a peak of male sexual activity from February to April. Ringed seal gestation lasts around 10.5 months, with a period of suspended development during the first 2–3 months (McLaren 1958; Smith 1973, 1987; M. Chambellant 2009). In late spring, ringed seals undertake their annual moult and require an ice platform to haul-out (McLaren 1958).

Body condition of ringed seals is poorest in early summer after fasting during the breeding and moulting periods (McLaren 1958; Breton-Provencher 1979; Ryg et al. 1990). During the open water period all age-classes are mixed and feed intensively (McLaren 1958; Smith 1987).

When the ice starts to form in late fall, adults gather close to shore to establish territories (McLaren 1958; Smith 1987). During this period, juveniles are actively excluded from these habitats (McLaren 1958; Smith 1987; Holst et al. 1999; Krafft et al. 2007). Adult ringed seals show signs of site fidelity during the winter months (McLaren 1958; Smith and Hammill 1981; Boveng et al. 2009; S.P. Luque 2009), and may have a weakly polygynous, resource-defence mating system (Smith and Hammill 1981; Krafft et al. 2007; D. Yurkowski 2009).

Ovulation and pregnancy rates of adult females in western Hudson Bay in 2003, 2005 and 2006 were 100% (n = 36). This result contrasts with values obtained in the 1990s of 92% and 55% (n = 100) for ovulation and pregnancy rates, respectively (Holst et al. 1999; Stirling 2005). The low pregnancy rate in the 1990s could be an artefact of the 1992 collection, when no pregnant females were found (Holst et al. 1999; Stirling 2005). The percentage of pups in the harvest was low in the 1990s (9.6%) compared to the 2000s (16.3%; Fig. 3). More juveniles, especially 1 and 2 year olds, were also collected in the 2000s than in the early 1990s (Holst et al. 1999).

These results could suggest that environmental conditions in the 1990s were not favourable resulting in low pup production, low young survival and/or emigration of young animals toward more suitable regions. In the 2000s, this trend seemed to have reversed with better pup production and survival, and/or immigration of young animals from other areas. Ferguson et al. (2005) confirmed that recruitment was generally low in the 1990s compared to the 1980s, and hypothesized a decadal cycle in recruitment, consistent with data from the 2000s presented here. Change in marine productivity, prey distribution and/or availability resulting from a longer open water season, the detrimental effect on unweaned or freshly weaned pups of the loss of the ice platform earlier in the season, and the lack of sufficient snow depth to build strong and protective lairs, have been suggested as factors involved in the low pup production and/or survival in western Hudson Bay in the 1990s (Ferguson et al. 2005; Stirling 2005).

Feeding Habits

Information on ringed seal feeding habits in Hudson Bay is scarce. As in other regions of the Arctic, ringed seals in Hudson Bay are thought to feed year-round, but with intensive feeding in late summer and fall, as shown by the increase in fat depth measurements in the fall (McLaren 1958; Breton-Provencher 1979; Ryg et al. 1990). During the open water period, ringed seals of all age classes mix together and form large feeding aggregations (McLaren 1958; Smith 1987; Harwood and Stirling 1992). Diet composition varies greatly with geographical location, season and life-stage, but Arctic cod *(Boreogadus saida*) and invertebrates such as mysids (Mysida), amphipods (Amphipoda) and euphasiids (Euphausiacea) are common prey (McLaren 1958; Breton-Provencher 1979; Lowry et al. 1980; Bradstreet and Finley 1983; Gjertz and Lydersen 1986; Smith 1987; Weslawski et al. 1994; Siegstad et al. 1998; Wathne et al. 2000; Holst et al. 2001; Labansen et al. 2007).

In southeastern Hudson Bay, the hyperiid amphipod *Parathemisto libellula*. euphasiids and the pelagic fish sandlance (*Ammodytes* sp.) were major prey of ringed seals, but Arctic cod were absent from the 218 stomach contents analyzed (Breton-Provencher 1979; Picture 5). In western Hudson Bay, 93% of the otoliths found in the stomach contents of ringed seals collected from 1998 to 2000 were from sandlance and 6% from Arctic cod (Stirling 2005).

Stomach content analyses provide qualitative and quantitative information on diet although differences in the digestion rates of large and small, hard and soft prey can bias diet estimation (Iverson et al. 2004). Stomach contents also represent only prey ingested shortly before death. Consequently, indirect methods, like stable isotope (SI) analysis, have been developed to determine diets.

