Fisheries and Oceans Canada
Pêches et Océans Canada

MARINE MAMMAL RESEARCH

AN OVERVIEW

The Centre of Expertise in Marine Mammalogy

Canada

Cover photo credits:
Bowhead whale: Ian Kerr
Harp seal: J. -P. Sylvestre
Killer whale: Barry Peters

MARINE MAMMAL RESEARCH

AN OVERVIEW

The Centre of Expertise in Marine Mammalogy

Published by:
Communications Branch
Fisheries and Oceans Canada
Ottawa, Ontario
K1A 0E6
www.dfo-mpo.gc.ca
DFO/2005-846

Cat. No: Fs23-489/2005
ISBN: 0-662-69351-5

Printed on recycled paper

ACKNOWLEDGEMENTS

This publication would not have been possible without the generous input of marine mammal scientists from Fisheries and Oceans Canada and other specialists across Canada. We acknowledge the numerous writers, photo providers, reviewers and all those who have offered valuable advice during the production of this publication.

We would particularly like to acknowledge the following contributors who have provided the text for this publication:

Don Bowen . . . . .Research Scientist, Marine Mammals, Halifax, NS
Estelle Couture . . . . .Program Advisor, Fish Population Science, Ottawa, ON
Fraser Davidson .Research Scientist, Physical Oceanography, St. John's, NL
Larry Dueck . . . . .Biologist, Marine Mammals, Winnipeg, MB
Steve Ferguson .Research Scientist, Marine Mammals, Winnipeg, MB
John Ford . . . . .Research Scientist, Marine Mammals, Nanaimo, BC
Viviane Haeberlé . . . . .Communication Advisor, Mont-Joli, QC
Mike Hammill . . . . .Research Scientist, Marine Mammals, Mont-Joli, QC
Lei Harris . . . . .Biologist, Marine Population Dynamics, St. Andrews, NB
Jack Lawson . . . . .Research Scientist, Marine Mammals, St. John's, NL
Véronique Lesage . . . . .Research Scientist, Marine Mammals, Mont-Joli, QC
Linda Nichol . . . . .Biologist, Marine Mammals, Nanaimo, BC
Ole Nielsen . . . . .Project Manager, Marine Mammals, Winnipeg, MB
Lianne Postma .Biologist, Molecular Genetics, Winnipeg, MB
Pierre Richard .Research Scientist, Marine Mammals, Winnipeg, MB
Peter Ross . . . . .Research Scientist, Marine Mammals, Sidney, BC
Patrice Simon . . . . .Senior Advisor, Fish Population Science, Ottawa, ON
Becky Sjare . . . . .Research Scientist, Marine Mammals, St. John's, NL
Lisa Spaven . . . . .Technician, Marine Mammals, Nanaimo, BC
Garry Stenson .Research Scientist, Marine Mammals, St. John's, NL
Rob Stewart . . . . .Research Scientist, Marine Mammals, Winnipeg, MB
Ed Trippel . . . . .Research Scientist, St. Andrews, NB

TABLE OF CONTENTS

MESSAGE FROM THE DIRECTOR OF CEMAM

Mike Hammill, PhD
Director of CEMAM
Maurice-Lamontagne Institute
Mont-Joli, Quebec

In 2004, Fisheries and Oceans Canada (DFO), the Canadian federal government department responsible for the management and conservation of marine mammals, launched a new initiative to improve the way it delivers marine mammal science to Canadians and to the federal government by grouping its science experts into a virtual Centre of Expertise in Marine Mammalogy (CEMAM).

CEMAM is charged with identifying marine mammal research priorities and increasing the visibility of its marine mammal program. It executes these programs to fulfill its mandate by increasing collaboration among marine mammal scientists working within and outside the government. This report is one of our first initiatives to inform Canadians, in a non-academic format, about the types of research we are involved in across the country.

