COSEWIC
Assessment and Status Report

on the

Ringed Seal
Pusa hispida

in Canada

SPECIAL CONCERN
2019

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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Ringed Seal on spring ice near Churchill, Manitoba – Photo by S.D. Petersen.

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COSEWIC
Assessment Summary

Assessment Summary – November 2019

Common name
Ringed Seal

Scientific name
Pusa hispida

Status
Special Concern

Reason for designation
This small seal needs sea ice to thrive. It is wide-ranging and is the most abundant marine mammal in the Canadian Arctic. It is an important species for Inuit and is the primary prey of Polar Bear. Its population levels and trends are uncertain, although the total population is about 2 million individuals. Aboriginal Traditional Knowledge from local communities across the species' range suggests that its population status varies regionally, but is generally considered stable. Reductions in the area and duration of sea ice due to climate warming in the Canadian Arctic, with consequent reductions in suitable pupping habitat due to loss of stable ice and a lower spring snow depth, are the primary threats to this species. The Canadian population is predicted to decline over the next three generations, and may become Threatened due to extensive and ongoing changes in sea ice and snow cover in a rapidly warming Arctic.

Occurrence
Manitoba, Ontario, Québec, Newfoundland and Labrador, Yukon, Northwest Territories, Nunavut, Pacific Ocean, Arctic Ocean, Atlantic Ocean

Status history
Designated Not at Risk in April 1989. Status re-examined and designated Special Concern in November 2019.

COSEWIC Executive Summary

Ringed Seal
Pusa hispida

Wildlife Species Description and Significance

Ringed Seal is a phocid seal with five subspecies, one of which occurs in Canada: Arctic Ringed Seal (*Pusa hispida hispida*). They are one of the smallest pinnipeds, with average adults being 1.5 m long and weighing 70 kg—males being slightly larger than females. Ringed Seal is important both economically and culturally to northern peoples and are important prey for the Polar Bear (*Ursus maritimus*).

Distribution

Ringed Seal has a circumpolar distribution over Arctic and subarctic waters, relying on sea ice as habitat. Their Canadian distribution ranges from Yukon in the west to southern Labrador in the east, with occasional sightings of vagrants south of the seasonal ice zone in both Pacific and Atlantic Oceans.

Habitat

Ringed Seal is strongly ice-adapted. Their habitat requirements follow the annual cryogenic cycle, with adults establishing territories during fall freeze-up. Prime breeding habitats occur on stable ice, which tends to be landfast ice occurring over relatively shallow waters (< 150 m). Breeding also occurs on mobile pack ice. Ringed Seal moults on sea ice in late spring and is widely distributed over waters of varying depths during the open-water season, presumably in response to prey distribution. Ringed Seal can be negatively affected by both extreme heavy-ice years (longer ice seasons) and extreme low-ice years (short spring ice seasons).

Biology

The Ringed Seal mating system is thought to be one of weak polygyny, but observations suggest that alternative strategies exist depending on region. Gestation (10–11 months) is divided into ~2–3 months of embryonic diapause and ~8 months of fetal growth. Pups are born in spring, in subnivean birth lairs, and are nursed for 5–8 weeks. Females mate near the end of lactation or directly after. Age at maturity is variable, but is 6 years on average, with males entering the breeding population later than females. Maximum life span has been recorded at 45 years, but average adult life span is likely about 20 years.

During the open-water season, they feed on a wide variety of pelagic and benthic prey to build up blubber reserves. The most common prey across their range are pelagic schooling fish such as Arctic Cod (*Boreogadus saida*), Sand Lance (*Ammodytes* spp.) and Capelin (*Mallotus villosus*), as well as amphipods, euphausiids, shrimp and other crustaceans.

Individual movements are variable across the range and are dictated by prey distribution. Movements can be extensive during the open-water season, and likely consist of both seasonal migrations and dispersal events for subadults. At freeze-up, when adults move into breeding areas and establish territories, subadults are either driven out or choose areas of mobile ice and polynyas where the costs of maintaining breathing holes are lower. Adults have been shown to exhibit breeding site fidelity.

Ringed Seal is the primary prey for the Polar Bear but is also preyed upon by Killer Whales (*Orcinus orca*), Walruses (*Odobenus rosmarus*), Greenland Sharks (*Somniosus microcephalus*), and humans. The Arctic Fox (*Vulpes lagopus*) can also be important predators on pups, particularly when snow cover is very low.

Population Sizes and Trends

Most information on Ringed Seal population size comes from aerial surveys, which are conducted when seals are hauled out on ice to moult. Because these surveys are sporadic and localized, estimates are uncertain and dated. However, species abundance is thought to be high, with an estimated 2.3 million seals (1.15 million mature individuals) in Canada and adjacent waters (West Greenland, Alaska, Russian Federation).

Threats and Limiting Factors

The Arctic has undergone substantial climatic change since the late 1970s: annual, perennial, and multi-year Arctic sea ice extent, as well as Arctic sea ice thickness and volume, have decreased while the Arctic ice-free season has lengthened. Over the 1967-2012 period, Northern Hemisphere snow cover extent also decreased in all months and especially during spring. For ice-dependent Arctic marine mammals such as Ringed Seal, these extensive unidirectional changes in sea ice and snow cover can equate to habitat loss and cascading ecological impacts. For example, a very warm year in 2010 resulted in poor Ringed Seal body condition in Hudson Bay. Seals experienced increased stress, giving birth to fewer pups in the following years. In the long term, the loss of habitat due to climate change poses the most significant threat. Decreases in sea ice extent also increase opportunities for commercial shipping, tourism and industrial development, which could increase disturbance, habitat modification and pollutants. Predation by the Polar Bear is the most significant mortality source. Hunting by humans may also be a limiting factor, but removal rates are likely an order of magnitude lower than those for Polar Bear. Pollutant levels are variable amongst regions, with some levels of increase having known effects on Polar Bear but unknown effects on seals.

Protection, Status and Ranks

There are no international agreements or conventions specifically intended to protect Ringed Seal, but the International Agreement on the Conservation of Polar Bears and their Habitat provides some measure of protection. Ringed Seal is not listed on any appendices of the Convention on International Trade in Endangered Species, and they are “Least Concern” on the International Union for the Conservation of Nature (IUCN) Red List (as both species and Arctic subspecies). They are ranked “N5B, N5N, N5M” in the latest Wild Species (General Status) Report (CESCC 2016). COSEWIC assessed the species as Special Concern in November 2019; it was previously assessed as “Not at Risk” in 1989, and they are currently not listed under the *Species at Risk Act*. The Arctic subspecies is listed as threatened under the United States *Endangered Species Act.* Ringed Seal is ranked as Least Concern in Greenland, Vulnerable in Norway (Svalbard), and is not listed in Russia.

In Canada, Ringed Seal is managed under the authority of the Marine Mammal Regulations (SOR/93-56) of the *Fisheries Act*. Seal hunting in marine waters of the Northwest Territories, Nunavut, Nunavik and Labrador are co-managed by various wildlife management boards, with scientific advice from the Department of Fisheries and Oceans. Existing national parks, national wildlife areas and other lands owned and managed by the Government of Canada afford little habitat protection. Existing and proposed marine protected areas and national marine conservation areas potentially afford some protection.

TECHNICAL SUMMARY

Pusa hispida

Ringed Seal

Phoque annelé

Netsik, netsuk

Range of occurrence in Canada: Manitoba, Ontario, Québec, New Brunswick (occasional), Nova Scotia (occasional), Prince Edward Island (occasional), Newfoundland and Labrador, Yukon, Northwest Territories, Nunavut, Pacific Ocean, Arctic Ocean, Atlantic Ocean

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines (2011) is being used)	13 years, based on age of first reproduction = 6, and assuming an average lifespan of 20 years.
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Unknown
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	Unknown
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations]. Reduction expected but uncertainty exists on quantifying the reduction.	Unknown
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Unknown
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	N/A
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	4,403,651 km² (8,146,022 km² w/ land included)
Index of area of occupancy (IAO) (Always report 2x2 grid value).	3,984,076 km² (996,019 grid cells)

Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations" (use plausible range to reflect uncertainty if appropriate)	Unknown
Is there an [observed, inferred, or projected] decline in extent of occurrence?	Yes – Projected retraction in southern range due to habitat deterioration
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	Yes – Projected retraction in southern range due to habitat deterioration
Is there an [observed, inferred, or projected] decline in number of subpopulations?	Unknown
Is there an [observed, inferred, or projected] decline in number of "locations"?	Unknown
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes – Observed decline in sea ice area, extent, quality and persistence. Projected loss of sea ice due to climate change.
Are there extreme fluctuations in number of subpopulations?	Unknown
Are there extreme fluctuations in number of "locations"?	N/A
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No – There is some annual variation in extent and distribution of sea ice that could influence distribution of breeding habitat

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals**
Total	1.15 million *(assuming 50% adults as per IUCN)* One large population - entire Canadian range and also shared with Greenland, United States (Alaska), and Russian Federation. No complete comprehensive population survey has ever been undertaken.
Total	1.15 million

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Unknown; data for quantitative analysis lacking

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? **Yes** i. High impact threat – Habitat loss caused by human-induced climate change ii. Negligible impact threats – Energy production and mining, Transportation and service corridors, Biological resource use, Natural systems modifications Limiting factors – Predation

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	USA – Threatened Greenland – Least Concern Russia – no listing
Is immigration known or possible?	Yes. Animals presently migrate between countries.
Would immigrants be adapted to survive in Canada?	Yes
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada? [1] Changes in sea ice conditions in the short term are subject to high spatiotemporal variability but long term trend is decline in sea ice conditions.	Uncertain
Are conditions for the source (i.e., outside) population deteriorating?	Uncertain
Is the Canadian population considered to be a sink[1]?	No
Is rescue from outside populations likely?	Yes

Data Sensitive Species

Is this a data sensitive species?	No

Status History

COSEWIC: Designated Not at Risk in April 1989. Status re-examined and designated Special Concern in November 2019.

[1] See Table 3 (Guidelines for modifying status assessment based on rescue effect)

Status and Reasons for Designation:

Status: Special Concern	**Alpha-numeric codes:** Not applicable
Reasons for designation: This small seal needs sea ice to thrive. It is wide-ranging and is the most abundant marine mammal in the Canadian Arctic. It is an important species for Inuit and is the primary prey of Polar Bear. Its population levels and trends are uncertain, although the total population is about 2 million individuals. Aboriginal Traditional Knowledge from local communities across the species' range suggests that its population status varies regionally, but is generally considered stable. Reductions in the area and duration of sea ice due to climate warming in the Canadian Arctic, with consequent reductions in suitable pupping habitat due to loss of stable ice and a lower spring snow depth, are the primary threats to this species. The Canadian population is predicted to decline over the next three generations, and may become Threatened due to extensive and ongoing changes in sea ice and snow cover in a rapidly warming Arctic.	

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Not applicable. Population is likely near 2.3 million individuals. A decline is projected due to loss of suitable habitat in three generations but there remains uncertainty over the actual population response which negates a quantification of that decline.
Criterion B (Small Distribution Range and Decline or Fluctuation): Not applicable. Range greatly exceeds thresholds; population is not fragmented and does not undergo extreme fluctuations. Decline is projected in quality of habitat.
Criterion C (Small and Declining Number of Mature Individuals): Not applicable. A continuing decline is projected, and the population exists as one subpopulation but likely near 1.15 million mature individuals.
Criterion D (Very Small or Restricted Population): Not applicable. Population size and range exceed thresholds.
Criterion E (Quantitative Analysis): Not applicable.

PREFACE

Canadian Ringed Seal populations were last assessed by COSEWIC as Not at Risk in April 1989 (Kingsley 1990). Much has been learned about Ringed Seal biology since they were last assessed, but there remain large gaps in our knowledge of the species.

Although Ringed Seal is now placed in a different genus than it was in the last assessment, this has more to do with the taxonomy of Grey Seals than a change that would have implications for the assessment process. Several population genetics studies reveal an overall pattern of isolation by distance, but none suggests that multiple designatable units are present.

Challenges in surveying Ringed Seal remain because they are difficult to detect in water during summer and may be hidden under sea ice and snow in winter. Aerial surveys are timed for the spring, when much of the population is hauled out on the ice to moult. The percentage of animals hauled out at any one time changes over the season and fluctuates during the day based on weather conditions—leading to uncertainty in seal estimates for most areas. This challenge, coupled with the very large range over which Ringed Seal is found, means that only a very small portion of their range has been surveyed and even less of their range is surveyed on a regular basis. These factors have led to the generation of a conservative estimate of population size (2.3 million) and very few areas with data to determine trend.

Community-based harvest monitoring has shown large fluctuations in pup production over time, relating to both exceptionally heavy and light ice years (shorter or longer open-water seasons). This connection between ice and snow conditions and Ringed Seal productivity is problematic because reductions in ice extent and ice cover duration, as well as increased ice mobility, are current trends being observed. Additional changes in the timing and amount of precipitation may be having, or will have, significant effects on Ringed Seal habitat. Currently, there are no strong indications that Ringed Seal numbers are declining in Canada, except in western Hudson Bay where estimated numbers have been declining since the 1990s, but surveys are increasingly difficult to undertake due to changing environmental conditions (e.g., early break-up and increased fog).

Ringed Seal is ubiquitous in the Arctic and subarctic, where they are economically and culturally important for northern peoples and are the major prey of Polar Bear. Climate change-induced habitat loss will significantly impact distribution and numbers. For this reason, other jurisdictions outside Canada have listed Ringed Seal as a species at risk.

Detailed reviews are available for Ringed Seal (e.g., Reeves 1998; Kelly *et al.* 2010a; Kovacs 2014; Lowry 2016) and for the Arctic subspecies (e.g., Kingsley 1990; Boveng 2016a).

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2019)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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2019

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Ringed Seal, *Pusa hispida* (Schreber, 1775) (Class: Mammalia, Order: Carnivora, Family: Phocidae, Subfamily: Phocinae), is a small earless (phocid) seal found throughout the Arctic and subarctic. Five subspecies are recognized, one of which, *P. h. hispida*, occurs in Canada (Rice 1998; Committee on Taxonomy 2014; Boveng 2016a; Lowry 2016). Common names for the species include the following: Ringed Seal, Arctic Ringed Seal, jar seal, fiord seal and common seal (English); phoque annelé and phoque marbré (French); Netsik (Inuit/Labrador); Nattiq (Inuit/North and East Baffin); Natiinat (Inuit); Natchiq, Natchiit and Natik (Inuit/North Slope); Natsiq/Natsik (Inuit/Nunavik and Nunavut); Natseq (Western Greenland); Ringsæl or netside (Danish); Norppa (Finnish); Ringsel (Norwegian); Ладожская нерпа (Russian); and Vikare (Swedish).

Ringed Seal is named in English and French for the ringed pattern that is visible on their coats.

The genus name for Ringed Seal has shifted back and forth between *Pusa* and *Phoca* in recent decades, with *Pusa* generally in favour at the current time (e.g., Rice 1998; Committee on Taxonomy 2014). Much of the debate has revolved around difficulties in reconciling molecular and morphological relationships between the Grey Seal (*Halichoerus grypus*) and *Phoca*/*Pusa* species (Rice 1998; Committee on Taxonomy 2014; Boveng 2016a; Lowry 2016). Several recent studies have grouped *Halichoerus* as a sister species to *Pusa caspica* (Caspian Seal) (i.e., a paraphyletic *Pusa* genus) (e.g., Árnason *et al.* 2006; Higdon *et al.* 2007; Nyakatura and Bininda-Emonds 2012), but other studies (e.g., Fulton and Strobeck 2010) have resolved *Halichoerus* as sister to the remaining members of the *Phoca*/*Pusa* species complex. The nomenclature for the species name (*hispida*) for the Arctic Ringed Seal has been widely accepted (Rice 1998; Boveng 2016a; Lowry 2016).

Throughout this document, unless otherwise indicated, Ringed Seal refers to Arctic Ringed Seal (*Pusa hispida hispida*).

Morphological Description

Ringed Seal is one of the smallest true (or earless) seals, with typical adult body sizes of roughly 1.5 m in length and 70 kg in weight (Kelly *et al.* 2010a). At birth, Ringed Seal is about 60-65 cm in length and 4.5-5.0 kg in weight, with some variation between study areas (e.g., McLaren 1958a; Smith and Stirling 1975; Lydersen *et al.* 1992). Ringed Seal pups grow quickly, reaching four times their birth weight at weaning (Hammill and Smith 1991; Lydersen *et al.* 1992), and then lose weight for several months after weaning (Smith 1987). There is some slight sexual dimorphism. McLaren (1958a) sampled 24 one-year-old seals from the Canadian Arctic, reporting average lengths of 103 cm and 94 cm for males and females, respectively, which is longer than one-year-old seals measured in the Beaufort and Chukchi Seas (Frost and Lowry 1981).

Ringed Seal is dimorphic in pelage, with light and dark phases (McLaren 1966; Kelly 1981). Light-phase seals have a dark grey saddle with superimposed light rings and lightly coloured lateral and ventral surfaces, while dark-phase seals have a dark background with light rings overall (Kelly *et al.* 2010a). Head and flippers (fore and hind) are generally dark grey to black (Rice 1998).