Stable isotope analysis is based on the natural occurrence of different isotopes of the same element and their differential fractionation during biological processes (Kendall et al. 1995; Kendall and Caldwell 1998). The differential fractionation of carbon (C) SI (^{13}C and ^{12}C) during photosynthesis confers phytoplankton with a unique carbon-isotopic signature that is passed on almost directly to consumers. In diet studies of marine mammals, carbon SI ratio (^{13}C/^{12}C) gives indication of foraging behaviour (e.g., benthic versus pelagic) and locations (if feeding occurs in isotopically different water masses; Hirons et al. 2001; Lesage et al. 2001; Kurle and Worthy 2002). The differential fractionation of the nitrogen (N) isotopes, ^{15}N and ^{14}N, occurs in consumers that preferentially integrate the heavier isotope to their tissues, resulting in an enrichment of 2–5‰ from diet to consumer through the food chain (Hobson and Welch 1992; Hobson et al. 1996; Lesage et al. 2002). In diet studies of marine ecosystems, nitrogen SI ratio (^{15}N/^{14}N) provides information on the relative place a given organism occupies in the food chain (Hobson and Welch 1992). Due to the specific metabolic rate of each tissue, looking at SI ratios in different tissues of the same animal provides dietary information of food assimilated over a range of time scales (Kurle and Worthy 2002; Lesage et al. 2002). Typically, tissues with a high metabolic rate represent a time scale of days or weeks (liver, kidney, serum), whereas tissues with a low metabolic rate represent food ingested months before (muscle, red blood cells).

Picture 5 Ringed seal stomach contents showing (**a**) Sand Lance (*Ammodytes* sp.), (**b**) hyperiid amphipod (*Parathemisto libellula*) and (**c**) euphausiids (*Tysanoessa* sp.) (Credit: DFO)

In southeastern Hudson Bay, stomach contents of ringed seals collected during the Inuit fall and early winter (October–January) subsistence harvest from 2003 to 2005, confirmed the importance of amphipods and sandlance in the diet of ringed seals around the Belcher Islands (Fig. 7). However, capelin (*Mallotus villosus*) and mysids represented important prey as well, and Arctic cod were present in more than 20% of the stomachs, which contrasts with results from the late 1970s (Breton-Provencher 1979). Most (95%) of the energy acquired came from fish, including 54% from capelin (M. Chambellant 2009).

Results from stomach contents of ringed seals collected during the Inuit fall (October) subsistence harvest in western Hudson Bay from 2003 to 2005 confirmed that sandlance is the main food resource of ringed seals there at that time of the year (Fig. 8). The relative contribution of invertebrates was small and that of Arctic cod insignificant (Fig. 8). In a traditional knowledge study conducted in western Hudson Bay, nine of ten Inuk hunters reported finding amphipods in ringed seal stomachs (Cleator 2001). Capelin was mentioned by six hunters and sandlance and