Canadians feel strongly about marine mammals and these feelings are as diverse as the people that form our country. Values can range from the conservation of endangered beluga in the St. Lawrence, right whales in the Bay of Fundy, and killer whales in the Pacific, to management of important subsistence harvests of beluga, narwhal and bowhead by the Inuit and management of the commercial seal hunt in rural Atlantic Canada. Many of these activities are controversial or involve making hard choices among several competing activities. The role of CEMAM is to ensure that the Minister of Fisheries and Oceans receives the best available scientific advice to aid in the decision-making process.

Within the Department, a team of almost 40 marine mammal specialists is located in offices and laboratories stretching across the country. This team works on a wide variety of innovative scientific projects to obtain information on the dynamics, ecology, habitat, migration and health of marine mammals from coast to coast to coast.

In this first publication, we present a general overview of marine mammal research conducted by the members of CEMAM within DFO. In future publications we will highlight results of specific projects being carried out across the country. I hope you enjoy reading about our work and don't forget to check out our website at: **www.osl.gc.ca/mm/en/index.html**

Mike Hammill

1.0

WHY STUDY MARINE MAMMALS?

Besides wanting to know more about the world that surrounds us and to better understand the ecosystem we live in, several factors influence the type of scientific research conducted by the Government of Canada in its role as decision-maker for the benefit of society. When it comes to scientific research on marine mammals, there are five broad categories: sustainable Aboriginal and commercial harvest; species at risk; impact and mitigation measures of human activities; climate change; and understanding the ecosystem.

Humpback whale
Photo credit: Hawaiian Islands Humpback Whale National Marine Sanctuary

Photo credit: Jack Orr

Inuit hunters target two walruses.
Many aboriginals have a constitutional right to harvest marine mammals.

Photo credit: Lois Harwood

Inuit eating traditional food called muktuk; the blubbery skin of the whale.

1.1 SUSTAINABLE ABORIGINAL AND COMMERCIAL HARVEST

For many Canadian Aboriginal societies, whales, seals and other marine mammals are a part of their culture and traditions, as well as an important food resource. Many Aboriginals have a guaranteed constitutional right to harvest marine mammals. Each year, the Canadian Inuit and Aboriginal people harvest narwhal and beluga as well as walrus and harp, hooded, ring and bearded seals for subsistence purposes.

In order to manage Aboriginal subsistence activities, Fisheries and Oceans Canada (DFO) must obtain information on animal abundance, distribution, stock identification and growth rate. These data are invaluable to ensure the sustainability of the harvest and the conservation of each stock. By knowing the population size and the rate at which this population grows, biologists can calculate the number of animals that can be harvested and make recommendations to managers on harvest levels that will ensure the sustainability of the resource. Factors that influence animal abundance and distribution, such as abundance of prey, mortality, disease and changes in habitat, are also considered before making a recommendation.

While only Aboriginals can harvest cetaceans (whale species) for subsistence purposes, some seal species are harvested to sustain a commercial economy. The Northwest Atlantic harp seal population supports an important commercial harvest. This traditional commercial activity provides economic benefits to remote areas of Quebec, Nunavut, Newfoundland and Labrador, and other Maritime provinces where few other economic alternatives exist.

Researchers examine the population size, growth rate, reproduction and migration of seals to provide scientific advice on the impact of various quota decisions on the seal population.

DFO fishery officers monitor the seal hunt in the Magdelene Islands, Quebec.
Photo credit: M. Plamondon

They provide advice to fisheries managers for different scenarios. The risk associated with each scenario is clearly identified so that the managers can make a decision knowing the risk associated with it, and by considering socio-economic factors and consulting with stakeholders.

The Government of Canada develops a management plan for this commercial harvest based on scientific advice. The plan sets quotas, seasons, location, harvest methods and other specifications to effectively manage this harvest.