Pups are born with a natal coat of white hair (lanugo), which is shed after 4-6 weeks before the pup is weaned. First-year animals are uniformly silver grey with faint rings (the “silver jar” of the fur trade) (McLaren 1958a; Smith and Taylor 1977), which become more obvious with age.

Population Spatial Structure and Variability

Ringed Seal is distributed throughout the circumpolar Arctic and subarctic, where there is seasonal sea ice habitat. Throughout their range, several subspecies have been identified (see **Taxonomy**), with the Arctic subspecies being the most broadly distributed and abundant.

Several studies have examined the population genetic structure of Ringed Seal using neutral nuclear microsatellite markers (Palo *et al.* 2001; Davis *et al.* 2008; Petersen 2008; Nyman *et al.* 2014; Hudson 2016) or using both mitochondrial and nuclear markers (Martinez-Bakker *et al.* 2013). These studies have included relatively few sample sites that are widely dispersed over the range. Current studies also use different combinations of microsatellite markers; therefore, differentiation is reported here in general terms rather than specific F_{ST} values. Measures of genetic differentiation are affected by the number and types of genetic markers used; thus, most studies are not directly comparable. However, all population genetic studies are broadly concordant in finding low levels of genetic differentiation across the entire range (Palo *et al.* 2001; Davis *et al.* 2008; Martinez-Bakker *et al.* 2013).

Palo *et al.* (2001) compared three locations, none within Canada, and found weak differentiation between Svalbard and the Baltic Sea. Similarly, when Davis *et al.* (2008) compared eight sites, including four in Canadian waters, they found little genetic differentiation over most of the range. Although samples from the White Sea on the northwest coast of Russia showed a low but significant F_{ST} difference compared to other sites, STRUCTURE (Pritchard *et al.* 2000) analysis (a Bayesian individual-based, rather than location-based analysis) failed to detect population structure (Davis *et al.* 2008).

Martinez-Bakker *et al.* (2013) noted that samples should ideally be taken during the breeding season to detect population structure because of the high mobility and movement patterns of Ringed Seal during the open-water season. When they examined samples from 11 sites across the range, including four Canadian sites in the Eastern Beaufort Sea, they observed high gene flow (low differentiation) among breeding locations and no differentiation among Eastern Beaufort Sea samples. When examining Ringed Seal from 12 communities in the Eastern Canadian Arctic, Petersen (2008) found low levels of genetic differentiation and no population genetic structure. Moreover, Hudson (2016) found no significant differentiation among 17 Canadian sites.

Sampling for population genetics has not been uniform across Ringed Seal's Canadian or global range. Available samples tend to be collected near communities as part of community-based harvest monitoring (Petersen 2008), which leaves large portions of the Arctic unsampled. However, given that Ringed Seal have high genetic diversity, high mobility and long generation times, there is little expectation that gene flow is disrupted across the range (Petersen *et al.* 2010). Several papers with samples at various scales have also not detected high differentiation (Palo *et al.* 2001; Davis *et al.* 2008; Petersen 2008; Martinez-Bakker *et al.* 2013; Hudson 2016). This suggests that despite the gaps in sampling it is unlikely that genetic structure has gone undetected in the Canadian Arctic.

Designatable Units

Designatable units can be defined within a species in Canada if there are recognized subspecies or varieties or if there is an argument for discrete units that are evolutionarily significant (COSEWIC 2014). To date, there is no evidence to suggest that Ringed Seal in Canada should be assessed as more than one designatable unit. A number of additional subspecies have been suggested in the past for Canada, including *P. h. beaufortiana* in the Beaufort Sea and *P. h. soperi* in Foxe Basin and on the west coast of Baffin Island (Anderson 1946; Hall and Kelson 1959; Amano *et al.* 2002). However, none of these has been further supported, and all are considered synonymous with *P. h. hispida* (Frost and Lowry 1981; Rice 1998; Amano *et al.* 2002).

Some authors have considered regions separately and thus implied some level of management unit division (Reeves 1998). For example, McLaren (1962) treated different Hudson Bay Trading posts independently in his analyses. In practice, Ringed Seal in the Western Arctic (NWT and Yukon) have been treated separately from the Eastern Arctic and Hudson Bay (Nunavut) but this is less of a management strategy and more a logistic one; monitoring methods are similar between regions (Ferguson pers. comm. 2017). Yurkowski *et al.* (2016a) compiled telemetry data from Ringed Seal throughout the Canadian Arctic, noting a westward movement of animals tagged in the Amundsen Gulf towards the Chukchi Sea and an eastward movement of seals tagged from Resolute Bay to Baffin Bay. However, Hudson (2016) did not detect significant genetic differentiation between Ringed Seal sampled in Ulukhaktok, the Northwest Territories (NWT) and Hudson Bay. Similarly, Beaufort Sea, Svalbard and Baltic Sea samples were not significantly differentiated (Martinez-Bakker *et al.* 2013).

Finley *et al.* (1983) suggested a reproductively isolated population of Ringed Seal inhabiting the pack ice of Baffin Bay. They observed morphological differences (pack ice seals were smaller) and gut parasite differences (pack ice seals had lower parasite loads) but could not genetically differentiate the two populations using isozymes (Finley *et al.* 1983). Although they noted that some differences could be due to differences in diet (i.e., a fish-based diet could lead to high parasite loads), they still proposed the offshore Baffin Bay area as a separate population. Inuit in Baffin Bay and the Labrador Sea have also identified physical differences between Ringed Seal in coastal versus pack ice regions (e.g., Williamson 1997; Rosing-Asvid 2010). Although there has been no subsequent study in this area, western Arctic research examining the distribution of Polar Bear (*Ursus maritimus*) predation on Ringed Seal suggests that competition for landfast ice habitat may force smaller adults to breed in offshore sub-optimal habitat (Pilfold *et al.* 2014).

There have been suggestions that differences in morphology, as well as clinal variations in size (i.e., larger seals at higher latitudes; Soper 1944, McLaren 1958a), could warrant population status (Fedoseev 1975; Finley *et al.* 1983). However, these differences are not supported by patterns of genetic differentiation at neutral genetic loci (Petersen 2008; Hudson 2016) and may be the result of differing areas having a longer duration of spring stable ice (McLaren 1958a) or higher productivity (Yurkowski *et al.* 2016c). Shorter nursing times may result in smaller animals at weaning, as well as smaller adults (McLaren 1958a).

Inland populations of Ringed Seal have been noted in Nettilling Lake (Baffin Island, Nunavut) and Lake Melville (Labrador, Newfoundland and Labrador) (Reeves 1998), but there are no genetic data to evaluate whether they represent unique populations. Overall, given the current state of information about Ringed Seal populations, there is no evidence to indicate that those in Canada should be assessed as more than one designatable unit.

Special Significance

Ringed Seal is a very important food source for Inuit and their dogs, although their use as a source of fuel (oil) and clothing (furs) has declined (Kingsley 1990).

Seal pelts are still an important source of income for Inuit harvesters throughout the Canadian Arctic and subarctic. Seal hunting remains an important socio-economic activity (McLaren 1958b; Wenzel 1987; Pelly 2001; Furgal *et al.* 2002) even though sales of pelts to the Government of Nunavut Department of Environment's Fur and Seal Program have declined (Ghazal pers. comm. 2017).

Ringed Seal is also the primary food source for Polar Bear, and access to seals is of critical importance to bear populations (Stirling and Archibald 1977; Smith 1980; Stirling and Derocher 1993) (see **Interspecific Interactions**). Ringed Seal is highly adapted to life in the Arctic marine environment (e.g., using breathing holes and snow lairs) (Smith and Stirling 1975; Smith 1976; Lydersen and Smith 1989) (see **Physiology and Adaptability**), and are considered an important indicator species for climate change effects (Laidre *et al.* 2008; Kovacs 2014) (see **Threats and Limiting Factors**).

DISTRIBUTION

Global Range

Ringed Seal has a circumpolar distribution (Figure 1, from Kelly *et al.* 2010a) and are strongly ice associated throughout their range. Maximal winter sea-ice cover in the Arctic roughly defines the global range of Ringed Seal, although vagrants are sometimes observed farther south where sea ice does not occur (e.g., Sable Island and Gulf of Maine; Lucas and McAlpine 2002; Waring *et al.* 2004). The following countries have Ringed Seal in their territorial waters: Canada, Greenland, Norway, Russia, United States of America and the Baltic Sea states. They occur in the Bering, Chukchi, Beaufort, Barents, White, Kara, Laptev and East Siberian seas, as well as the Canadian Arctic Archipelago, Hudson Bay, Hudson Strait, Davis Strait, Baffin Bay and Labrador Sea (Boveng 2016a), in addition to occupying some lake and river systems in Canada.

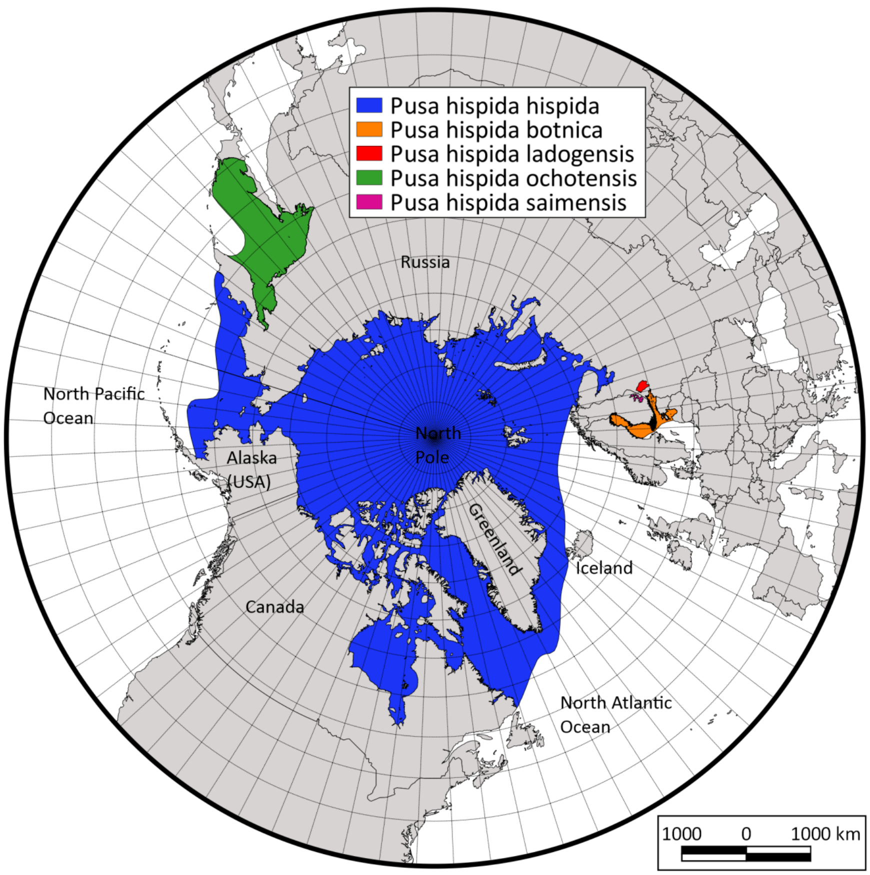

Figure 1. Global range of the five Ringed Seal (*Pusa hispida*) subspecies, data from Kelly *et al.* (2010a). Only one subspecies, *P. h. hispida* (Arctic Ringed Seal), occurs in Canadian waters (map projection: North Pole Stereographic).

Canadian Range

Ringed Seal is widely distributed in Arctic and subarctic Canada, ranging from the Yukon North Slope (and into Alaska and Russia as a contiguous population) in the west and south and east to southern Labrador (Figure 2, from Kelly *et al.* 2010a). Their distribution ranges throughout the Arctic Ocean, north of Canada's Arctic Islands, and into Greenland waters in eastern Baffin Bay and Davis Strait.

Figure 2. Geographic range of Ringed Seal (*P. hispida hispida* subspecies) in Canadian waters and adjacent areas. Ringed Seal is also found along the northern coastline of Newfoundland, and sporadic records exist for the other Atlantic provinces, but breeding range is limited by the availability of sea ice for pupping. Dotted black line shows limits of Canada's Exclusive Economic Zone (EEZ). Data from Kelly *et al.* (2010a) (map projection: Canada Lambert Conformal Conic).

Figure 2 shows Ringed Seal ranging south to southern Labrador. The area around Lake Melville, or slightly south along the coast, is thought to be a typical southern limit for pupping (due to ice availability) (Stenson pers. comm. 2017), but Ringed Seal is found all the way down the Labrador coast.

In winter, Ringed Seal move south with the ice and are hunted on Newfoundland's northern peninsula and northeast coast. They are not as abundant as on the Labrador coast, but some are collected every year (Stenson pers. comm. 2017). Ringed Seal also occur, at least sporadically, on Québec's lower north shore, east of Anticosti, but there is little information available and collections have not been made in many years (Hammill pers. comm. 2017). They have also been recorded on Sable Island (Lucas and McAlpine 2002). Some range maps exclude James Bay, but Ringed Seal is known to occur throughout the area (Smith 1975; Gosselin pers. comm. 2017).

Extent of Occurrence and Area of Occupancy

Ringed Seal has an extent of occurrence (EOO) of 8,146,022 km², including land, in Canada (4,403,651 km² with land excluded, i.e., ca. 45% land within the minimum convex polygon (MCP)), and an index of area of occupancy (IAO) of 996,019 2 km by 2 km grid cells = 3,984,076 km². Values for EOO and IAO were not reported in the last COSEWIC assessment (Kingsley 1990), but the geographic range of Ringed Seal in Canada has not changed significantly since that time. Calculations were made using the range map in Kelly *et al.* (2010a), which was clipped to include the species' range within the Canadian Exclusive Economic Zone only.

Ringed Seal moves from Canadian waters into adjacent jurisdictions (Greenland, Alaska and Russia; see **Dispersal and Migration**), but the boundaries of any population are uncertain. Information on the distribution of the species' most limiting habitat (e.g., pupping areas, critical habitat, etc.) is not known, so IAO was calculated as the number of cells over species observation/distribution records. The IAO calculation reported here uses the full Canadian range. Landfast ice could be considered the most limiting habitat for Ringed Seal because birth lairs are usually found in this habitat, but Ringed Seal also gives birth in pack ice habitat, which is widespread (see **Habitat**). Birth lairs are presumed to occur at a much lower density in the pack ice, but this habitat is still used for critical life history functions (see **Life Cycle and Reproduction** and **Dispersal and Migration**). Using a reduced range (e.g., landfast ice only) would result in a smaller IAO but it would still be much larger than the threshold of Criteria B for Endangered and Threatened species (>500 km² and >2 000 km², respectively).

All GIS-based analyses and calculations were completed using a Canada Albers Equal-Area projection in ArcView 3.3 (ESRI Inc., Redlands, CA) and QGIS 2.16.3.

Search Effort

The distribution maps for Ringed Seal were developed based on a shapefile made available by Kelly *et al.* (2010a). The shapefile includes the global geographic ranges of the five *Pusa* subspecies, and was created based on an extensive literature review. The range map (Kelly *et al.* 2010a) was compared to other sources (e.g., Reidman 1990; Jefferson *et al.* 1993; Hammill 2009) to look for potential errors or omissions. Its accuracy for eastern Canada, along the southern limit, was confirmed through discussion with regional experts (Gosselin pers. comm. 2017; Hammill pers. comm. 2017; Stenson pers. comm. 2017).

HABITAT

Habitat Requirements

Ringed Seal is a marine species that is adapted to living in close association with sea ice and, as such, is a pagophilic (ice-loving) species. Their presence and density are variable throughout their range, presumably in response to prey availability and distribution (Reeves 1998). Sea ice is used as a platform to raise pups, rest and moult (Frost and Lowry 1981; Kingsley 1990; Reeves 1998).

Because habitat use can change with ice concentration and time of year, this document will summarize information from the open-water and ice-covered seasons. It should be noted that most information is derived from studies of Ringed Seal that occupy near-shore areas and their behaviour may differ from those occupying offshore areas (Finley *et al.* 1983). Most of the published studies of ice habitat have also been conducted close to shore and may be similarly biased (Reeves 1998).

<u>Open-Water Season</u>

During the open-water season, Ringed Seal are not constrained in their movements and often travel long distances (see **Dispersal and Migration**). Travelling individuals utilize a variety of ocean depths, and foraging can be inferred because most satellite telemetry tags used on Ringed Seal also collect dive information (Yurkowski *et al.* 2016a).

Habitat use is variable among regions, age classes and size classes. Yurkowski *et al.* (2016a) identified a latitudinal gradient in movement ecology, with seals at higher latitudes spending less time in a resident behavioural state compared to seals at lower latitudes where the ice-free season is longer. In Hudson Bay, Luque *et al.* (2014) found that both adults and subadults travel more and move through deeper water depths during the open-water season. In Baffin Bay, on the Greenland coast, Born *et al.* (2004) found that adult seals were more likely to dive deeply than subadult seals. In the North Water region, Teilmann *et al.* (1999) found that smaller seals used the top 50 m of the water column while larger seals dove deeper, but all the seals they tracked made at least occasional dives to >250 m. Crawford *et al.* (2012) tracked adult and subadult Ringed Seal off the coast of Alaska and found differences in habitat use between the two groups during all seasons, with subadults occupying areas in deeper water and at a greater distance from the edge of the permanent ice pack in the open-water season (Crawford *et al.* 2012). More information about diving and movement is available in the **Physiology and Adaptability** and **Dispersal and Migration** sections, respectively.