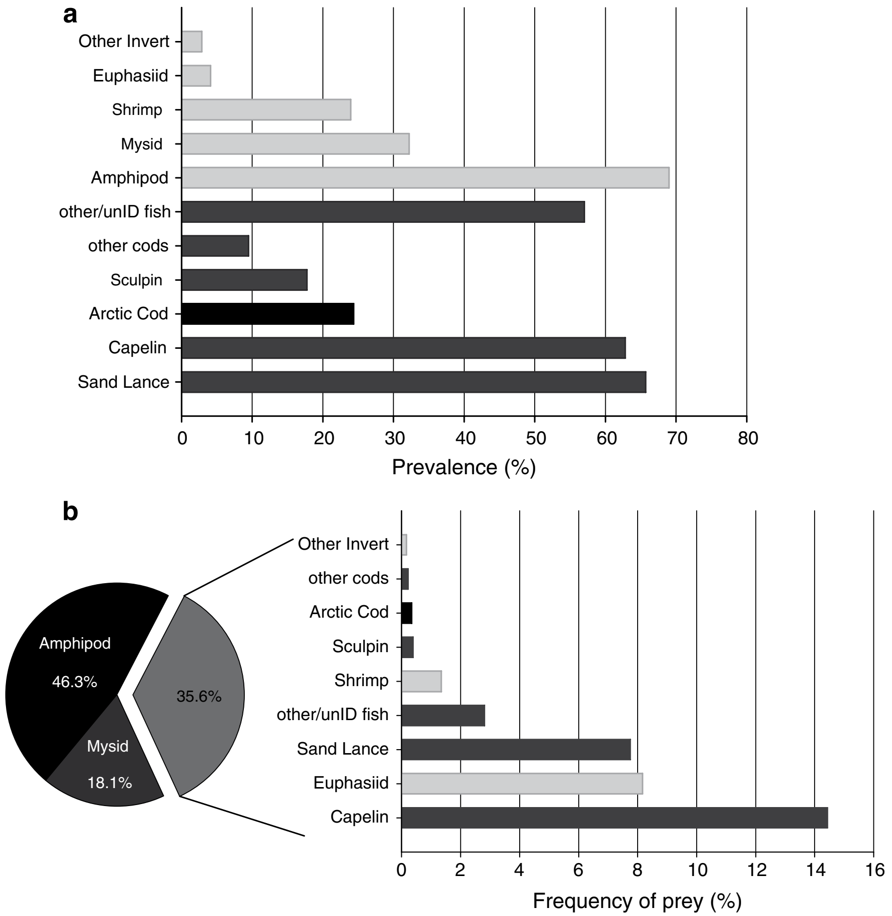


Fig. 7 Diet of ringed seals expressed as (**a**) prevalence and (**b**) frequency of prey found in stomachs collected in southeastern Hudson Bay from 2003 to 2005. Prevalence was defined as the number of stomachs containing a given prey item divided by the total number of stomach examined

Arctic cod by five. Other prey mentioned were Greenland cod (*Gadus ogac*), sculpin (Scorpaenifromes) and Arctic char (*Salvelinus alpinus*). Mysids, euphausiids, shrimps (Decapoda) and snailfish (*Liparis* sp.) were not identified by the hunters as prey of ringed seals. Contribution of invertebrates to the energy acquisition by ringed seals represented only 0.04% while sandlance contributed 65% (M. Chambellant 2009).

The mean carbon and nitrogen SI ratios observed in muscle and liver collected in western Hudson Bay in 2004 and 2006 provided some insights into ringed seal diet over a longer time frame (Fig. 9). The carbon SI signature of ringed seal tissues could indicate that they fed on a mixed diet of pelagic and benthic/epi-benthic organisms. The nitrogen SI signature indicated that cods in general, and Arctic cod

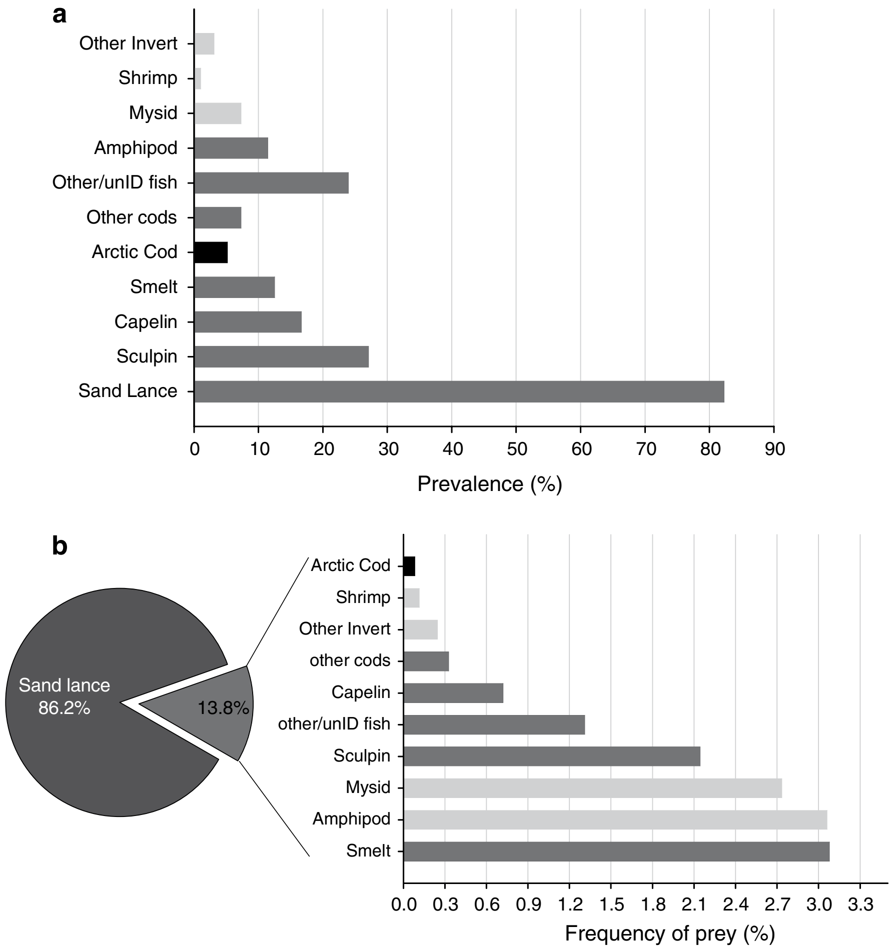


Fig. 8 Diet of ringed seals expressed as (**a**) prevalence and (**b**) frequency of prey found in stomachs collected in western Hudson Bay from 2003 to 2005. Prevalence was defined as the number of stomachs containing a given prey item divided by the total number of stomach examined

in particular, did not seem to be part of the diet. The muscle nitrogen SI signature suggested that ringed seals diet in early summer may be based on amphipods whereas in the fall (liver signature), the SI analyses supported the importance of sandlance in this region.