1.2 SPECIES AT RISK

New legislation enacted in 2003, the *Species at Risk Act* (SARA), requires that a recovery strategy and action plan be developed for all species identified as Extirpated, Threatened or Endangered. The plan identifies actions to ensure that these species recover to healthy levels. Management plans are required for species listed as Special Concern.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC), an independent scientific advisory body, has designated some species of marine mammals as Threatened or Endangered. These include several whale species, such as Pacific killer whales, some beluga populations, blue whales and Pacific humpback whales. Many were harvested heavily during the industrial whaling period of the 19th and 20th century. Although commercial whaling in Canada was banned in 1972, some species still remain at low levels.

Fisheries and Oceans Canada (DFO) is responsible for the conservation and recovery of marine species listed under SARA. Because of their life history and historical exploitation levels, marine mammals make up a significant component of this responsibility. To address its SARA responsibilities, the Department assesses and monitors

The bowhead whale in the Arctic is designated as “Threatened” by COSEWIC.
Photo credit: M. Holmes

species of conservation concern, identifies critical habitat, understands and delineates ecological interactions, assists COSEWIC in developing status reports, prepares recovery strategies and action plans, identifies acceptable removal limits and recovery targets, and develops other useful scientific approaches. Due to the 'trans-boundary' distribution of many marine mammal species, considerable national and international coordination and cooperation is required.

In recent years, much scientific research has been conducted on the little-known species at risk to provide scientific information for the assessment of their status. Once assessed, DFO scientists monitor the species' status to see if recovery goals are being met. Scientific research provides a basis for advice to recovery teams and to the Minister on recovery goals, allowable harm levels and mitigation measures.

In some cases, the directed harvest or incidental catch of species considered at risk of extinction may be allowed. However, it is crucial that scientists examine closely the characteristic of the given species' population and advise on the level of harm (or removal) that could be allowed without jeopardizing the recovery of the population.

Photo credit: BIO Photo Section

Human activities such as oil and gas production have a direct impact on marine mammal habitat.

1.3 IMPACT AND MITIGATION MEASURES OF HUMAN ACTIVITIES

Human activities may have a direct impact on some marine mammal species. Whale-watching tourism, oil and gas exploration, marine transport routes, and fishing are all activities that may affect marine mammal populations. Understanding their behaviour in the presence of such human activities is important to the development of mitigation measures that will minimize potential negative impacts. Research on critical habitat, tolerance to disturbance and migration corridors all assist in ensuring that Canada's economic activities do not negatively affect biological resources.

The Atlantic walrus is designated as "Special Concern" by COSEWIC.
Photo credit: Jack Orr

Photo credit:
DFO Newfoundland

Grey seal mother and pup. Many species of seals need ice to reproduce.

Current climate models predict that northern regions will be most severely affected by climate change. For example, predictions of increasing temperatures will mean that Hudson Bay will be ice-free within the next 50 years. Such changes could result in reductions in polar bear and ringed seal abundance, which will have important implications for the northern economy and subsistence culture. Being able to predict how ecosystems will react to climate change will facilitate human adaptation to it.

1.4 CLIMATE CHANGE

Climate change will affect marine ecosystems through changes in ice, and the duration of ice-free and ice-covered seasons which in turn affect ocean temperature and salinity regimes. This may result in ecosystem shifts in species composition, distribution and production dynamics. Understanding these changes is necessary to address potential impacts of climate change on Canada's wildlife and economy.

1.5 UNDERSTANDING THE ECOSYSTEM

Scientific advice needs to be provided in support of ecosystem-based management plans. This ecosystem approach is a strategy for the integrated management of all marine activities to promote conservation and sustainable use in an equitable way. Marine mammal scientists conduct research to understand ecosystem processes and patterns, and their response to natural and anthropogenic effects.

To achieve this, the Department must acquire a better understanding of the physical and biological processes taking place in the marine environment. Marine mammals are often at the top of their trophic level; that is, they are the top predators. They are influenced by prey abundance and distribution, climate, ice cover, and the presence and abundance of predators. In recent years, scientists have studied diet and habitat preference of various species to better understand

Walruses like ice platforms to rest even when land is nearby.
Photo credit: Rob Stewart

Photo Credit: Ian Kerr

Bowhead whales are an important component of the Arctic ecosystem.