<u>Ice-Covered Season</u>

The ice-covered season imposes different constraints on different segments of the population. Younger animals tend not to be found on landfast ice, either because they are pushed out by breeding-aged territory holders (Stirling 1973; Smith 1987) or because they can save energy reserves by not maintaining breathing holes over the winter (Crawford *et* *al.* 2012). In the Beaufort, Chukchi and Bering seas, subadults are found on pack ice or at the ice edge as it grows over the winter and retreats in the spring (Crawford *et al.* 2012). Ringed Seal also tends to be found on heavier ice than other ice-adapted seals (Simpkins *et al.* 2003). McLaren (1958b) observed that adult seals made up most, if not all, of the animals harvested on the landfast ice of southwestern Baffin Island and that subadult animals occupied the offshore areas. Subadult Ringed Seal tagged near Resolute, Nunavut, migrated to Baffin Bay (Yurkowski *et al.* 2016a), but it has also been suggested that the offshore pack ice of Baffin Bay contains more than just subadults and constitutes a separate population of Ringed Seal (Finley *et al.* 1983).

Sea ice is also used by all +1 age classes for moulting during the spring. While hauled out on the ice, Ringed Seal engages in various antipredator behaviours that include hauling out away from the ice edge (i.e., at the centre of larger ice floes in the pack ice or at cracks in landfast ice), by orienting themselves with their head towards their escape route (ice hole or crack) and by positioning their head to be downwind (Kingsley and Stirling 1991; see more about vigilance behaviours in **Physiology and Adaptability**). Landfast ice, in general, has higher densities of hauled-out seals compared to pack ice (Kingsley *et al.* 1985). Kingsley *et al.* (1985) and Stirling *et al.* (1982) found a preference for basking seals to be hauled out over shallower waters (<150 m and <100 m, respectively) in the Beaufort Sea, although this may be related to a preference for landfast ice.

<u>Breeding Habitat</u>

If a critical habitat could be argued for Ringed Seal, it would be the sea ice habitat used for parturition and lactation (Hammill and Smith 1989, 1991; Furgal *et al.* 1996). In the fall, as the sea ice forms, adult Ringed Seal set up territories in the best habitats (Smith and Stirling 1975). These areas consist of places with good snow coverage and where stable landfast ice will form (McLaren 1958a; Smith and Stirling 1975; Cleator 2001). These tend to be areas where the ice forms pressure ridges, with plates of ice being forced up out of the plane of the water surface. This protruding ice will then catch blowing snow and form drifts on the windward and lee side of the ridge, in which a den or lair can be dug (Smith and Stirling 1975). In a similar situation, the ice in fiords with glaciers can provide habitat as the bergs from the glacier freeze into the ice and likewise collect snow (Lydersen and Ryg 1991). Aboriginal Traditional Knowledge sources and scientific researchers identify a number of den types that serve as areas for resting, suckling, birth and escape (Smith and Stirling 1975, 1978; Cleator 2001; Furgal *et al.* 2002). For more discussion of lairs, see **Physiology and Adaptability**.

Snow cover has also been identified as important to the formation of drifts for denning and to overall pup production (Smith 1987; Ferguson *et al.* 2005; Iacozza and Ferguson 2014). Birth lairs tend to be larger, with more snow cover over them, compared to lairs used by rutting males (Lydersen and Gjertz 1986). Ferguson *et al.* (2005) found that snow depths of less than 32 cm were correlated with reduced recruitment in western Hudson Bay. Hezel *et al.* (2012) considered 50 cm of accumulated snow in drifts next to pressure ridges to be the minimum requirement for denning, and used a remotely sensed snow cover depth of 20 cm on level ice as a model threshold that would result in an appropriate snow depth for denning in drift areas.

On a broad scale, it has been noted that complex coastlines are especially productive because they have abundant stable ice habitat (McLaren 1958a). However, pack ice has also been identified as breeding habitat in Baffin Bay (Finley *et al.* 1983), the Barents Sea (Wiig *et al.* 1999) and the Okhotsk Sea (Fedoseev and Yablokov 1964 in Wiig *et al.* 1999). These areas may represent a source of many seals. Indeed, Stirling and Øritsland (1995) suggest that in some areas the population of Ringed Seal required to support the estimated Polar Bear population cannot be filled by the estimated productivity of landfast ice habitat alone. This could indicate that suitable breeding habitat can exist where the pack ice is relatively stable and, like landfast ice, accumulates snow drifts suitable for birth lairs. Unfortunately, little research is conducted in these habitats due to the logistical challenges they present.

Habitat Trends

Ringed Seal is an ice-adapted species. Therefore, the loss of sea ice is a loss of habitat for this species. They are adapted to seasonal sea ice (which forms and melts annually) and, within that, to a relatively narrow range of sea ice conditions. Throughout most of the Arctic, Ringed Seal recruitment and abundance are related to both ice and snow conditions (Harwood *et al.* 2000; Ferguson *et al.* 2005; Harwood *et al.* 2012b; Iacozza and Ferguson 2014). Extreme heavy ice years or extreme late break-up can have negative demographic effects (Harwood *et al.* 2012b).

<u>Trends in Sea Ice</u>

Arctic sea ice has changed significantly in the last 30 years (IPCC 2013). In much of the Ringed Seal’s range, the length of the ice-covered season has declined (Parkinson 2014; Laidre *et al.* 2015). This has been due to both earlier spring break-up and later fall freeze-up (Parkinson and Cavalieri 2002; Gagnon and Gough 2005; Howell *et al.* 2009; Galley *et al.* 2012; Stern and Laidre 2016). There have also been changes in ice types, in the form of a reduction in multi-year ice (ice that lasts for more than one year), as well as a correlated reduction in ice thickness (Kwok *et al.* 2009; Stroeve *et al.* 2012; Meier *et al.* 2014). A shift from multi-year to annual ice in some regions (e.g., Canadian Arctic Archipelago) may improve Ringed Seal habitat, but overall trends in habitat quality and availability are expected to be negative.

Aboriginal Traditional Knowledge holders throughout the species’ range in Canada and adjacent jurisdictions (Alaska, Greenland) have observed changes in sea ice. Observed changes include later freeze-up and earlier break-up (a longer open-water season), thinner ice, a reduction in both multi-year ice and landfast ice, and fewer icebergs and pressure ridges. These trends have been reported from west to east: in Alaska (e.g., Voorhees *et al.* 2014; Huntington *et al.* 2016, 2017); the Canadian Beaufort Sea (e.g., Slavik 2013; Joint Secretariat 2015); the central Arctic (e.g., Keith *et al.* 2005; Keith 2009); Foxe Basin, Hudson Bay, and Hudson Strait (e.g., the Communities of Ivujivik, Puvirnituq and Kangiqsujuaq *et al.* 2005; Laidler 2006; Ford *et al.* 2009; Laidler *et al.* 2009; Shannon and Freeman 2009); Davis Strait and Baffin Bay (e.g., Dowsley 2005, 2007; Kotierk 2010); northern Labrador (York *et al.* 2015); and West Greenland (e.g., Born *et al.* 2011).

The abovementioned changes are linked to global atmospheric and oceanic temperatures, which are increasing due to greenhouse gas emissions (IPCC 2013), and they are predicted to continue in the same direction into the foreseeable future (Kelly *et al.* 2010a). Estimates of an ice-free summer in the Arctic vary, but could be as soon as 2020 to 2050 (Serreze *et al.* 2007; Overland and Wang 2013). Explicit modelling of trends in sea ice to 2100 were conducted by Kelly *et al.* (2010a) for the US ESA listing process, with simulations showing trends to earlier spring break-up, later fall freeze-up, and summer retraction of sea ice to core areas, such as the central Canadian Archipelago. They also examined regional differences in sea ice trends and found similar results, albeit with more model uncertainty (Kelly *et al.* 2010a).

In Svalbard, models indicate that if ice retreats more than 600-700 km from the coast of Svalbard, it will become energetically unprofitable for seals pupping in this area to use that sea ice for foraging (Freitas *et al.* 2008b). Recent ice loss near Svalbard has shifted summer marginal ice edges over less productive deeper waters, with a resulting increase in energetic costs to seals (Hamilton *et al.* 2015). Observed shifts in the increased use of terrestrial haul-out sites for resting have been documented coincident with sea ice loss (Lydersen *et al.* 2017). In the Baltic Sea, loss of sea ice for pupping is predicted to reduce the population to 16% of historical numbers by 2100 (Sundqvist *et al.* 2012).

Trends in Snow Cover

Snow cover on sea ice is important for thermal protection and predator avoidance for Ringed Seal pups (Smith and Stirling 1975; Lydersen and Smith 1989; Kelly and Quakenbush 1990; Smith and Lydersen 1991). Ferguson *et al.* (2005) noted a reduction in snow depth in western Hudson Bay, and Aboriginal Traditional Knowledge holders have also observed reductions in the snow cover needed for birth lairs (e.g., Keith *et al.* 2005; Joint Secretariat 2015). Although it is predicted that precipitation will increase with a warming climate (Walsh 2008; IPCC 2013), this precipitation must occur at the appropriate air temperature in order to fall as snow on ice, and it is predicted that snow accumulation on ice will decrease (Kelly *et al.* 2010a). Reduced snow accumulation will reduce the available habitat for building subnivean lairs and will also melt sooner in the spring, leaving Ringed Seal pups exposed to the elements and predators (Kelly *et al.* 2010a). Hezel *et al.* (2012) predicted that snow accumulation will be delayed in projected models, resulting in decreases in spring snow depth. Similarly, snow depth is projected to decline in Hudson Bay, with direct effects on Ringed Seal recruitment expected (Iacozza and Ferguson 2014). Ultimately, climate change models predict a similar fate for the Ringed Seal as for Polar Bear: that breeding habitat will not be available in the southern portions of their range because the ice season will be too short (Castro de la Guardia *et al.* 2013; Hamilton *et al.* 2014).

Trends in Ocean Productivity

Arctic ecosystems and species have adapted to the presence of ice and, as a consequence, changes in ice will have broad impacts on the entire ecosystem of which Ringed Seal is a part. Changes that have already been observed in other Arctic species include: mismatches in prey availability (Gaston *et al.* 2005), northward range expansions of predators (Higdon and Ferguson 2009), and changes in community structure (Grebmeier *et al.* 2006; Post *et al.* 2009; Marcoux *et al.* 2012; also see **Threats and Limiting Factors** section).

For further discussion of the impacts of trends described above, particularly climate change, see **Threats and Limiting Factors**.

BIOLOGY

Information on the biology of Ringed Seal in Canada comes from a combination of research and Aboriginal Traditional Knowledge from all parts of their global range. There is no evidence that the biology differs fundamentally among regions except as it relates to the productivity of the system and the dynamics of the subpopulation.

Life Cycle and Reproduction

The following section refers primarily to studies of the life cycle of Ringed Seal within their Canadian range unless otherwise indicated. Variations in life history parameters relating to **Habitat**, **Physiology and Adaptability** and **Threats and Limiting Factors** are discussed in corresponding sections.

Single Ringed Seal pups are born between March and May, in a birth lair that has been excavated by their mother, above a breathing hole in a snowdrift (Smith and Stirling 1975; see **Habitat** section). Pups nurse for 5 to 8 weeks in stable, landfast ice (McLaren 1958a; Smith 1973; Hammill *et al.* 1991; Lydersen and Hammill 1993a) or as little as 3 in moving pack ice (Burns 1970), before being weaned and abandoned around the time of ice break-up (Hammill and Smith 1991). An earlier weaning period, between mid-April and mid-May, has been observed in lower latitudes such as Hudson Bay, which may ensure an uninterrupted lactation period in an area with earlier spring break-up (Harwood *et al.* 2000; Chambellant *et al.* 2012).

Before weaning, pups spend half of their time making short feeding dives under the ice (Lydersen and Hammill 1993b; Furgal *et al.* 1996; Lydersen 1998). Weights of lactating females can decline by an estimated 32% (Hammill *et al.* 1991), which is offset by drawing on fat reserves as well as active supplementation via feeding under the ice (Hammill 1987; Kingsley 1990; Kelly and Wartzok 1996).

After weaning their young, female Ringed Seals spend the majority of their time hauled out on the sea ice to moult (Kelly *et al.* 2010b). For both sexes, the moulting season occurs from late March until July, peaking in June (Frost and Lowry 1981). During this season, individuals haul out onto ice along cracks or leads to bask in the sun (McLaren 1958a; Smith 1973), presumably to raise skin temperature for proper hair regrowth (Feltz and Fay 1966; Boily 1995; Paterson *et al.* 2012), which is energetically expensive (Boily 1995; see **Physiology and Adaptability**). The amount of time spent basking increases over the course of the moulting season, and non-breeding seals moult earlier than breeding adults (Vibe 1950).

Following ice break-up, Ringed Seal maximizes energy and reserves by feeding intensively during the open-water season (Young and Ferguson 2013a). Overall, Ringed Seal shows a high degree of diet variability depending on the availability of different prey species in the area. Across their range, Ringed Seal feeds on a wide variety of pelagic and benthic prey. However, at finer geographic scales they tend to focus on 2-4 species (McLaren 1958a; Johnson *et al.* 1966; Weslawski 1994; Siegstad *et al.* 1998; Yurkowski *et al.* 2016c), the most common of which are pelagic schooling fish such as Arctic Cod (*Boreogadus saida*), as well as amphipods, euphausiids, shrimp and other crustaceans (Chambellant 2010; Cleator 2001).

Diet composition varies by latitude (McLaren 1958a; Yurkowski *et al.* 2016b,c). Sand Lance (*Ammodytes* spp.) and Capelin (*Mallotus villosus*) dominate the diets of Ringed Seal in the southern range such as western Hudson Bay (Chambellant 2010; Chambellant *et al.* 2013), southeast Hudson Bay (Breton-Provencher 1979; Young and Ferguson 2013b), Ungava Bay and northern Labrador (McLaren 1958a), whereas Arctic Cod is the main prey item for Ringed Seal in northern areas, such as the western Canadian Arctic (Smith 1987), the high Canadian Arctic (Bradstreet and Finley 1983), northern Foxe Basin, southwest Baffin Island (McLaren 1958a), northern Baffin Island (Holst *et al.* 2001) and Resolute Bay (Matley *et al.* 2015; Yurkowski *et al.* 2016a). Yurkowski *et al.* (2016b,c) observed latitudinal patterns in diet and attributed them to differences in prey availability.

In studies of Ringed Seal diet, three additional forms of variation have been explored—age class, seasonal and interannual variation—the latter two of which are discussed in the **Habitat** and **Physiology and Adaptability** sections. Some studies have reported that pups feed more on invertebrates than adults (Lowry *et al.* 1980; Bradstreet and Finley 1983; Smith 1987; Holst *et al.* 2001; Crawford *et al.* 2015), although others have not found a biologically significant difference (McLaren 1958a; Holst *et al.* 2001; Chambellant *et al.* 2013). For their first year, pups appear to be limited to feeding in shallow depths due to their size (Kelly and Wartzok 1996).

The sex ratio between male and female pups is 1:1, and this pattern persists into adulthood (McLaren 1958a; Smith 1973; Breton-Provencher 1979; Smith 1987; Holst *et al.* 1999; Chambellant 2010). Mean age at maturity has been shown to vary with the productivity of the environment (Holst and Stirling 2002; Krafft *et al.* 2006). In most areas, both sexes reach sexual maturity between 4 and 7 years of age (McLaren 1958a; Mansfield 1967; Tikhomirov 1968; Smith 1973, 1987; Holst *et al.* 1999; Holst and Stirling 2002), although some female Ringed Seals can reach maturity at three years (Krafft *et al.* 2006) or as late as 9 years (Kingsley and Byers 1998). Maturity and ovulation are related to body condition, and ovulating females tend to be in better body condition than non-ovulating females (Harwood *et al.* 2000, 2012b). Although females forage during lactation to support the energetic cost, body condition declines during this period (Lydersen 1995; Lydersen and Kovacs 1999). Nguyen *et al.* (2017) suggest caution when using ovulation rate as an absolute indicator of reproductive output for Ringed Seal. For example, in Hudson Bay, no relationship was found between ovulation rate, pregnancy and percentage of pups in the fall harvest (Chambellant *et al.* 2012; Young *et al.* 2015).

The breeding system of Ringed Seal has not been resolved conclusively. Some believe them to have a weakly polygynous, resource-defence mating system (Smith and Hammill 1981; Kingsley 1990; Yurkowski *et al.* 2011) while some have suggested a monogamous or mixed breeding system rather than polygyny (Kelly *et al.* 2010b). Arguments for limited polygyny have been based on several observations: aggressive behaviour and bite wounds on adult and subadult males (Smith and Hammill 1981; Smith 1987; Smith *et al.* 1991; but see Kelly *et al.* 2010b; Crawford *et al.* 2015); segregation between age classes and disparate sex ratios in landfast ice breeding areas (Smith 1987); increased underwater vocalizations during the breeding season (Stirling *et al.* 1983; but see Richardson *et al.* 1995); restricted diving (Kelly and Wartzok 1996); restricted movements by males during the breeding season; and scent marking by males (Smith 1987; Hardy *et al.* 1991; Ryg *et al.* 1992), which could indicate that they guard the primary breathing hole of one post-parturient female until she is receptive (Kelly *et al.* 2010b). Kelly *et al.* (2010b) also argue that the necessity of maintaining breathing holes constrains polygyny in Ringed Seal, and that males may employ mixed strategies, as Hooded Seals (*Cystophora cristata*) have (Kovacs 1990).