Previous and present results indicated that sandlance is, and has been, a major component of ringed seal fall diet in Hudson Bay at least since the 1980s (Breton-Provencher 1979; Stirling 2005; this study). Arctic cod consumption however seems to be trivial in Hudson Bay compared to other Arctic locations, where more Arctic cod than any other fish were found in ringed seals stomachs (Northern Foxe Basin and southwestern Baffin Island: McLaren 1958; western Canadian Arctic: Smith 1987;

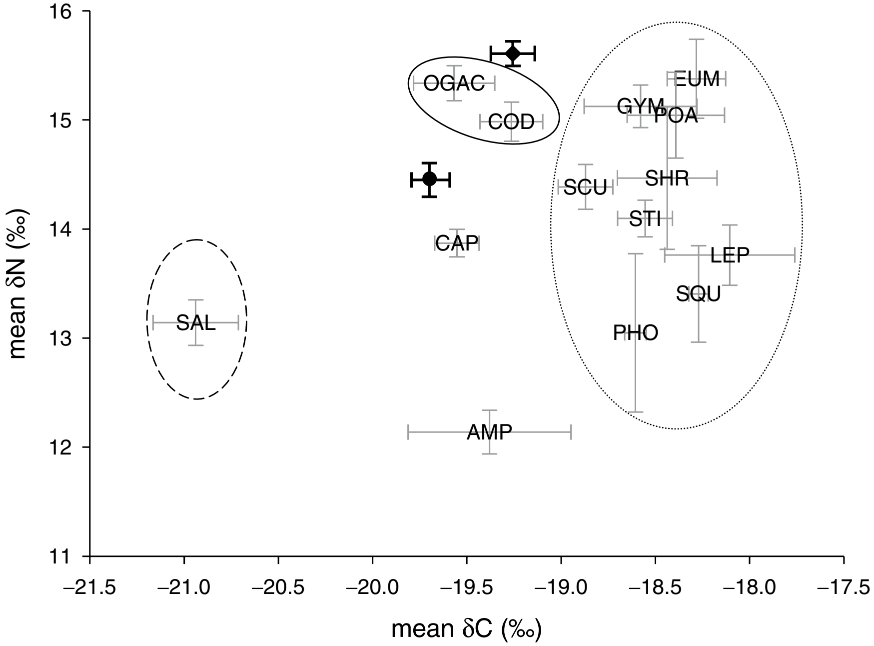


Fig. 9 Mean carbon (C) and nitrogen (N) stable isotope ratios (dC and dN) in ringed seal muscle (*dot*) and liver (*diamond*) collected in western Hudson Bay in 2004 and 2006 and potential prey species (*grey error bars*) collected in Hudson Bay in 2006 and 2007. Circles indicate groupings of animals from the same ecological background (pelagic: *dashed line*, benthic: *dotted line* and epibenthic/cods: *solid line*). SAL: sandlance (*Ammodytes sp.*); AMP: amphipods (*Parathemisto libellula*); CAP: capelin (*Mallotus villosus*); PHO: banded gunnel (*Pholis fasciata*); SQU: squids; LEP: daubbed shanny (*Leptoclinus maculatus*); STI: Arctic shanny (*Stichaeus punctatus*); SHR: shrimps; SCU: sculpins (*Triglops sp.*); POA: Atlantic poacher (*Leptagonus decagonus*); EUM: fourline snakeblenny (*Eumesogrammus praecisus*); GYM: fish doctor (eelpout; *Gymnelus viridis*); COD: Arctic cod (*Boreogadus saida*); OGAC: Greenland cod (*Gadus ogac*)

high Canadian Arctic: Bradstreet and Finley 1983; Barents Sea: Wathne et al. 2000; Greenland: Siegstad et al. 1998). Stomach content analysis from ringed seal inhabiting Ungava Bay and the northern coast of Labrador revealed that sandlance was the most abundant fish preyed upon, and that Arctic cod number in stomachs was anecdotal (McLaren 1958). These dietary differences support the existence of a latitudinal gradient in ringed seal feeding habits, based on preference and/or availability of fish, as has been suggested by McLaren (1958) and Siegstad et al. (1998).