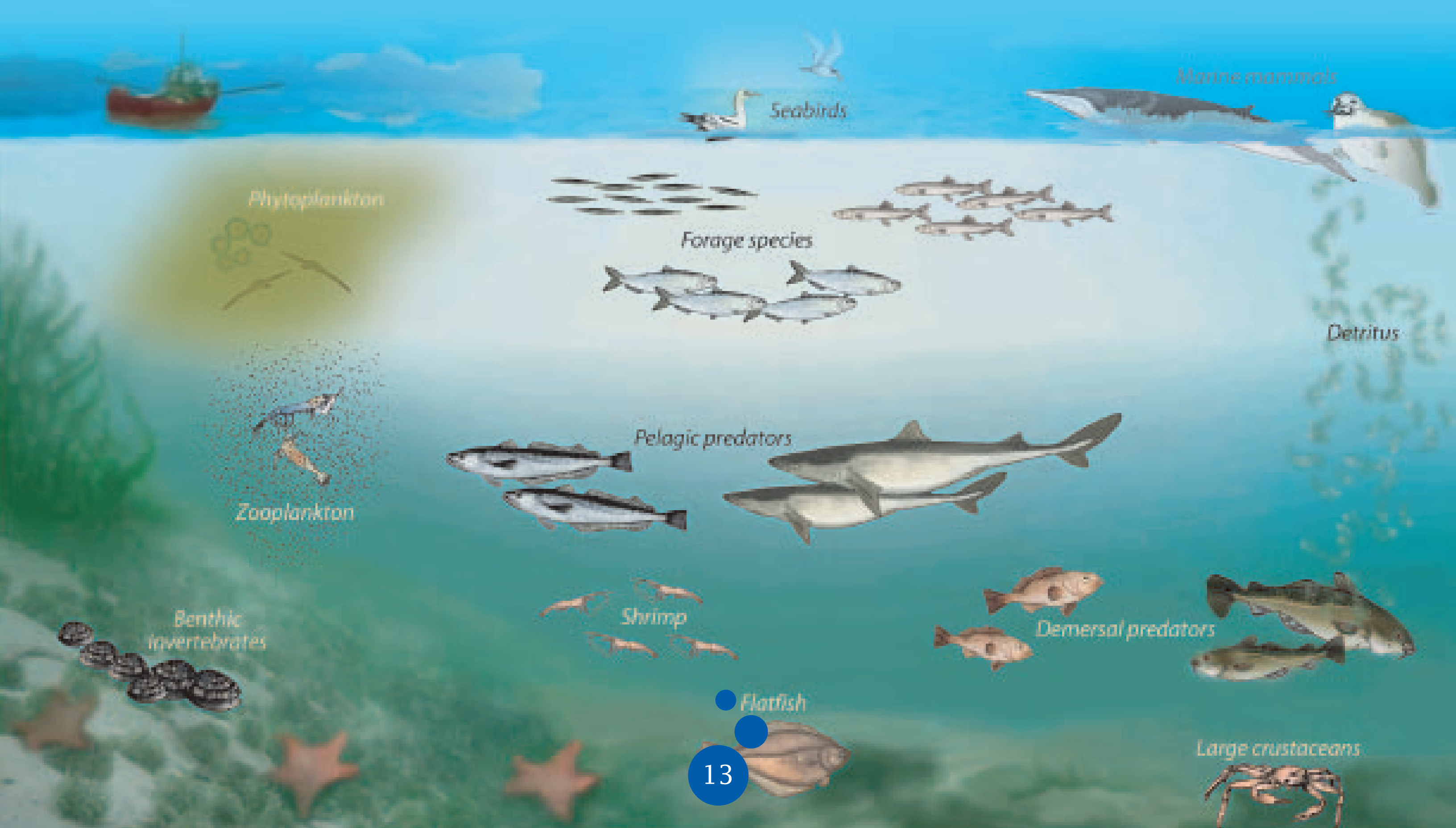
Photo credit: Yves Morin

Sable Island, Nova Scotia has the largest colony of grey seals in the world. As top predators, they are a significant component of the marine ecosystem.

the interaction between different organisms and their environment. These scientific projects are designed to enhance DFO's ability to make predictions under various scenarios, such as climate-change impact on marine mammal distribution and abundance, and impacts of increased harp seal abundance on groundfish.