At freeze-up, adults and maturing subadults move into breeding areas and attempt to establish territories, with some showing signs of site fidelity during the winter and spring (McLaren 1958a; Smith and Hammill 1981; Kelly and Quakenbush 1990; Kraftt *et al.* 2007; Kelly *et al.* 2010b). Sexually mature adults tend to occupy the prime, stable pack ice habitat suitable for birth lairs (McLaren 1958a; Smith 1973; Smith and Hammill 1981). Some subadults have been observed being driven away from prime breeding areas by adults (Stirling 1973; Smith 1987), and most spend the winter months along the ice edge, leads or polynyas (McLaren 1958a; Stirling *et al.* 1981; Krafft *et al.* 2007; Crawford *et al.* 2012; see more about subadult dispersal in **Dispersal and Migration**).

Peak spermatogenetic activity and maximum testes size occur when males are in rut from March to mid-May (McLaren 1958a; Johnson *et al.* 1966) and they emit strong-smelling facial secretions from sebaceous and apocrine glands (Smith and Stirling 1975; Hardy *et al.* 1991). Some believe this scent is used as a territorial marker or an attractant that induces oestrus in females within the territory (Hardy *et al.* 1991; Ryg *et al.* 1992). Aboriginal Traditional Knowledge from the Admiralty Inlet area of Nunavut indicates that adult males begin to secrete this odour from shortly after ice consolidation until Ringed Seal basks on top of the ice prior to and during the moult in June (Furgal *et al.* 2002), which is a longer period than has been reported in the scientific literature in the past (Hardy *et al.* 1991; Ryg *et al.* 1992).

Females ovulate towards the end of lactation (Smith 1987), and mating is thought to occur underwater around the time pups are weaned in mid- to late May (Smith 1987; Lydersen 1995). Gestation (typically 10–11 months) is divided into ~2–3 months of delayed implantation and ~8 months of active gestation (McLaren 1958a; Smith 1987; Hammill and Smith 1989), which is longer than for many other pinnipeds. Heavy ice years have been associated with several reproductive declines since the 1970s (Smith 1987; Kingsley and Byers 1998; Harwood *et al.* 2000, 2012b; Stirling 2002; Nguyen *et al.* 2017). Light ice years can also negatively impact reproduction (Ferguson *et al.* 2017; additional details are discussed in **Habitat** and **Threats and Limiting Factors**).

Ringed Seal is relatively long-lived, with a maximum age of 43-45 years being recorded (McLaren 1958a; Lydersen and Gjertz 1986). However, relatively few seals over 20 years of age are observed in the wild (Lydersen and Gjertz 1986; Smith 1987; Holst *et al.* 1999) and the average age for females is higher than for males (Lydersen and Gjertz 1986). Overall, the average lifespan has been estimated at 15–20 years (Frost and Lowry 1981) to 25–30 years (Kovacs 2014). Causes of death are discussed in **Interspecific Interactions** and **Threats and Limiting Factors**.

The generation time of Ringed Seal, measured based on the average age of parents in the population, is uncertain. There are gaps in knowledge of population demographics, survival rates, relative numbers of adult females of a given age, and the age of the oldest reproducing female. All these factors also vary spatiotemporally (Holst and Stirling 2002; Krafft *et al.* 2006). Lacking strong empirical data, a precautionary generation time value was estimated using the third calculation method recommended by the IUCN (2013), where:

<u>Generation time = age of first reproduction + z (length of the reproductive period)</u>

When z = 0.5 is used in the absence of empirical data on survivorship and the relative fecundity of young versus old individuals in the population, the resulting estimate = 6 + 0.5 (14) = 13 years, assuming that most seals do not live past 20 (see above). The same estimate is generated using the approach Pianka (1988) suggested to obtain a rough estimate, namely:

<u>Generation time = (age of first reproduction + age at last reproduction) / 2</u>

The value calculated here, 13 years, lies between other estimates of a 18.6-year generation length (Lowry 2016) or 11 years suggested by Smith (1973) and Palo *et al.* (2001). Kelly *et al.* (2010a) stated that Ringed Seal has a “long generation time” but did not report any empirical values.

Physiology and Adaptability

Ringed Seal is the most widely distributed seal in the Arctic (Allen 1880; Chapskii 1940; King 1983), first adapting to the extremes of the Arctic and then, more recently, to surface predators (Smith and Stirling 1975; Smith 1976; Kingsley 1990; Stirling *et al.* 1991; Stirling and Øritsland 1995). Having evolved in challenging habitats characterized by long periods of cold temperatures and ice cover, Ringed Seal is uniquely adapted to maintain breathing holes by scratching sea ice with the claws of their fore flippers (Stirling 1974, 1977; Smith and Stirling 1975). They are also adapted to variable food availability as well as predictable periods of positive and negative energy balance (Harington 2008).

Blubber

Ringed Seal has evolved a body type built for Arctic waters. Blubber is distributed consistently over the body, maximizing its availability for insulation, except in its hind section, which is described as “overinsulated” because it has a higher thickness-to-radius ratio. Ryg *et al.* (1988) described this blubber distribution, reporting that fat is lost most quickly from the overinsulated region during periods of mass loss (e.g., during moult, when seals can lose 30-35% of their blubber stores (Ryg *et al.* 1990)), thus reducing the negative thermal effects of the fat loss. Ryg *et al.* (1988) also suggested that this blubber distribution pattern could reflect a compromise between insulation and the streamlining required for water resistance while Ringed Seal is swimming. Heat stress during the hyperphagic period has been suggested as a threat if Ringed Seal becomes overinsulated while water temperatures remain high (Ferguson *et al.* 2017).

Diving

Three-dimensional tracking models have categorized Ringed Seal dives as either for travel, exploration or foraging/socialization, and they indicate that individuals can switch between these behaviours several times during a dive (Simpkins *et al.* 2001).

Ringed Seal can dive deeper than 250 m and remain submerged for over 20 min, although dives of less than 10 min long are most common (Lydersen 1991; Kelly and Wartzok 1996; Teilmann *et al.* 1999; Gjertz *et al.* 2000; Born *et al.* 2004; Crawford *et al.* 2019). Diving capacity varies by body mass, with larger individuals being capable of diving deeper and longer (Kelly and Wartzok 1996; Kelly 1997; Teilmann *et al.* 1999; Kunnasranta *et al.* 2002). Diving behaviour also differs by sex (Kelly and Wartzok 1996; Teilmann *et al.* 1999, Harwood *et al.* 2015). In winter, females make more dives that are deeper and longer lasting compared to males and subadults, presumably to meet energetic demands of upcoming pupping and nursing (Harwood *et al.* 2015).

Ringed Seal dive mostly during the day in late summer, fall and winter, and dive mostly at night during the spring to early summer breeding and moulting periods (Kelly and Quakenbush 1990; Lydersen 1991; Teilmann *et al.* 1999; Kunnasranta *et al.* 2002; Carlens *et al.* 2006; Kelly *et al.* 2010b). In order to dive and feed throughout the year, including periods of darkness (Johnson *et al.* 1966), Ringed Seal can navigate in the absence of light

(Hyvärinen 1989; Wartzok *et al.* 1992). Captive experiments indicate that they largely use vision to locate breathing holes from under the ice, followed by auditory and vibrissal (touch via whiskers) senses for short-range navigation (Elsner *et al.* 1989).

Whiskers (vibrissae) appear to be important for spatial adjustment in diving mammals lacking sonar systems, and seals have a high number of nerve fibres penetrating each of their vibrissa follicles relative to other mammals. Hyvärinen and Katajisto (1984) hypothesized that this enables them to 1) sustain sensory functions in cold water (with glycogen serving as an energy source in anaerobic diving conditions) and 2) hunt by sensing turbulent wakes from their prey (Beem and Triantafyllou 2015).

Lairs

One evolutionary trade-off of having a blubber-rich body streamlined for diving is that it makes Ringed Seal less mobile on hard surfaces, making them more vulnerable to surface predators. Smith *et al.* (1991) hypothesized that these two selective pressures forced Ringed Seal into a different evolutionary strategy than its larger Antarctic counterpart, the Weddell Seal (*Leptonychotes weddellii*), which pups on the ice. Ringed Seal builds subnivean (below the snow) lairs on the ice so the pups are protected.

Subnivean lairs are generally of two types—birth (or birthing) lairs and resting (or haul-out) lairs—and are built in complexes that allow Ringed Seal to escape predators (Smith and Stirling 1975; see more about lairs in **Habitat**). Birth lairs provide both physical and thermal protections that are important for the survival of neonates. Although pups are protected from dry cold by their natal lanugo (Øritsland and Ronald 1973, 1978; see **Morphological Description**), they are prone to irreversible hypothermia when wet and exposed to the elements (Smith *et al.* 1991). Thus, they rely on regaining thermoneutrality within their insulating birth lairs, which can be 15–27˚ C warmer than ambient temperatures (Kelly and Quakenbush 1990; Smith *et al.* 1991).

Although most occurrences of pups entering the water are feeding bouts, they can be forced to submerge by approaching predators, in which case the presence of a complex of alternative lairs (Smith and Stirling 1975; Smith and Stirling 1978; Smith and Hammill 1981) becomes important. The relatively low success rate of Polar Bear predation attempts at lairs (Smith 1980; Hammill and Smith 1990, 1991) attests to the efficiency of the birth lair complex at protecting Ringed Seal from bear predation. Resting lairs are assumed to provide subadults and adults with similar protections, although few studies have been conducted on the mechanisms involved (Taugbøl 1984; Smith *et al.* 1991). One study (Kelly and Quakenbush 1990) suggested that complexes of closely spaced lairs are the work of multiple seals that accrue a “predator swamping” advantage in areas of heavy predation. However, it is also possible that they provide other advantages in this poorly understood social system.

Vocalizations

Several studies have analyzed vocalizations of wild Ringed Seal in the Canadian Arctic (Stirling 1973; Smith and Stirling 1978; Stirling *et al.* 1983; Calvert and Stirling 1985; Jones *et al.* 2014). Described call types include yelps, barks, growls and woofs, most of which are less than 0.5 s long. Little interannual or geographic variation has been found, but seasonal differences have been detected, with fewer calls occurring during open-water periods (Jones *et al.* 2014).

Ringed Seal has a reduced vocal repertoire, quiet volume and lack of geographic variation in acoustic behaviour that is consistent with the hypothesis that there is strong selective pressure to avoid detection under ice (Stirling 1973; Stirling *et al.* 1983; Stirling and Thomas 2003), as is the observation that the range of best hearing in Ringed Seal is over three octaves above their upper limit of dominant vocal energy (Sills *et al.* 2015). Ringed Seal also likely relies, to some degree, on acoustic cues for detecting prey, navigating through Arctic waters and avoiding predators—particularly in a lair, where approaching predators cannot be detected by sight (Schusterman *et al.* 2000).

Parental Care

Ringed Seal pups grow relatively slowly compared to other northern phocids, and have a relatively long lactation period, which requires a significant time and energetic investment from females (McLaren 1958a; Smith 1987; Hammill *et al.* 1991). However, this appears to be a better adaptation than the alternate strategy, employed by other species, of assuming the high energetic costs of building fat reserves (Smith *et al.* 1991). Females also appear to actively supplement any weight lost during lactation by feeding beneath the ice (Hammill 1987; Hammill *et al.* 1991; Smith *et al.* 1991).

Vigilance

Although comprehensive behavioural studies are problematic for a species that spends the majority of its time in subnivean lairs or in water, Ringed Seal appears to invest heavily in vigilance behaviours while hauled out on ice, scanning their surroundings before emerging from the water, re-entering the water then re-emerging several times before settling on the ice and lifting their heads periodically while basking (Smith and Hammill 1981). They appear to use sight, smell and hearing to detect potential threats. Presumably, this is an important adaptation under selection pressure from surface predators (Stirling 1977; Smith and Hammill 1981; predators are also discussed in the **Interspecific Interactions**). Vigilance behaviours vary significantly among individuals, which could be further evidence for a co-evolutionary strategy given that predators could increase their success based on consistent patterns (Stirling 1974; Smith and Hammill 1981). Additional information about vigilance behaviour is presented in **Habitat**.

Dispersal and Migration

Ringed Seal is distributed on a pan-Arctic scale and tracking studies have revealed seasonal and latitudinal differences in dispersal and migration patterns. Although movement can be limited during the winter, likely in relation to sea ice conditions, some subadults and adults migrate long distances during the summer months when sea ice extent is minimal (Kelly and Quakenbush 1990; Teilmann *et al.* 1999; Gjertz *et al.* 2000; Born *et al.* 2004; Harwood *et al.* 2007, 2012a, 2015; Freitas *et al.* 2008a; Kelly *et al.* 2010b; Crawford *et al.* 2012; Yurkowski *et al.* 2016a).

Because no studies have followed individual seals for multiple years, there are only snapshots available to characterize home range size. During the ice-covered season home ranges tend to be smaller, when ice limits movement, and more so when territories are being held in landfast ice. At the same time of year, home ranges can be much larger when animals are in mobile ice or near polynas. During break-up and the open-water season, and/or for juveniles and subadults, home ranges can be broad. Several studies have recorded adults and subadults moving extensively (Smith 1987; Heide-Jørgensen *et al.* 1992a; Kapel *et al.* 1998; Gjertz *et al.* 2000; Freitas *et al.* 2008a; Kelly *et al.* 2010b; Crawford *et al.* 2012; Luque *et al.* 2014; Yurkowski *et al.* 2016b).

Home range sizes of individuals can vary widely but are generally smaller for adults compared to sub-adults (Luque *et al.* 2014). Home ranges of 10,300-18,500 km^2 have been recorded in the North Water area (Teilmann *et al.* 1999; Born *et al.* 2004), and 90% volume contours averaged 21,649 km^2 for adult males, 76,658 km^2 for adult females and 122,854 km^2 for subadults in the Prince Albert Sound and eastern Amundsen Gulf regions, compared to winter ranges, which were on average 15% smaller (Harwood *et al.* 2015). Similarly, although open-water ranges were smaller for Ringed Seal in the Canadian Beaufort Sea (<1-13.9 km^2 for males and <1-27.9 km^2 for females), and were possibly underestimated, some individuals moved up to 1,800 km from their winter/spring home ranges in summer and then returned to the same 1–2 km^2 sites in the winter (Kelly *et al.* 2010b).

There is growing evidence that adults are philopatric, returning annually to the same wintering and breeding sites in the landfast ice in the fall (Smith and Hammill 1981; Kelly *et al.* 2010b), possibly following a similar pattern to their Antarctic counterparts, Weddell Seals, whose site fidelity increases with age and to sites where breeding has been successful (Cameron *et al.* 2007).

When adults start to establish territories in prime breeding areas prior to freeze-up, some subadults embark on long-distance migrations (Smith 1987; Heide-Jørgensen *et al.* 1992a; Teilmann *et al.* 1999; Freitas *et al.* 2008a; Harwood *et al.* 2012a). Some travel thousands of kilometres to areas of high prey abundance (Kapel *et al.* 1998; Freitas *et al.* 2008a; Kelly *et al.* 2010b; Crawford *et al.* 2012; Harwood *et al.* 2012a), likely as an adaptation to reduce competition with adults for resources (McLaren 1958a; Smith and Hammill 1981; Smith 1987; Hammill and Smith 1989; Freitas *et al.* 2008a; Crawford *et al.*

2012). In other areas, their migrations have been linked to advancing and retreating ice (e.g., Crawford *et al.* 2012).

While migrating, subadult travel rates vary. Some of the highest rates (0.9 m/s) have been recorded in the western Canadian Arctic, where travelling distances of 2,138 km between the Canadian Beaufort Sea and Chukchi Sea have been recorded (Harwood *et al.* 2012b). These individuals travelled within 100 km of shore, over the continental shelf or slope, and they moved through three international jurisdictions.

Interspecific Interactions

<u>Predators</u>

Polar Bear, Arctic Fox (*Vulpes lagopus*) and humans are Ringed Seal's most significant predators. Insights into these predator-prey dynamics in Canada have come from scientific studies, as well as Aboriginal Traditional Knowledge studies such as Cleator (2001), Furgal *et al.* (2002), Keith *et al.* (2005) and Joint Secretariat (2015). Human uses of Ringed Seal, including hunting, are discussed in **Special Significance** and **Threats and Limiting Factors**. Other predators include Walrus (*Odobenus rosmarus*), Greenland Shark (*Somniosus microcephalus*), Killer Whale (*Orcinus orca*), and occasionally Common Raven (*Corvus corax*), gulls (family Laridae), Red Fox (*Vulpes vulpes*), Gray Wolf (*Canis lupus*) and Wolverine (*Gulo gulo*) (Kingsley 1990; Reeves 1998; Ridoux *et al.* 1998; Kelly *et al.* 2010a; Lowry 2016).