Conclusion

Changes in the Hudson Bay ecosystem have been occurring over the last 3 decades. Surface air temperatures in spring (Skinner et al. 1998) and the length of the ice-free period (Gagnon and Gough 2005b) have increased significantly, whereas sea-ice extent (Parkinson and Cavalieri 2008) and snow depth (Ferguson et al. 2005) have decreased. Sea ice break-up in western Hudson Bay is now occurring ~3 weeks earlier than in the 1970s (Gagnon and Gough 2005b; Stirling and Parkinson 2006) and climate change scenarios for the Hudson Bay region predict that trends observed in recent years will continue (Gough and Wolfe 2001; Gagnon and Gough 2005a).

The consequences of a shorter period of ice cover on marine, ice-associated species have been observed in Hudson Bay. At the end of the 1990s, the reduction in the mid-July sea-ice cover in northern Hudson Bay was correlated with a regime transition, wherein the prey thick-billed murres (*Uria lomvia*) brought back to their chicks shifted away from species typical of Arctic waters (e.g., Arctic cod) and toward those typical of subarctic waters (e.g., capelin; Gaston et al. 2003). As well, the body condition, reproduction rate, cub survival and abundance of polar bears in western Hudson Bay have declined over the last 25 years, and this trend has been correlated to earlier break-up of sea ice (Stirling et al. 1999; Regehr et al. 2007). Ringed seals in Hudson Bay have received less research and only recently have been the focus of dedicated studies, and concerns in the context of the ongoing climate warming have been raised (Ferguson et al. 2005; Stirling 2005).

In this chapter, I reviewed our current knowledge of ringed seals in Hudson Bay. A decline in ringed seal density estimates in western Hudson Bay occurred from 1995 to 1999 but was not statistically significant when the 2000s survey results were included. As Ferguson et al. (2005) suggested for recruitment, a decadal cycle in ringed seal abundance has been hypothesized, with low number of seals in western Hudson Bay in the late 1990s and a peak in the mid-2000s. This result suggested environmental conditions were not favourable for ringed seals in the 1990s but changed positively in the 2000s. The positive change in pregnancy rates and pup recruitment that occurred at the beginning of the 2000s supported this hypothesis.

In the Arctic environment, decadal fluctuations, particularly in the ice regime through atmospheric forcing (e.g., North Atlantic Oscillation) have been observed (Mysak and Manak 1989; Hurrell 1995; Mysak et al. 1996). Variations in life-history parameters of several Arctic species have been linked to climatic variations (Skinner et al. 1998; Ottersen et al. 2001; Post and Forchhammer 2002; Stirling 2002; Derocher 2005; Ferguson et al. 2005; Regehr et al. 2007). In western Hudson Bay, snow depth has been identified as a key factor in ringed seal recruitment but so far, correlations with environmental variables remained unclear and/or statistically not significant (Ferguson et al. 2005; M. Chambellant 2009). However, exceptionally cold and heavy ice conditions were recorded over the eastern Arctic at the beginning of the 1990s (McCormick et al. 1995; Mysak et al. 1996; Gough et al. 2004) and could have triggered the decline in number and demographic parameters of ringed seals in Hudson Bay, as occurred in the western Arctic in the 1970s and 1980s (Smith 1987; Kingsley and Byers 1998; Stirling 2002).

Ringed seals are sensitive to specific environmental factors, like snow depth and ice stability, for reproduction and survival. Thus, if current environmental trends continue in Hudson Bay, as projected, a long term decline of ringed seals might be underlying the natural decadal cycle. In fact, while the percentage of pups in the harvest in western Hudson Bay has almost doubled in the 2000s relative to the 1990s, the absolute number (16%) is still low when compared to other Arctic locations with similar ovulation/pregnancy rates (Smith 1973; Breton-Provencher 1979; Smith 1987). Supporting a possible decline in ringed seal numbers in western Hudson Bay is the declines in population parameters of polar bears over the past 25 years (Stirling et al. 1999; Regehr et al. 2007). Indeed, polar bear diet relies heavily on ringed seals, and especially on ringed seal pups, for reproductive success and survival and a positive linear relationship was found between ringed seal and polar bear population estimates (Stirling and Oritsland 1995).

The impacts of rapid and unidirectional climatic changes on ringed seals are not yet explicit. In order to better comprehend ringed seal population dynamic and its interaction with environmental variables, and be able to assess and predict effects of current environmental trends, long time-series of density, demographic and dietary data are needed. Intense research efforts are particularly critical in Hudson Bay, a subarctic region where climate change is expected to occur first and faster (Walsh 2008) and, where ringed seals occur at the southern limit of their range.

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