Researchers also conduct studies to identify appropriate ecosystem indicators, which can quickly determine ecosystem health.

Marine ecosystem
Photo credit: St. Lawrence Observatory www.osl.gc.ca



2.0

WHAT IS THE CENTRE OF EXPERTISE IN MARINE MAMMALOGY?

Marine mammal conservation and management issues facing Fisheries and Oceans Canada (DFO) are varied and complex. The study and understanding of marine mammal populations requires specific expertise that differs from what is commonly needed for fish populations. Unique techniques are often used to conduct research on these long-lived, warm-blooded animals of the ocean. Seals and whales are often involved in long-distance migration, have low reproductive and growth rates, and require unique methodology to estimate their abundance.

To improve the efficiency and effectiveness of their work, marine mammal scientists working on the Pacific, Atlantic and Arctic populations have formed a Centre of Expertise in Marine Mammalogy (CEMAM). They share resources and expertise, as the issues they face on each coast are often similar.

CEMAM coordinates and organizes the scientific research and program delivery undertaken by the Department. CEMAM's primary role is to provide strategic direction for marine mammal research and monitoring within DFO, to promote collaboration among marine mammal researchers and to improve coordination of national marine mammal research and operational needs.

CEMAM consists of scientists based in nine DFO locations across the country: Sidney and Nanaimo, British Columbia; Yellowknife, Northwest Territories; Winnipeg, Manitoba; Mont-Joli, Quebec; St. Andrews, New Brunswick; Halifax, Nova Scotia; St. John's, Newfoundland, and Ottawa, Ontario. They work together toward a common goal: to conduct research in support of the management and conservation of marine mammals in Canada.

Marine mammals are large, highly mobile and wide-ranging animals. As a result, research often requires the integration of labour and skills from many different sources. Much of DFO research is carried out through partnerships and collaborations with others, such as other DFO scientific experts (e.g., modelers, fisheries ecologists, oceanographers), industry, First Nations communities, non-governmental organizations (NGOs), universities and the international science community.

CEMAM maintains a website (www.osl.gc.ca/mm/en/index.html) where summaries of DFO scientific expertise, as well as current projects and collaborative possibilities are listed.

2.1 WHAT KIND OF RESEARCH DOES DFO CONDUCT?

Marine mammal research is organized into three broad themes:

- Population dynamics;
- The role of marine mammals in marine ecosystems; and
- Human impacts on marine mammals.

These three themes are reviewed in greater detail in the subsequent sections of this publication.

Composite image of a minke whale lunge-feeding along south shore in the St. Lawrence Estuary.
Photo credit: Claude Nozères

3.0

POPULATION DYNAMICS

Population dynamics is the study of short and long-term changes in population size and composition i.e. age structure and ratio of males to females. It also attempts to understand the causes of these changes e.g. abundance of food, predation, levels of harvest, habitat availability, and how they affect reproduction and survival of individuals in the population.

Identifying factors that affect populations is an important goal of research on the dynamics of populations. An understanding of these dynamics is considered critical for sustainable harvest management and effective conservation of marine mammals.

Female hooded seal and pup
Photo credit: DFO

3.1 ABUNDANCE

Information on marine mammal abundance and distribution is needed to: 1) address questions related to the Species at Risk Act (SARA) to determine if a population is of conservation concern or showing signs of recovery; 2) identify critical habitat as well as Ecologically and Biologically Significant Areas; 3) identify the impacts of industrial activity; and 4) to recommend harvest quotas. Many different techniques can be used to estimate abundance; the most commonly used are mark-recapture, aerial surveys, boat surveys and photo identification.