The Polar Bear's diet mostly comprises Ringed Seal and Bearded Seal (*Erignathus barbatus*), with some regional and temporal variation (Stirling and Archibald 1977; Smith 1980; Stirling and Øritsland 1995; Derocher *et al.* 2002, 2004; Thiemann *et al.* 2008; Galicia *et al.* 2016). When the Ringed Seal pupping season begins in late spring, Polar Bear enters a period of intense feeding that continues into early summer to replenish depleted fat reserves (Stirling and McEwan 1975; Stirling and Archibald 1977; Smith 1980; Ramsay and Stirling 1988). They primarily kill newborn pups, by breaking through the birth lair roof, and will attempt to catch the mother seal when she returns for her pup (Stirling and McEwan 1975; Smith 1980; Kelly *et al.* 2010a; Joint Secretariat 2015). Polar Bear predation increases significantly when pups are prematurely exposed as a consequence of unseasonably warm conditions or when snow depths decrease (Hammill and Smith 1991).

Hunting bears will usually open more than one birth lair in their attempt to kill a seal. Interannual variations in snow conditions may affect the bear's ability to detect and break into lairs (Ramsay and Stirling 1988), and pups in thin-roofed lairs are more vulnerable to predators than those in thick-roofed lairs (Smith and Stirling 1975; Hammill and Smith 1991; Furgal *et al.* 1996; Joint Secretariat 2015). Polar Bear has been observed bypassing non-birth subnivean lairs occupied by adults, and they appear to selectively avoid lairs of rutting males (Smith 1980). Smith (1980) suggested that the strong odour associated with mature males made the meat less palatable.

Polar Bear also stalks seals lying on the ice or at their breathing holes (Kumlien 1879; Freuchen 1935), particularly during the late-spring / early-summer moult when bears are still accumulating fat reserves to last through the ice-free period. They also hunt Ringed Seal in the winter, at which time they are most successful in ice-edge and shear-zone areas inhabited by subadults and less successful at catching breeding adults in the landfast ice (Kingsley 1990). There are accounts of Polar Bear preying on Ringed Seal while swimming (Furnell and Oolooyuk 1980), but these are rare.

Although not to the same degree as Polar Bear, the Arctic Fox is also an important predator of Ringed Seal (Smith *et al.* 1991). Foxes kill newborn seal pups by digging into their birth lairs (Kumlien 1879; Degerbøl and Freuchen 1935; Smith 1976), but only appear capable of killing newborn pups (Smith *et al.* 1991). Predation on a Ringed Seal pup by a Red Fox has also been reported (Andriashek and Spencer 1989).

Atlantic (*Odobenus rosmarus rosmarus*) and Pacific (*O. r. divergens*) Walrus prey on Ringed Seal (Vibe 1950; Mansfield 1958; Fay 1960; Lowry and Fay 1984). Most seal-eating by Pacific Walruses is predation, rather than scavenging (Lowry and Fay 1984), and the presence of Atlantic Walruses tends to drive Ringed Seal away from an area (Reeves 1998).

Greenland Shark is common throughout much of the Arctic, and Ringed Seal may comprise a significant portion of their diet (Fisk *et al.* 2002; McMeans *et al.* 2010; Leclerc *et al.* 2012), although the overall frequency of predation by this species is unknown (Kelly *et al.* 2010a).

Killer Whale prey on Ringed Seal in open water, along ice margins or in areas with low ice concentration, but the whales are limited by their inability to penetrate far into pack ice (Kelly *et al.* 2010a).

Other predators of Ringed Seal pups include Wolves, dogs, Wolverine and Common Raven (Kumlien 1879; Burns 1970; Lydersen and Smith 1989; Kingsley 1990; Burns *et al.* 1998; Reeves 1998). Smith *et al.* (1991) suggested that predation by Glaucous Gull (*Larus hyperboreus*) may be one of the important factors limiting the southern range of Ringed Seal. Predation on newborn pups by surface predators other than Polar Bear and Arctic Fox is typically prevented by the pups' concealment in lairs (see **Physiology and Adaptability**, and discussion of the implications of climate change in **Threats and Limiting Factors**).

<u>Non-Predators</u>

Although Ringed Seal occupies areas of sea ice that are impenetrable by other Arctic species in the winter, they encounter a wide range of species during the open-water season and in areas of pack ice. Where Ringed Seal diets overlap with those of these species, competition may be a factor affecting their distribution and abundance in some circumstances (Kovacs 2014).

Potentially competing species include sea birds, fishes and other marine mammals, including other pinnipeds such as Atlantic Walrus, Bearded Seal, Harp Seal (*Pagophilus groenlandicus*), Harbour Seal (*Phoca vitulina*) and Hooded Seal, although few have explored these competitive relationships. Wathne *et al.* (2000) found 100% niche overlap in the diets of Ringed Seal and Harp Seal in the Barents Sea; however, they also found niche separation, with Harp Seal preying on larger fish than Ringed Seal. Harp Seal migrates into the Arctic during the summer and could be a significant seasonal competitor. There is some indication that Harbour Seal is increasing in Hudson Bay (Florko *et al.* 2018) and has been shown to have some overlap in diet (Young *et al.* 2010).

Ringed Seal ranges also overlap with those of Arctic cetaceans such as Beluga Whale (*Delphinapterus leucas*), Narwhal (*Monodon monoceros*) and Bowhead Whale (*Balaena mysticetus*). Ringed Seal favours some of the same geographic areas that Bowhead Whale and Beluga Whale use for feeding during late summer, presumably because they are highly productive areas (Harwood 1989; Harwood and Stirling 1992; Harwood *et al.* 2015). This overlap may also lead to competition for food resources, especially between Ringed Seal and Beluga (Yurkowski *et al.* 2016b).

POPULATION SIZES AND TRENDS

Sampling Effort and Methods

A variety of techniques have been used to survey Ringed Seal, across multiple spatial scales, including ship surveys (e.g., McLaren 1958b,1962; Diemer *et al.* 2011), crewed aerial surveys of seals and seal holes (and with various detection methods including visual, photographic and infra-red; e.g., Burns and Harbo 1972; Stirling *et al.* 1982; Lunn *et al.* 1997; Chambellant *et al.* 2012; Young *et al.* 2015), and on-ice searches for holes or lairs using trained detection dogs (Smith and Stirling 1978; Hammill and Smith 1990; Williams *et al.* 2006).

Most available abundance or density estimates come from aerial surveys, which are usually conducted during the spring basking period, when the greatest numbers of seals are expected to be hauled out to moult. The number of seals on the ice is sometimes multiplied by a correction factor to estimate population size, or the hauled-out numbers are used as a population index. Environmental conditions can influence haul-out patterns, and the timing of annual snow and ice melt varies widely from one year to another (reviewed by Kelly *et al.* 2010a). Unless surveys are designed to coincide with similar ice and weather conditions, comparisons between years can be erroneous, even if surveys were conducted during the same time of year (Kelly *et al.* 2010a).

Abundance and trends in Ringed Seal populations are difficult to accurately assess due to factors such as the large extent and remoteness of their range, the variable and constantly changing nature of their sea-ice habitat, seasonal and interannual movements and time spent under water/ice, all of which make surveys expensive and logistically challenging (Kelly *et al.* 2010a). There has also been limited international cooperation to conduct large-scale surveys across political boundaries (Kelly *et al.* 2010a). That said, large scale collaborative surveys for Arctic seals have occurred between US and Russian scientists in recent years (Conn *et al.* 2014; Muto *et al.* 2017). Indigenous harvesters also note that it is hard to monitor long-term changes in the abundance of species like Ringed Seal because they are highly mobile and go through cycles in terms of their local abundance (e.g., Berger 1976; Slavik 2013; Joint Secretariat 2015).

Abundance

<u>Global Population Estimates</u>

Estimates of global abundance range from 2.5 million (Miyazaki 2002) to 6-7 million (Stirling and Calvert 1979). Reeves (1998) suggested a world population of no less than a few million animals. Hammill (2009) estimated a “very crude” global population size of the Arctic subspecies to be between 2.8 and 5.1 million seals.

In their assessment of global status of the subspecies, Kelly *et al.* (2010a) divided the range into four regions: Greenland Sea and Baffin Bay; Hudson Bay; Beaufort and Chukchi Seas; and the White, Barents and Kara Seas (a reflection of the geographical groupings of published research studies and not any population structure). They estimated a total population of 2,060,400 individuals, which was conservative because some estimates were not corrected for seals in the water (basking population only) and the full subspecies distribution was not included because data were not available for parts of the Russian Arctic coast and the Canadian Arctic Archipelago.

A recent review compiled regional estimates from a large portion of the *hispida* subspecies’ range, totalling about 2.9 million individuals (Laidre *et al.* 2015), which was used by IUCN in 2016 to estimate the global population of mature individuals to be 1,450,000 animals (Boveng 2016a). An accurate worldwide population estimate is made difficult by the fact that large areas of the species’ range have not been surveyed, and by uncertainty regarding the relationship between observed numbers and actual population sizes (Frost and Lowry 1981; Reeves 1998; Kelly *et al.* 2010a).

<u>Canadian (and Adjacent Areas) Population Estimates</u>

The total Ringed Seal population in Canada and adjacent waters (West Greenland, Alaska and Russia) is estimated as 2.3 million seals, with low confidence, because some areas are lacking information (Table 1). Some areas of the Canadian range have no comprehensive estimates. For example, there have been limited surveys in the Canadian Arctic Archipelago (e.g., Kingsley *et al.* 1985; Kelly *et al.* 2010a) and there is insufficient information to estimate regional abundance.

Table 1. Estimated size of Ringed Seal population in Canada and adjacent waters. Portions of the Canadian range are included based on data availability.

Region (Jurisdiction(s))	Estimate	Source(s)	Comments
Baffin Bay (Canada, Greenland)	787,000	Finley *et al.* 1983	Aerial surveys in 1979. Considered by both Kelly *et al.* (2010a) and Laidre *et al.* (2015) to be best available estimate. Trend unknown, possibly stable (based on Greenland harvests). Alternate model-based estimates (Polar Bear energetic model and sea ice and density models) suggested Baffin Bay population size of 1,200,000 seals (Kingsley 1998).
Hudson Bay, James Bay (Canada)	516,000	Smith (1975)	1974 aerial surveys, densities extrapolated to entire region based on the distribution of ice types. Includes 61,000 seals in James Bay (considered an underestimate due to the advanced break-up of the ice at time of the survey and subsequent low density estimates). Laidre *et al.* (2015) used this estimate in their assessment, with an unknown trend. Recent surveys suggest that abundance (density) follows a cyclical pattern (Young *et al.* 2015). This estimate does not include Foxe Basin.
Beaufort and Chukchi Seas (Canada, USA, Russian Federation)	1,000,000	Frost *et al.* (2004); Bengtson *et al.* (2005)	Kelly *et al.* (2010a) (and Laidre *et al.* 2015) considered 1,000,000 seals a "reasonable estimate" for the total population, including at least 50,000 in Canadian waters, with an unknown trend.
Total	2,303,000		Negatively biased - excludes areas of Ringed Seal range in Canada, e.g., central Arctic Archipelago, Labrador coast.

Numerous surveys have been conducted in relatively small study areas, but it is difficult to extrapolate to regional-scale estimates. There are also no estimates available for Ringed Seal abundance along the Labrador coast (although local Inuit reported that the population was increasing in the mid-1990s, chiefly due to a decline in harvesting, Williamson 1997). It must also be noted that much of the information used to generate the total population estimate is dated; however, the sources used, and alternate sources and estimates, are discussed below for each region. A total population of 2.3 million Ringed Seal translates to 1,150,000 mature individuals, assuming 50% adults as per the IUCN assessment (Boveng 2016a).

<u>Baffin Bay Region Population Estimates</u>

Surveys in 1979 covered northeast Baffin Island landfast ice and Baffin Bay pack ice habitats (Finley *et al.* 1983). More than 67,000 seals were estimated for the landfast ice areas, with another 417,000 in the Baffin Bay pack ice. The estimate was corrected to a total of 787,000 seals in Baffin Bay (Canada and Greenland) once seals missed during the surveys were accounted for (Finley *et al.* 1983). Miller *et al.* (1982) reported on surveys of West Greenland landfast ice that were also conducted in 1979, estimating 97,800 Ringed Seal for that region of eastern Baffin Bay. They also estimated an additional 15,500 seals in the landfast ice along the east coast of Devon Island and north to 80° latitude (Miller *et al.* 1982).

Kelly *et al.* (2010a) used the estimate of 787,000 by Finley (1983) as the only comprehensive estimate available for the region, and they considered the relative consistency of Greenland harvests over time (Kapel and Rosing-Asvid 1996) to provide some confidence that the population has not significantly changed. Laidre *et al.* (2015) also used the 1979 estimate of 787,000 seals in Baffin Bay (Finley *et al.* 1983) in their assessment but considered the trend to be unknown.

Kingsley (1998) estimated the size of the Baffin Bay Ringed Seal population using two methods, one based on Polar Bear energetic models and another using published density data and estimates of ice areas. He used linked models of Polar Bear growth and energy needs, Polar Bear population structure and Ringed Seal energetic yield to estimate that a standing population of 1.2 million Ringed Seal would be needed to sustain Polar Bear predation levels and a human harvest of 100,000 seals per year (and assuming that the entire population is accessible to harvest/predation; the standing population would be higher if it was partly inaccessible). The estimate based on sea ice type and availability and estimated Ringed Seal density was 697,200 hauled out ("sightable") seals, which would yield a similar population estimate as the Polar Bear predation model (1.2 million seals) (Kingsley 1998).

<u>Hudson Bay Region Population Estimates</u>

The earliest population estimate for Ringed Seal in this region was 218,300 in the 1950s, based on density estimates in different types of landfast ice and the amounts of those ice types available (McLaren 1958b). In 1974, Smith (1975) conducted aerial surveys throughout much of western Hudson Bay. Flight tracks were categorized by ice type, and survey densities were extrapolated to the entire region based on the distribution of ice types, resulting in an estimate (rounded to the nearest 1,000) of 455,000 Ringed Seal in Hudson Bay. This estimate was much larger than the 1950s estimate, but Smith (1975) included pack ice habitats in his calculations, which McLaren (1958b) did not. Smith (1975) estimated an additional 61,000 seals in James Bay, and considered this to probably be an underestimate due to the advanced break-up of the ice at the time of the survey and subsequent low density estimates. Laidre *et al.* (2015) used this combined estimate of 516,000 seals in Hudson and James bays in 1974 (Smith 1975) in their assessment, with an unknown trend.

More recent aerial survey estimates are available, but they are limited to western Hudson Bay and have generally reported on hauled-out abundance (a population index, and not a population estimate). Young *et al.* (2015) report on data from systematic aerial strip transect surveys flown in western Hudson Bay in late May to early June of 1995-1997, 1999, 2000, 2007-2010 and 2013 (also see Lunn *et al.* (1997) and Chambellant *et al.* (2012)). Each survey attempted to replicate the same 10 transects from the Hudson Bay shoreline in the west to the 89° W longitude line in the east, and from Churchill, Manitoba in the south to Arviat, Nunavut in the north—a study area originally designed by Lunn *et al.* (1997) to cover the winter and spring hunting habitat of the Western Hudson Bay Polar Bear population (Stirling and Derocher 1993). The density of hauled out Ringed Seal ranged from 1.22 seals/km^2 in 1995 (population index = 104,162 seals) to 0.20 seals/km^2 in 2013 (population index = 16,746 seals). Density estimates varied significantly and followed a cyclical pattern with the exception of 2013 (Young *et al.* 2015; Ferguson *et al.* 2017). There was an overall negative trend over time, but a multiple linear regression weighted by survey effort showed no significant trend in density. The authors suggested that the low density estimate in 2013 might indicate that population changes unrelated to a natural cycle are taking place (Young *et al.* 2015).

Ferguson *et al.* (2017) compared environmental patterns to Ringed Seal reproduction, body condition, recruitment and stress in Hudson Bay from 2003 to 2013, linking longer open-water periods to decreased body condition and increased stress (cortisol). During this period, the year 2010 was the earliest spring break-up and the latest ice formation in Hudson Bay, which coincided with high cortisol levels and declines in reproductive rates. Ferguson *et al.* (2017) concluded that while negative demographic responses were gradually occurring with sea ice declines in Hudson Bay, an episodic environmental event had likely played a significant role in a punctuated decline in Ringed Seal abundance.

Ringed Seal is also found throughout Foxe Basin, north of Hudson Bay. McLaren (1958b) also estimated the number of seals in this region (ca. 100,000 seals), using the same methods described above, but no recent data are available except some limited industry-sponsored surveys (e.g., BIMC 2012). No Foxe Basin abundance estimates are reported here.

<u>Beaufort and Chukchi Seas Population Estimates</u>

Most population assessments in the Beaufort and Chukchi Seas are confined to Canadian and U.S. waters, and there are few data for animals in the Russian sector (Kelly *et al.* 2010a). Surveys were conducted in 2012 and 2013 but have not been fully analyzed (Conn *et al.* 2014; Muto *et al.* 2017). Based on aerial surveys in 1985-1987, Frost (1985) derived estimates of 250,000 Ringed Seal in the Alaskan landfast ice of the Chukchi and Beaufort Seas, with a total of 1-1.5 million when seals in pack ice habitats were included. The most recent Bering Sea estimate is 170,000 seals (Conn *et al.* 2014).

In western Canadian Arctic waters, surveys in some areas were first flown in the early 1970s (Smith 1987), and extensive surveys were flown in the early 1980s (Kingsley and Lunn 1983). The 1981 and 1982 surveys of the eastern Beaufort and Amundsen Gulf regions were the most comprehensive. Kingsley and Lunn (1983) estimated the number of hauled-out Ringed Seal in the eastern Beaufort at 5,400-5,500 and the number in Amundsen Gulf as 30,900 in 1981 and 70,500 in 1982. This wide interannual variability is similar to other regions (e.g., western Hudson Bay; Lunn *et al.* 1997) and highlights the need for a better understanding of the relationships between Ringed Seal behaviour, environmental conditions and survey methods (Kelly *et al.* 2010a). Surveys in the southern Canadian Beaufort Sea have revealed decadal-scale fluctuations in Ringed Seal abundance (Stirling *et al.* 1977, 1982; Smith 1987; Harwood and Stirling 1992), and it is suggested that these changes mainly relate to environmental variation, particularly changes in the sea ice regime (Stirling *et al.* 1977; Smith 1987).

Kelly *et al.* (2010a) summarized the available data (e.g., Frost *et al.* 2004; Bengtson *et al.* 2005) for the Beaufort and Chukchi Seas in their status assessment, and they considered a “reasonable estimate” for the total population to be 1,000,000 seals (not assigned to any particular year(s)), including at least 50,000 in Canadian waters (eastern Beaufort Sea and Amundsen Gulf). Laidre *et al.* (2015) used the Kelly *et al.* (2010a) estimate in their summary, with an unknown population trend. Hammill (2009) suggested total of 1-1.5 million seals for Alaska.

Fluctuations and Trends

There are no data available for a wide-ranging population assessment, and there is insufficient information on trends at the level of the designatable unit (i.e., the entire range in Canada and adjacent areas) and limited data at the regional (or smaller) level. This adds substantial uncertainty to any status assessment. For example, Kelly *et al.* (2010a) assumed that seal numbers in Baffin Bay were stable because Greenland harvests have remained relatively consistent over time, but this assumption has not been tested. Surveys for Ringed Seal abundance generally occur at smaller spatial scales than the regions discussed above, and it is difficult to extrapolate results to larger regions (see **Abundance**). Surveys in the southern Beaufort Sea (Stirling *et al.* 1977, 1982; Smith 1987; Harwood and Stirling 1992) and western Hudson Bay (Young *et al.* 2015) have revealed decadal-scale fluctuations in Ringed Seal abundance that are thought to be related to environmental variation, particularly changes in the sea ice regime (Stirling *et al.* 1977; Smith 1987; Ferguson *et al.* 2017). In western Hudson Bay, there has been an overall negative trend in density over time, but the decline is not statistically significant.

Some harvesters believe seals are travelling to places where there are better ice conditions, but that their numbers have not declined (e.g., Slavik 2013). Hunters in Alaska have described some local reductions in seal abundance due to changing ice conditions, but they note that Ringed Seal remains abundant and that the overall population is stable (Voorhees *et al.* 2014; Huntington *et al.* 2016, 2017). The degree of interchange between these seals and those in western Canadian waters is unknown.

Inuit in the central Arctic community of Gjoa Haven, Nunavut have indicated that the population of Ringed Seal in the area is healthy (Keith *et al.* 2005; Government of Nunavut 2012). In Taloyoak, Nunavut, hunter observations have been variable and contradictory, with some saying Ringed Seal numbers have decreased over time and others suggesting they have increased over time (Government of Nunavut 2015). Hunters in Grise Fiord, Nunavut have observed a decrease in the number of Ringed Seal in their area (Government of Nunavut 2013). Baffin Bay harvesters who were interviewed about Polar Bear provided little information on Ringed Seal abundance, with one Qikiqtarjuaq, Nunavut interviewee saying that changing ice conditions were making it harder for bears to find seals, but noting that the seal population was unchanged (Dowsley 2005, 2007). Pangnirtung, Nunavut Inuit have reported seeing fewer Ringed Seal in Cumberland Sound, noting a suspicion that this is related to increased human activities and noise pollution in addition to increased predation from a growing Polar Bear population (Government of

Nunavut 2014). Some Aboriginal Traditional Knowledge holders in southern Davis Strait reported that seal numbers were low from 2005 to 2010, and that a larger proportion of seals were adults, possibly due to climate change impacts on pups (Kotierk 2010). Hunters in Chesterfield Inlet, Nunavut (western Hudson Bay) have reported that Ringed Seal is decreasing in number (Government of Nunavut 2010). Overall, there are reports of declines in some areas, but information is not available across the entire species range. It is also unknown whether local changes represent declines or distribution shifts with sea ice changes (Slavik 2013).

Ringed Seal recruitment and abundance are related to both ice and snow conditions (Harwood *et al.* 2000, 2012b; Ferguson *et al.* 2005; Iacozza and Ferguson 2014; see **Habitat**). Environmental extremes, including both heavy-ice years and years with early break-up, can have negative demographic effects (Harwood *et al.* 2012b; Ferguson *et al.* 2017). Arctic sea ice has changed significantly in the last 30 years and there has been an increase in the length of the open-water season, due to both earlier spring break-up and later fall freeze-up (Parkinson and Cavalieri 2002; Gagnon and Gough 2005; Parkinson 2014; Laidre *et al.* 2015). Snow cover on sea ice is a critical component of pupping habitat (Smith and Stirling 1975; Lydersen and Smith 1989; Kelly and Quakenbush 1990; Smith and Lydersen 1991). Spring snow depth has been declining in western Hudson Bay, with negative impacts on Ringed Seal (Ferguson *et al.* 2005). Models predict continued declines in spring snow depth, with direct effects on Ringed Seal recruitment (Hezel *et al.* 2012; Iacozza and Ferguson 2014).

Rescue Effect

Ringed Seal has a high dispersal ability (see **Dispersal and Migration**), and genetic analysis has not identified major constrictions to gene flow across their circumpolar range (see **Population Spatial Structure and Variability**). As such, the Canadian Ringed Seal population is fully connected to Ringed Seal in other Arctic regions (e.g., western Greenland/ eastern Baffin Bay, Alaskan and Russian Beaufort/Chukchi Seas) that could provide immigrants adapted to live in Canadian waters.

THREATS AND LIMITING FACTORS

Threats

Direct threats faced by Ringed Seal assessed in this report were organized and evaluated based on the IUCN-CMP (World Conservation Union-Conservation Measures Partnership) unified threats classification system (Master *et al.* 2012). Threats were defined as the proximate activities or processes that directly and negatively impact Ringed Seal. These were assessed for the one DU, with results on the impact, scope, severity, and timing presented in tabular form in Appendix 1.

The overall calculated and assigned threat impact is High to Low. The greatest potential anthropogenic threat to Ringed Seal is projected habitat loss due to climate change. The other threats of Energy Production & Mining, Transportation & Service Corridors, and Biological Resource Use were considered negligible.

Climate change & severe weather [IUCN Threats #11.1 – Habitat shifting & alteration] – High to Low

Although some benefits (e.g., shifts from multi-year to annual ice in the Canadian Arctic Archipelago) may occur in the short-term and in some areas, loss of habitat due to climate change is a major threat in the medium (next three generations) to long term for Ringed Seal. Estimates of the time until an ice-free summer occurs in the Arctic vary, but this could occur as early as 2020-2050 (Serreze *et al.* 2007; Overland and Wang 2013) and significant ice reductions in southern areas of the range could occur much sooner (Castro de la Guardia *et al.* 2013). A study on the demography of Ringed Seal in Amundsen Gulf and Prince Albert Sound projected declines in Ringed Seal population size in all but the most optimistic climate change scenarios (Reimer *et al.* 2019).

Loss in snow cover is expected to increase susceptibility of Ringed Seal to predation (NOAA 2012). Loss of sea ice could have direct effects on Ringed Seal populations by reducing pup survival, increasing the energetic costs of moulting and reducing haul-out sites important for resting (see **Habitat**). Where sea ice loss causes the ice to retreat over deep, unproductive waters, Ringed Seal travels farther, dives longer and spends less time hauled out on ice—suggesting that they are expending more energy to forage than in the past (Hamilton *et al.* 2015). Indirect effects include shifts in ecosystem composition and function (see **Habitat**), access by novel predators and competitors (see **Interspecific Interactions**) and increased anthropogenic activity.

Inuvialuit harvesters indicate that Ringed Seal needs the type of environmental conditions that are good for ice algae accumulation, because Arctic cod feed on the algae and seals eat the cod (Joint Secretariat 2015). New scientific research supports these observations and shows that ice algae are a critical component of the Arctic marine food web through all trophic levels (Brown *et al.* 2018). Therefore, not only will declines in sea ice reduce physical habitats for Ringed Seal, but it will also potentially lead to changes in the supply of energy through the system.

Acidification

Warming ocean waters and higher atmospheric CO_2 levels will cause increased acidification of the oceans (summarized in Kelly *et al.* 2010a). The effects of acidification are expected to be most significant in lower trophic levels, where they can affect the ability of some zooplankton to form calcium carbonate shells (Orr *et al.* 2005). Acidification may also affect the physiology of marine invertebrates and fish (Pörtner *et al.* 2004; Pörtner 2008). Recent rates of change in acidity have been 100 times faster than in the last 100,000 years (Raven *et al.* 2005). It is expected that these changes could have indirect effects on Ringed Seal if the ecosystem is restructured due to acidification (Kelly *et al.* 2010a).

Acidification has secondary impacts because a lowered pH reduces the absorption of low frequency sound (Brewer and Hester 2009). This will make the oceans noisier in the same range of frequencies important for some marine mammals. Although Ringed Seal is not thought to use sound to communicate in the same manner as other seals (e.g., Bearded Seals) and whales, increasing acoustic noise in the marine environment may have other unknown effects such as masking the approach of predators.

Invasive & other problematic species & genes (IUCN Threats #8.2 [Problematic native species/diseases], 8.6 [Diseases of unknown cause]) – Unknown

Disease

Ringed Seal has co-evolved with a variety of parasites and diseases. Information on pathologies is limited (Tryland *et al.* 1999), but some new information has become available in recent years. Antibodies for the morbillivirus phocine distemper virus (PDV) (Cosby *et al.* 1988), which is antigenically related to canine distemper (Liess *et al.* 1989), were found in Ringed Seal in eastern Canada in the 1980s and across Arctic Canada in the early 1990s (Osterhaus *et al.* 1988). The prevalence was highest in areas of the eastern Canadian Arctic, where Ringed Seal was sympatric with Harp Seal (Duignan *et al.* 1997), which have been implicated in a PDV epizootic in Harbour Seal populations in western Europe in 1998 (Heide-Jørgensen *et al.* 1992b). Overall, prevalence of PDV has been higher than expected in Ringed Seal considering their solitary and territorial behaviour, although transmission could occur among subadults aggregating in sub-optimal breeding habitat (Duignan *et al.* 1997).

The number of tumours reported in marine mammals has increased, including the first case of adenocarcinoma of the small intestine in Pinnipedia, which was reported for an 11-year old Ringed Seal in Hudson Bay (Mikaelian *et al.* 2001). This increase, however, may be more of an indication of the number of animals and pathogens being investigated than of actual prevalence. The same can be said for parasites. However, some potential expansions have been confirmed by Aboriginal Traditional Knowledge, such as the increase in the frequency of liver abnormalities Inuit hunters reported in their Ringed Seal catches in Admiralty Inlet, Nunavut (Furgal *et al.* 2002). The small white nodules and lesions may have been caused by an infection by a trematode, which had been previously reported in the livers and gall bladders of Ringed Seal (Dawes 1956), but the reason for the increased prevalence is unclear. An Inuit hunter from Clyde River also recently reported that the livers of some seals did not appear healthy (Dowsley 2005, 2007).

Since 2011, a novel ulcerative dermatitis disease has been reported in Ringed Seal from Northern Alaska (Stimmelmayr in Kovacs 2014). The disease is characterized by a variety of lesions on the eyes, snout, hind flippers, tail and trunk of all age classes. Affected individuals are lethargic and unusually approachable and have an increased tendency to haul out on land (Huntington *et al.* 2016, 2017). Inuvialuit hunters have also found dead seals on beaches, and with similar symptoms, in the Canadian Beaufort Sea (Joint Secretariat 2015). The disease appears to impact the lungs, liver and immune system, and results in some mortality (Kovacs 2014). Hunters in Davis Strait, Baffin Bay and eastern Hudson Bay have also observed hair loss in Ringed Seal (Dowsley 2005, 2007; Kotierk 2010; Government of Nunavut 2011). Nunavik hunters have expressed concern about the health of Ringed Seal in Hudson Bay, Ungava Bay and Hudson Strait, with observations of sick seals and changes in condition (seals sinking instead of floating) (Nunavik Marine Regional Wildlife Board, unpublished data).

Intracellular pathogens from the genus *Brucella* have also been detected in Ringed Seal. Forbes *et al.* (2000) were the first to find this organism in an individual from Pangnirtung in 1995, and this was the first confirmed case of brucellosis in marine mammals from Canada. Nielsen *et al.* (1996) found anti-*Brucella* antibodies in Ringed Seal through a serological survey of marine mammals from the Canadian Arctic. Although some hosts are asymptomatic, Brucellosis infections have been associated with placentitis/abortions, neonatal mortality, meningoencephalitis, abscesses and other syndromes in marine mammals. The *Brucella* bacteria is likely transmitted to Ringed Seal from enzootically infected animals such as the Arctic Fox (Nielsen *et al.* 1996, 2001; Tryland *et al.* 1999). In one study, the infection in true seals sampled in Alaska seems to be relatively common yet shown to be transient and decreasing with increasing age for Harbour Seal, becoming virtually absent at the age of sexual maturity. Similar patterns were present also for the other true seal species including Ringed Seal; however, firm conclusions could not be made due to sample size (Nymo *et al.* 2018). Quakenbush tested Ringed Seal sampled in Alaska between 2003 and 2014 and reported that 4 of 93 (4.3%) tested positive (Quakenbush 2015).

Ringed Seal is also an intermediate host of one of the most common parasites in the world (Tenter *et al.* 2000), the coccidian parasite *Toxoplasma gondii*, which is a cause of encephalitis in marine mammals (Dubey *et al.* 2003). In the first large-scale study of *T. gondii* in the Canadian Arctic, Simon *et al.* (2011) found that prevalence in Ringed Seal ranged from 2.4% in Chesterfield Inlet, to 5.8–7.9% in Ulukhaktok, Tuktoyaktuk, Sachs Harbour and Sanikiluaq, to 15.6% in Arviat and 23.1% in the Hall Beach area. They also found year-to-year variation in prevalence and reported that seroprevalence did not increase continuously with age (Simon *et al.* 2011). This latter pattern did not appear to be linked to morbidity or mortality rates of *T. gondii* infection (Gajadher *et al.* 2004), transplacental transmission (Miller *et al.* 2008; Dubey 2010) or spontaneous clearing of infection from adults (Gajadher *et al.* 2004; Dubey 2010), and the authors concluded that it likely indicates that Ringed Seal becomes infected at a young age (Simon *et al.* 2011). The behaviour(s) that subject young seals to higher rates of infection remains unclear, but diet likely plays a role (Born *et al.* 2004; Robertson 2007; Massie *et al.* 2010; Vincent-Chambellant 2010).

Wild and domestic felids are the only known definitive hosts of *T. gondii* (Measures *et al.* 2004; Dubey 2010), which appears to be transferred to marine environments via oocysts in surface run-off (Conrad *et al.* 2005; Miller *et al.* 2008). Fecal contamination of marine environments by terrestrial mammals is also a problem for other protozoan parasites such as *Giardia* and *Cryptosporidium* (Appelbee *et al.* 2005; Miller *et al.* 2010). Cysts from *Giardia* were found in Ringed Seal in the Ulukhaktok area of the Northwest Territories in

1997 (Olsen *et al.* 1997), which appears to be the first report of this infection in marine mammals. These seals were also tested for *Cryptosporidium* but were negative, although infections have been found in other Ringed Seal (Hughes-Hanks *et al.* 2005). Transmission from terrestrial and marine mammals could also be occurring with *Neospora canium*, the antibodies for which were first reported in Ringed Seal in Alaska, but the mode of transmission is unclear (Kovacs 2014).

The most abundant parasites hosted by Ringed Seal are helminths of the gut tract (Johansen *et al.* 2010), including nematodes that create some damage to the tissue of their intermediate and definitive hosts. Ringed Seal is often infected by anisakids, the adult and larval stages of which live in the gastric and intestinal parts of the digestive tract. Common species include *Contacaecum osculatum*, which is morphologically indistinguishable from another anisakid worm, its sister species *Pseudoterranova decipiens* (McClelland 1980; Brattey and Stenson 1993). *P. bulbosa*, a nematode previously only recorded in Bearded Seal, was also recently found, along with *C. osculatum*, in the stomach of a Ringed Seal in Arviat, Nunavut (Karpiej *et al*, 2014). Ringed Seal appears to be the definitive host for *C. osculatum* and *P. decipiens*, based on evidence of adult specimens in the stomachs of Ringed Seal from Arviat (Soltysiak *et al.* 2013). Both species have been associated with ulcerous gastric lesions and inflammation in the stomach (McClelland 1980), where the degree of pathological changes appears to be determined by proportion of each species, size of infection and host diet and immunity (Soltysiak *et al.* 2013).

The nematode *Trichinella nativia* has been found in Ringed Seal at low prevalences (Forbes 2000). A lower prevalence in Ringed Seal compared to Polar Bear, Walrus, and Arctic Fox could be because cannibalism is a primary means of infection for these hosts and Ringed Seal is only infrequently exposed to infected carcasses (Forbes 2000).

Ringed Seal is also host for three genera of lung nematodes: *Otostrongylus* sp., *Dipetalonema* sp. (Delyamure 1955) and *Parafilaroides* sp. (Delyamure and Alexiev 1966), two of which have been reported in Ringed Seal in the Amundsen Gulf. There, *Parafilaroides hispidus* caused no significant lesions but *O. circumlitus* caused extensive mucous production, mucosal hyperplasia, peribronchitis and endarteritis, mainly in young of the year, 28% of which had concurrent infections (Onderka 1989). The prevalence of the nematode is similar in the eastern Arctic (Bergeron *et al.* 1997), and it could also be impacting diving abilities, and ultimately survival (Bergeron *et al.* 1997; Gosselin *et al.* 1998). The heartworm *Acanthocheilonema spirocauda* (Measures *et al.* 1997) also infects Ringed Seal, particularly when they are young.

<u>Pollution (IUCN Threats #9.1 [Domestic & urban waste water], 9.2 [Industrial and military effluents], 9.3 [Agricultural and forestry effluents], 9.4 [Garbage & solid waste], 9.5 [Air-borne pollutants]) – Unknown</u>

Much of the work on pollutants and contaminants in Ringed Seal relate to human health concerns for northern people who consume marine mammals; secondarily, some research has also focused on the implications for Polar Bear and possible population effects of contaminants (Zhu *et al.* 1995; Dietz *et al.* 1998; Muir *et al.* 1999; Fisk *et al.* 2005;

Letcher *et al.* 2010; AMAP 2018). Ringed Seal is one of the top predators in the Arctic food chain and, as such, can bioaccumulate these compounds. Tynan and DeMaster (1997) noted that climate change could increase the transport of pollutants into the Arctic from lower latitudes due to increased precipitation bringing more contaminated water to the Arctic.

Noise

Exploration and drilling activities, and the infrastructure needed to supply and maintain sites, can be a source of disturbance through direct displacement of animals from habitat. Noise has been identified as a potential source of disturbance for Ringed Seal in this context (Southall *et al.* 2007). Seismic surveys create a sound wave that is used to image the sea floor and subsurface layers. In recent years, for open-water surveys, the sound waves are created using compressed air (Harris *et al.* 2001). Using a mid-powered airgun array, Harris *et al.* (2001) noted some avoidance by Ringed Seal of areas within 150 m of operation but little change in behaviour farther from the ship. They did note the most common behaviours were diving and swimming away, but also noted that the observers were primarily tasked with detection of marine mammals within a defined radius and thus could not follow behaviours effectively. They observed seals close to the array when it was firing but overall seals were farther away (median distance 234 m) during operations compared to when the guns were not firing (median distance 144 m). Seismic exploration activities have been approved for the Canadian side of Baffin Bay but court challenges are ongoing (Skura 2016).

Ringed Seal is also susceptible to disturbance by noise during the ice-covered season when they are hauled out in dens or on the ice moulting. Kelly *et al.* (1986) documented Ringed Seal exiting their dens in response to a variety of anthropogenic activities from approaches by humans and dogs to snowmobiles and helicopters. In general, they found that mechanical noise caused a reaction at farther distances. They also observed that there were fewer active seal structures within 150 m of seismic lines and that Ringed Seal abandoned dens three times more frequently in areas of noise disturbance (Kelly *et al.* 1986). The energetic cost of abandoning a den is unknown but may be significant (Kelly *et al.* 2010a). Moulton *et al.* (2005) surveyed haul-out densities of Ringed Seal before, during, and after the construction of a gravel island and subsequent drilling operations. They concluded that there was no significant change in spring Ringed Seal density over this time period (1997 to 2001; Moulton *et al.* 2005). Similarly, Harwood *et al.* (2007) found no detectable effect of one season of drilling on Ringed Seal in the Beaufort Sea using a before – during study design. Using telemetry data, Cott *et al.* (2003) reported that seismic surveys in the Beaufort Sea did not appear to affect the timing or route of Ringed Seal migration.

Noise also could potentially cause physical damage to seals near the source. This could be in the form of hearing loss or auditory threshold shifts (Clark 1991). Although seals have been observed near sources of intense sound (e.g., seismic activity, blasting, pile driving) it is unknown if they incur hearing damage. Hastie *et al.* (2015) tracked Harbour Seals and predicted noise levels for each seal due to pile driving activities. They suggest that for half of the seals they tracked the sound exposure exceeded the estimated permanent auditory damage threshold. The noise impacts on Ringed Seal remain largely unknown.

Spills

Risk of harm to marine mammals from an oil spill has long been identified (Engelhardt 1983) and some oiling experiments have been conducted on Ringed Seal (Smith and Geraci 1975; Engelhardt *et al.* 1977). They may be at higher risk in the event of an oil spill when there is ice cover because the oil will concentrate in cracks and leads that seals are forced to use to breathe (Engelhardt 1983). Contact and ingestion can occur when compounds are inhaled or can occur when the oil adheres to the fur and is either absorbed through the skin or when it is groomed off (Smith and Geraci 1975). Engelhard (1983) noted that oiled seals passively cleaned their pelage within one day of swimming in clean water in contrast to Sea Otter (*Enhydra lutris*) and Polar Bear, which groomed the oil out of their pelage. However, kidney damage was noted along with potential liver involvement that could progress if the experiment was longer (7 days) (Engelhardt *et al.* 1977).

Smith and Geraci (1975) conducted field and laboratory oiling experiments and while seals oiled in the field recovered, all three laboratory-oiled seals died within 71 min of oiling. They noted that the laboratory animals likely had much higher levels of stress related to captivity that contributed to the outcome but also noted that oil spills in a year which seals were already stressed could have a magnified impact on the population (Smith and Geraci 1975). Eye damage has also been noted as a risk to Ringed Seal in oiled waters (Engelhardt 1983).

Direct exposure to crude oil damages Ringed Seal eyes and accumulates in some tissues, and prolonged exposure could be fatal, but the potential impacts of oil spills on Ringed Seal populations are unclear in expansive areas where seals can avoid the affected area (McLaren 1990). However, residues from the consumption of oiled fish can accumulate in tissues such as blubber, which compromises liver and kidney function when metabolized (Smith and Geraci 1975; Engelhardt 1983). In addition, the impacts of oil spills on Ringed Seal populations could be severe if they occurred close to breeding habitats (Smith 1987).

Persistent Organic Pollutants

Persistent organic pollutants (POPs) found in pesticides have been shown to accumulate in the fatty tissues of lower trophic levels and be transferred up the food chain to Ringed Seal (Muir *et al.* 1988, 1992, 1999; Letcher *et al.* 2010; AMAP 2017). In particular, organochlorine contaminants (OCs) have been a concern given the impacts on health and reproductive performance of seals (e.g., Helle *et al.* 1976; Helle 1980). While concentrations of "legacy" OCs in Ringed Seal have declined significantly in the Arctic (Addison and Smith 1974; Muir *et al.* 1999; Rigét *et al.* 2004, 2018), those of OCs such as chlorobenzenes and endosulfan have been increasing in the Canadian Arctic (Muir *et al.* 1999; Rigét *et al.* 2018), with higher concentrations observed in the west than in the east (e.g., Kucklick *et al.* 2006).

Several new classes of chemicals have been detected in Ringed Seal such as polybrominated diphenyl ethers (PBDEs), short chain chlorinated paraffins (SCCPs), polychlorinated naphthalenes (PCNs), perfluoro-octane sulfonic acids (PFOS) and perfluorocarboxylic acids (PFCAs) (Martin *et al.* 2004; Wolkers *et al.* 2004; Bossi *et al.* 2005; Braune *et al.* 2005; Quakenbush 2007; Quakenbush and Citta 2008). PBDEs are widely used as flame retardants and are known to accumulate in lipids (Hites 2004; AMAP 2017). Levels are increasing in humans and marine mammals with a doubling time of about 7 years for Canadian marine mammals (Hites 2004). However, research is only starting to emerge regarding levels, trends and effects for most compounds (Kovacs 2014).

Heavy Metals

Important heavy metals studied in Ringed Seal include mercury, lead, cadmium, nickel, arsenic and selenium (see Wagemann and Muir 1984; Wagemann *et al.* 1996; Rigét and Dietz 2000; Dietz *et al.* 2013). Mercury and cadmium have been studied across the range of Ringed Seal and are variable among sites, with higher mercury concentrations in the liver in the western Canadian Arctic and higher cadmium levels in the eastern Canadian Arctic (Rigét *et al.* 2005). They also found that concentrations of both mercury and cadmium were higher in adult seals compared to subadults in all locations.

The long-term pattern in mercury concentration derived from teeth indicates that levels were low and stable in the western Canadian Arctic from pre-industrial times to the 19^{th} century but then increased dramatically in the current era (Outridge *et al.* 2009). On a short-term scale, a pattern of higher muscle mercury levels in both shorter (heavier ice) and longer (light ice) open-water seasons compared to average years was detected in Ringed Seal from the Amundsen Gulf (Gaden *et al.* 2012). The authors attributed this to changes in the availability of prey (Arctic Cod) and thus mercury exposure.

Limiting Factors

<u>Predation</u>

Ringed Seal is vitally important prey for Polar Bear, which typically consume one seal every few days when hunting on sea ice (Kovacs 2014). Bears hunt seals in moving, offshore ice, as well as along floe edges and on stable shorefast ice (Stirling and Archibald 1977; Stirling and Latour 1978; Smith 1980). In winter, they are most successful in ice-edge and shear-zone areas inhabited by naive subadult seals, and have less success catching breeding adults in the fast ice (Kingsley 1990; Keith *et al.* 2005; Joint Secretariat 2015).

Hammill and Smith (1991) estimated that 75-100% of Ringed Seal killed by Polar Bear were pups, and that bears removed from 8 to 44% of the annual pup production prior to weaning in Barrow Strait. However, they considered this a potential underestimate given that their study concluded 4-6 weeks prior to break-up, a period during which bears would have continued to feed heavily (Ramsay and Stirling 1988).

Stirling and Øritsland (1995) calculated that a population containing 1,800 Polar Bear would need ca. 77,400-80,293 Ringed Seal per year, and Kingsley (1998) estimated that the Polar Bear in Baffin Bay (N = ca. 4,000) would need to eat 120,000 to 160,000 Ringed Seal per year to sustain themselves. Across the entirety of the Canadian range, Kingsley (1990) estimated that 15,000-20,000 Polar Bear, each needing 40 seals/year, would kill 600,000-800,000 seals annually—an order of magnitude larger than the human harvest.

The global distributions of Arctic Fox and Ringed Seal overlap broadly (Hersteinsson and Macdonald 1992), and foxes spend considerable time on the sea ice (Smith 1976; Kingsley 1990; Roth 2002; Pamperin *et al.* 2008). In the western Canadian Arctic, Arctic Fox was the most frequent cause of death among young (< 1 year old) Ringed Seal, with 9-40% of the annual pup production killed (Smith 1976, 1987). Significant predation has also been documented in the southeast Baffin Island area (Smith 1976; Smith *et al.* 1979). In other regions, Arctic Fox entered 21% (Svalbard) and 13% (Alaskan Beaufort Sea) of lairs and killed 38% and 25% of the pups in those lairs, respectively (Lydersen and Gjertz 1986; Kelly and Quakenbush 1990). There are no estimates of the average or typical rates of fox-related mortality across the species' range (Kingsley 1990). As with Polar Bear, interannual variation in Ringed Seal predation rates have been detected for Arctic Fox, with rates increasing in years when lemming (*Lemmus trimucronatus* and *Dicrostonyx* sp.) populations are low (Roth 2003).

There is no information on predation rates from Atlantic Walruses, but Inuit in eastern Canada note that it occurs most often in areas where deep water makes it harder for Walruses to access benthic prey (Gunn *et al.* 1988; Piugattuk 1990; Kappianaq 1992; Kappianaq 1997). Predation by Greenland Sharks similarly cannot be quantified (Kelly *et al.* 2010a).

Killer Whale observations are increasing in both the eastern Canadian Arctic and in Alaskan and Russian waters (the Beaufort and Chukchi seas; George and Suydam 1998; Melnikov *et al.* 2007; Higdon and Ferguson 2009; Higdon *et al.* 2012, 2014). Killer Whale Predation on Ringed Seal has been recorded in eastern Canada (Higdon 2007; Ferguson *et al.* 2012a,b). Killer Whale are occasionally seen in the Canadian Beaufort Sea, but predation on Ringed Seal has not been observed there (Higdon *et al.* 2013). Predation rates are unknown, and may be increasing, but overall are likely minor in relation to losses from Polar Bear and Arctic Fox.

Predation by other species (e.g., gulls, Common Raven, wolves) is negligible over most of the species' range (Kelly *et al.* 2010a).

Number of Locations

Habitat deterioration from sea-ice decline and lack of adequate snow cover associated with human-induced climate change is the most common plausible threat to the population, but there is considerable variation predicted in the severity and timing of change in ice conditions in the future over a very large area (**Habitat Trends** section). Therefore, the number of locations is unknown, but considered to exceed thresholds.

PROTECTION, STATUS AND RANKS

Legal Protection and Status

There are no international agreements or conventions specifically intended to protect Ringed Seal, but the International Agreement on the Conservation of Polar Bears and their Habitat protects Polar Bear feeding areas, which implies a measure of protection for Ringed Seal and their habitat (Kingsley 1990). Ringed Seal is not listed on any appendix of CITES [Convention on International Trade in Endangered Species]. COSEWIC assessed the species as Special Concern in November 2019; it was previously assessed as “Not at Risk” in 1989, and it is currently not listed under the *Species at Risk Act*.

In December 2012, NOAA Fisheries announced that the Arctic, Baltic (*P. h. botnica*) and Okhotsk Sea (*P. h. ochotensis*) subspecies of Ringed Seal would be listed as Threatened under the United States *Endangered Species Act* (NOAA 2012). This listing was challenged in court and Ringed Seal was delisted (Muto *et al.* 2017); however, the ruling was reversed and Ringed Seal is currently listed as Threatened under the United States *Endangered Species Act*. The Arctic Ringed Seal that exist in U.S. waters were already protected under the *Marine Mammal Protection Act* (MMPA). Ringed Seal is ranked as Least Concern in Greenland (Boertmann 2007), Vulnerable in Norway (Svalbard) (Swenson *et al.* 2010) and are not listed in Russia (Red Data Book 2001).

In Canada, Ringed Seal, like all marine mammals, fall under the Marine Mammal Regulations (SOR/93-56) of the *Fisheries Act* (Government of Canada 2015). In 1980, the Seal Protection Regulations (C.R.C., c. 833) were enacted under the *Fisheries Act*, which permitted any resident to take seals for themselves, their family or dogs, or to sell or trade seal meat to a resident or a traveller for the same purpose (Department of Fisheries and Oceans 1978). These provisions placed no restrictions on the sale or barter of skins produced through the harvest (Kingsley 1990). In 1993, the Seal Protection Regulations were consolidated with those for other marine mammals in the Marine Mammal Regulations of the *Fisheries Act*. Seal hunting in the marine waters of the Northwest Territories, Nunavut, Nunavik and Labrador are co-managed by various wildlife management boards (Fisheries Joint Management Committee (FJMC) in the Inuvialuit Settlement Region (Northwest Territories), Nunavut Wildlife Management Board (NWMB) in the Nunavut Settlement Area, Nunavik Marine Region Wildlife Board (NMRWB) in the Nunavik Marine Region, and Torngat Joint Fisheries Board (TJFB) in the Labrador Inuit Settlement Area), under the applicable sections of their respective land claims agreements. The co-management process in two of these jurisdictions, Nunavut and Nunavik, is briefly described in COSEWIC (2017). Scientific advice is provided by the Department of Fisheries and Oceans, which manages Ringed Seal in other jurisdictions in cooperation with other agencies.

The Marine Mammal Regulations of the *Fisheries Act* also include a provision (MMR 4(1)) for a Marine Mammal Fishing Licence (MMFL) for Ringed Seal. Less than 100 of these licences were being sold per year in the 1980s (Kingsley 1990). In the most recent 10-year period, 2007 to 2016 inclusive, an average of 22 (median 21) licences were sold each year from the Iqaluit Fisheries and Oceans Canada office (range 4-51) (Hall pers. comm. 2017), most in relation to Walrus Sport Hunters who also request a seal licence (Young pers. comm. 2017). An MMFL for harvesting seal would only be issued to a non-resident who is visiting Nunavut. A small number of licences would also be issued by other agencies (e.g., Government of Nunavut Department of the Environment) in outlying communities, but annual totals for Nunavut are likely well below 100 (Young pers. comm. 2017; Hall pers. comm. 2017). Small numbers may be sold to visitors to other jurisdictions within the Ringed Seal range, which generally falls within Seal Hunting Areas 1 to 4. As specified in the Marine Mammal Regulations, a resident immediately adjacent to these areas may also hunt for seals without a licence for food purposes. All MMFLs include a condition to “Report harvest to local DFO office”, but it is very rare for DFO to receive a report on a seal harvesting (Young pers. comm. 2017).

Non-Legal Status and Ranks

At the species level, Ringed Seal is “Least Concern” on the IUCN Red List (Lowry 2016), and the Arctic, Baltic, and Okhotsk Sea subspecies are similarly ranked (Boveng 2016a,b; Härkönen 2015). The other two subspecies are at risk; the Ladoga Ringed Seal, *P. h. ladogensis* being listed as Vulnerable (Sipilä 2016a) and the Saimaa Ringed Seal, *P. h. saimensis* being listed as Endangered (Sipilä 2016b).

Canadian wildlife species are assessed via the NatureServe ranking process through the Program on the General Status of Species in Canada, through which Ringed Seal is ranked “N5B, N5N, N5M” (Secure) at the national and sub-national (Western Arctic Ocean, Eastern Arctic Ocean, and Atlantic Ocean) scales (CESCC 2016).

Habitat Protection and Ownership

Existing and proposed protected areas such as national parks, national wildlife areas (NWAs), migratory bird sanctuaries, *Oceans Act* marine protected areas (MPAs), national marine conservation areas, Indian Reservations, and other lands owned and managed by the Government of Canada afford little protection to Ringed Seal habitat. Some seals use the sea ice adjacent to protected terrestrial areas, but these sites offer no specific protection of Ringed Seal habitat. The Ninginganiq NWA in northeast Baffin Island includes the shoreline and islands of Isabella Bay and adjacent ocean out to 12 nautical miles from shore, and thus directly protects some important fast ice habitat for Ringed Seal. Some habitat is also protected by MPAs in the Inuvialuit Settlement Region (Anguniaqvia

Niqiqyuam, Tarium Niryutait) and southern Labrador (Gilbert Bay). The Lancaster Sound NMCA, once finalized, should offer additional protection. Inuit and Inuvialuit have the right to hunt in national parks and other conservation areas within the Inuvialuit Settlement Region, Nunavut, Nunavik, and Nunatsiavut.

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Jeff W. Higdon is a consulting biologist based in Winnipeg, MB. His PhD is from the University of Manitoba, where he carried out research on the biogeography of world pinnipeds and the influence of evolutionary adaptations to sea ice on the distribution patterns of polar species. Since 2005, he has conducted extensive field research on Arctic marine mammals. Other research projects have involved collecting and interpreting

Aboriginal Traditional Knowledge, historical research on marine mammal hunting, spatial analysis of animal movements and habitat selection, and assessments of potential environmental impacts to marine biota from proposed development projects and Arctic shipping. Current research activities include developing Arctic monitoring programs, conducting risk assessments, reviewing industrial development projects, and preparing wildlife species status updates. Jeff has worked for government, Inuit, and conservation organizations and written over 40 peer-reviewed scientific papers, book chapters and technical reports.

Stephen D. Petersen (MSc, PhD, Assiniboine Park Zoo, Winnipeg, MB) is the Head of Conservation and Research for Assiniboine Park Zoo. The Conservation and Research Department runs active field and zoo-based programs from the labs and offices at the Leatherdale International Polar Bear Conservation Centre. Recent research projects at the LIPBCC have focused on the ecology and genetics of Arctic mammals (Polar Bear and seals) as well as engaging citizen scientists to help monitor Arctic species like beluga whales. Stephen has a PhD from Trent University (Ontario), MSc from Acadia University (Nova Scotia) and BSc from the University of Alberta (Alberta). Stephen is also Adjunct Professor at both University of Winnipeg and University of Manitoba, a past-president of the Manitoba chapter of The Wildlife Society, and serves on the Terrestrial Mammal Sub-Committee of COSEWIC (the Committee on the Status of Endangered Wildlife in Canada).

Meagan Hainstock (MSc, Polar Bears International, Winnipeg, MB) is the Senior Director for Canada with Polar Bears International. She has worked on a variety of research projects relating to marine mammals in Canada and abroad, including studies of Ringed Seal and Beluga in Canada, and she specializes in science communications for a variety of audiences.

COLLECTIONS EXAMINED

No collections were examined.

Appendix 1. COSEWIC Threats Assessment for Ringed Seal, *Pusa hispida.*

Species or Ecosystem Scientific Name	Ringed Seal, *Pusa hispida*			
Element ID		**Elcode**		
Date (Ctrl + ";" for today's date):	27/06/2018			
Assessor(s):	Draft completed by report authors (27 June 2018), telecon 3 Aug 2018: Jeff Higdon, Stephen Petersen, David Lee, Hal Whitehead, Dwayne Lepitzki, Karen Timm, Tom Jung, Kyle Ritchie, Mark Basterfield, Mike Hammill, Marie-Auger Methe, Jim Goudie, Aqqalu Rosing-Asvid, Dave Yurkowski, Chanda Turner, Emily Way Nee, Paul Irngaut, Bert Dean, Colin Webb, Michael Ferguson, Christine Abraham, Kate Davis			
References:	draft calculator and provision (6-month draft) COSEWIC status report			

Overall Threat Impact Calculation Help:			**Level 1 Threat Impact Counts**	
	Threat Impact		**high range**	**low range**
	A	Very High	0	0
	B	High	1	0
	C	Medium	0	0
	D	Low	0	1
	Calculated Overall Threat Impact:		High	Low
	Assigned Overall Threat Impact:		**BD = High - Low**	
	Impact Adjustment Reasons:			
	Overall Threat Comments		Generation Time = 13 years (3 generations = 39 years); EOO=4,403,651 km².	

Threat		**Impact (calculated)**		**Scope (next 10 Yrs)**	**Severity (10 Yrs or 3 Gen.)**	**Timing**	**Comments**
1	Residential & commercial development						
1.1	Housing & urban areas						
1.2	Commercial & industrial areas						!Potential for military base to be developed in northern waters (e.g., Resolute Bay). Ship port development at some sites in progress (deep sea port, small craft harbour- Iqaluit, small craft harbour - Pond Inlet).
1.3	Tourism & recreation areas						"Tourism and recreation sites with a substantial footprint" - there aren't any substantial areas on sea ice or water with a substantial footprint. Increasing cruise ship and private craft use of the Arctic (see shipping and recreational activities) Pond Inlet is in the process of building a small craft harbour; other communities showing interest in this type of development as well. These sites could be used for tourists in the next decade. Extent of direct overlap with seal habitat is unknown but small proportions of population could be displaced.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2	Agriculture & aquaculture						
2.1	Annual & perennial non-timber crops						
2.2	Wood & pulp plantations						
2.3	Livestock farming & ranching						
2.4	Marine & freshwater aquaculture						No aquaculture in species range at present and none proposed to our knowledge, but possibility for development exists.
3	Energy production & mining		Negligible	Small (1-10%)	Negligible (<1%)	High - Low	Undersea mineral exploration and potential future oil/gas activities potential threat. The nature and frequency of exploration will increase and potentially impact more seals each year.
3.1	Oil & gas drilling		Negligible	Small (1-10%)	Negligible (<1%)	High - Low	Presently some oil and gas development in Alaska (Southern Beaufort), and a small number of Canadian seals are exposed to this outside of Canada's boundaries. In Greenland, the Government has published an oil and mineral strategy (2014-2018) that attempts to maintain the current levels of exploration activity in the hope that they will result in a commercially viable oil discovery. In 2017 and 2018, the Government intends to to focus its licensing activities in Baffin Bay and Davis Strait which shares seals with Canada. The Nunavut Impact Review Board is currently coordinating an Strategic Environmental Assessment in Baffin Bay and Davis Strait (SEA). The purpose of SEA is to understand the possible types of offshore oil and gas related activities that could be proposed in the Canadian offshore waters of Baffin Bay and Davis Strait. In 2016, the federal government announced that Canadian drilling in the Arctic will be reviewed every 5 years after an initial moratorium on offshore oil and gas activity in the Arctic. In the Yukon, a small part of Canadian population would be affected at the borders with Alaska and Greenland where oil and gas is present, and some animals would be exposed at a very local level. Industry interest in oil and gas exploration and development in the Beaufort Sea has increased since 2007. The resource potential of the Beaufort Sea is estimated at 67 trillion cubic feet of natural gas and 7 billion barrels of oil in the Mackenzie Delta/Beaufort Sea basin. Literature suggests displacement may occur but may not be permanent. It is uncertain but probably neglible if there would be population level impact.
3.2	Mining & quarrying						Mining itself is not a threat but shipping of products may be. There are active mines in Nunavut, Nunavik and Nunatsiavut, with other mines proposed or in development.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
3.3	Renewable energy						
4	Transportation & service corridors		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
4.1	Roads & railroads		Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Railway transporation of iron ore has been approved (southern shipping route) - proposed (northern shipping route) for the Mary River Iron Mine (Baffinland) but potential impacts to Ringed Seal are unknown. Some ice road use off of Alaska where some dens can be impacted by ice road building. Changes in sea ice are expected to occur further south, and changes in ice road construction including frequency and placement may reduce impact such as fewer ice roads being utilized. However, ice road construction further north may increase if mine exploration increases.
4.2	Utility & service lines						Proposal for Quintillion Expressnet telecommunications line across Arctic to connect to Europe to Nunavut. Proposed line goes along mainland Canada (has been laid in Alaska but not yet in Canada). Secondary line when funded, would go up east Baffin Coast to connect northern communities. Marine footprint impacts involve laying cable out from slow moving ship, and may not affect seals when cable on sea floor.
4.3	Shipping lanes		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Most communities are serviced by shipping (bulk sealifts and fuel resupply), which may increase with development. Mines are also supplied by shipping, and ore may be shipped out for processing (e.g., Mary River). The potential also exists for local impacts of icebreaking through pupping habitat. At present there is limited icebreaking (mainly Community Government Service support for community resupply, some shipping of ore from mines in Nunavik (Hudson Strait) and Nunatsiavut), but it could increase in the future. Baffinland has proposed icebreaking to service the Mary River Iron Mine but these plans were suspended but could be brought forward again. Includes ship strikes (i.e., damage to birth lairs, pup mortality), displacement, increased stress levels due to disturbance.
4.4	Flight paths						Aircraft fly over Ringed Seal habitat throughout much of the Canadian range, but impacts are likely to be negligible because of altitude of aircraft.
5	Biological resource use		Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals						
5.2	Gathering terrestrial plants						

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
5.3	Logging & wood harvesting					
5.4	Fishing & harvesting aquatic resources	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Ringed Seal is harvested throughout the range. The harvest is largely unquantified. Harvest levels are lower than during the dog sled era. Recently, there are indications from Nunavut, that the harvest is decreasing but there is uncertainty if this reflects declining abundance, effort, or participation in the pelt purchase program used as one measure to monitor harvest. Commercial fishing may impact the Ringed Seal population but current data from Alaska suggest that the by-catch is low (3.9 seals/year). There are areas where no harvesting occurs, but given potential for long distance movements and migration, these individuals may be exposed.
6	Human intrusions & disturbance	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
6.1	Recreational activities	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Some on-ice (i.e., floe edge) arctic tourism but impacts minimal. Biggest impacts to seals likely via cruise ships and private yachts - see shipping above. Strikes, displacement, increased stress from disturbance likely. In next decade with decline in sea ice, more sites may become increasingly accessible than in the past for tourism, which may increase the scope.
6.2	War, civil unrest & military exercises	Negligible	Unknown	Negligible (<1%)	High (Continuing)	The Department of National Defence executes 2-4 Annual Sovereignty Operations (Nunavlivut, Nunakput, Nanook). Navy refueling station project proposed for Nanasivik, Nunavut. Ranger patrols occur in every community, including taking military on sea ice for exercises. Military patrols may occur within the next 10 years with acquisition of ice capable Arctic/Offshore Patrol Vessels.
6.3	Work & other activities	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Undersea mineral exploration and potential future oil/gas activities potential threat. The nature and frequency of exploration will increase and impact more seals each year. (scored under 3.1 and 3.2). Considers all community activities on ice.
7	Natural system modifications	Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	
7.1	Fire & fire suppression					
7.2	Dams & water management/use	Unknown	Small (1-10%)	Unknown	High (Continuing)	A consideration in the Hudson Bay system, where changes are occuring due to freshwater inputs from hydroelectric dams. Hydroelectric developments in Hudson Bay are influencing the hydrologic cycle, impacts to seals unknown. Similar development proposed near Iqualuit but there has been no activity to date.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications		Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	If Killer Whale (top predator) range extension leads to increase in Ringed Seal predation, this could present an ecosystem modification and a population level effect. Some impacts of Killer Whales on seal prey were discussed but impacts unknown (but likely negative). Other seal populations may be increasing in abundance and or use of the Arctic (Harbour Seals and Harp Seals) and could present increased competition for prey. Hydroelectric developments in Hudson Bay are influencing the hydrologic cycle and the impacts to seals remain unknown. Communities in Hudson Bay have stated that these developments have impacted wildlife (Voices from the Bay: Traditional Ecological Knowledge of Inuit and Cree in the Hudson Bay Bioregion). Hydroelectric development has been proposed near Iqlauit (Nunavut) but there has been no activity to date. Tidal developments are not occuring at present.
8	Invasive & other problematic species & genes		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
8.1	Invasive non-native/alien species/diseases						Increased shipping increases potential of invasive species introductions via ballast water or hull fouling. Some invasive species are moving north and may already be in Ringed Seal range in Labrador, with unknown impacts.
8.2	Problematic native species/diseases		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Disease expansion - brucellosis and other unicellular parasites, little data, but increasing throughout Arctic, especially with new vectors. However, causes are unknown. Distemper and other viruses expanding as well.
8.3	Introduced genetic material						
8.4	Problematic species/diseases of unknown origin		Unknown	Unknown	Unknown	Unknown	
8.5	Viral/prion-induced diseases		Unknown	Unknown	Unknown	Unknown	
8.6	Diseases of unknown cause		Unknown	Unknown	Unknown	Unknown	Cases of hair loss reported in the southern Beaufort Sea and Nunavik; however causes are unknown.
9	Pollution		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	
9.1	Domestic & urban waste water		Negligible	Negligible (<1%)	Unknown	High (Continuing)	In wastewater there are potential local sources for contamination (including persistent pollutants) - little information available at present. Sediments from ice roads discussed. Waste systems discussed.
9.2	Industrial & military effluents		Unknown	Small (1-10%)	Unknown	High (Continuing)	Potential for spills, leakage from tanks considered here. It was noted that there are naturally occuring oil seeps along the coast of Baffin Island.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
9.3	Agricultural & forestry effluents						Little to no agriculture or forestry activties adjacent to Ringed Seal habitat.
9.4	Garbage & solid waste		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Garbage dumps in communities throughout Ringed Seal range but limited/no effect on seals. Garbage (household waste and from cruise ships) dumped in water (can cause entanglement) or on sea ice could have an effect, as could plastic pollution which is pervasive in marine environments. Microplastics were discussed but impacts on seals unknown**.** Impacts of newer contaminants discussed and are yet unknown.
9.5	Air-borne pollutants		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Long range transport of pollutants through air when chemicals volatilize, movement through water as well. PCBs and radioactive material can have a wide regional impact, especially in marine systems. Atmospheric transport of pollutants and pesticides was considered. Mercury was also discussed. Routine burning at community dump sites is another source of air-borne pollutants. Impacts of newer contaminants discussed and are yet unknown.
9.6	Excess energy		Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Population level impacts from acoustic noise in the open water season as shipping from resupply and tourist activity increases is unknown. The US military has agreed not to use military grade sonar in exercises. Again, impacts to Canadian population unknown.
10	Geological events						
10.1	Volcanoes						
10.2	Earthquakes/ tsunamis						Earthquakes have been recorded in Baffin Bay but their impacts on Ringed Seal are unknown.
10.3	Avalanches/ landslides						Avalanches or landslides could impact coastal habitat but impacts likely to be minor.
11	Climate change & severe weather	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	
11.1	Habitat shifting & alteration	BD	High - Low	Pervasive (71-100%)	Serious - Slight (1-70%)	High (Continuing)	Sea ice habitat and snow are crucial for Ringed Seal (maternity denning, basking/moulting habitat), and declines in ice extent and quality are the biggest threat to persistence. Changes to habitat and associated responses by seals will vary in both space and time, with possibility that some areas may have improved conditions (such as areas that have been covered by thick multi-year ice in the past and now tend to be covered with annual ice). Sea ice presence is also a critical factor in the Arctic marine food web and changes could have pronounced ecosystem-level effects. Projections on population impacts from Baltic sea ice loss on pupping was discussed. Range in severity was used to reflect uncertainty.
11.2	Droughts						Droughts do not pose a threat.

Threat		Impact (calculated)		Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
11.3	Temperature extremes		Unknown	Small (1-10%)	Unknown	High (Continuing)	Temperature extremes can affect maternity dens and cause them to collapse, which exposes pups to weather and predators. Such events are usually local in scale and likely would not cause a population level impact. In the past early rain events have had impacts on den collapse, and rain on ice and snow events are predicted to increase. Aerial surveys in some sites are being run earlier than historically (potentially suggesting a shift in life history events or a logistical necessity to detect seals efficiently).
11.4	Storms & flooding		Unknown	Unknown	Unknown	High (Continuing)	Increasing storm events can lead to effects on ice development (e.g., causing ice to break up), but such storms also make harvesting more difficult and could lead to reduced human-caused mortality. Impacts are not well understood and are therefore scored as unknown.
11.5	Other impacts						
Classification of Threats adopted from IUCN-CMP, Salafsky *et al.* (2008).							