3.1.1 EVALUATING SEAL ABUNDANCE

MARK-RECAPTURE

Mark-recapture methods are techniques that can be used to estimate marine mammal abundance. Traditionally, animals were marked with tags, or brands, and then the animals were released into the population. In recent years some researchers have been able to use unique markings on animals as 'natural markers'. The first sighting of these animals represents the marking phase. The recapture phase occurs when the 'marked' animals are recovered either from harvesting or re-sighting. At this recovery or re-sighting phase, the number of marked and unmarked animals is recorded.

Knowing the number of deployed tags, and the ratio of tagged and untagged animals in the 'recaptures' makes it possible to estimate the total population size. The calculations are relatively straightforward if the following assumptions are met: marks are not lost; no errors occur in the recording of marks; no animals leave the population (emigration); there are no new arrivals (immigration); no births or deaths; and marking does not affect the probability of catching the animal.

Although the principle underlying mark-recapture techniques is relatively simple, it is very sensitive to violations of the underlying assumptions, both at the marking or tag deployment stage and at the tag recovery or re-sighting stage. Unfortunately, in dealing with wild populations, ideal situations rarely occur.

Designing mark-recapture experiments takes considerable care, and work has been done to develop approaches that are less sensitive or take into account violations of the assumptions mentioned above. However, this may introduce other assumptions that add to the complexity of the calculations. Large recoveries of marks are also needed; otherwise, the uncertainties surrounding the estimates tend to be quite large.

Photo credit: Jean-François Gosselin (seals) and Claude Nozères (tag)

Marked harbour seals in the St. Lawrence. The pyramid tag on their head is glued to the fur which falls off during the annual moult.

Since it has been difficult to satisfy requirements, mark-recapture methods are not used as frequently in Canada as they were in the past to estimate seal abundance. These techniques are still used to estimate abundance of some whale species (e.g., killer, humpback and blue whales), and are also used to determine mortality rates of animals by following the number of times a marked animal is re-sighted over time.

E385 is a brand put on a female grey seal. She is one of hundreds of marked females that are monitored to determine reproductive performance and survival.
Photo credit: Don Bowen

DID YOU KNOW THAT?

#1

HOW TO ESTIMATE TOTAL POPULATION SIZE FROM COUNTS OF SEAL PUPS?

Seals spend most of their time at sea and are usually diving so they are infrequently seen at the surface. Even during periods, such as the breeding season, when seals haul-out on land or ice, not all components of the population haul-out at the same time. This means that it is not possible to simply count the number of seals at sea or on land, and use this count as an estimate of the total population.

Fortunately, in many species of seals, pups are born on land or ice over a short period of time (about one to four weeks) making it possible to estimate the total number born each year. Given that each adult female gives birth to a single pup, the number of pups born provides an estimate of the number of adult females in the population. Although not all adult females give birth each year, it is usually possible to determine the fraction giving birth from observations or samples taken from the population just before the breeding season. Dividing the number of pups by the fraction of females giving birth provides an estimate of the total number of adult females in the population.

For many species, the number of adult males and females in the population is roughly equal. Even where this is not the case, it is often possible to estimate the adult sex ratio. Thus, know-

AERIAL SURVEYS

Visual and/or photographic aerial surveys have become the preferred approach to evaluate seal abundance in Canada.

Three aerial survey approaches are used. These include surveys that photograph (or video tape) hauled-out seals and then these animals are counted on the images in the lab; surveys that simply count animals visually; or a combination of the two. Photographic surveys provide a permanent record of the number of hauled-out animals that can be verified at a later date and allow for accurate counts of large groups, but also take longer to analyse and are more costly.

Photo credit:
DFO Newfoundland

The pups found on harp seal whelping patches are counted for the purpose of estimating population abundance.

Visual surveys are easier to complete and analyse because photos do not need to be read, but generally, do not allow for any further interpretation of the data once the survey is complete. The development of geo-referenced counts will allow for some additional analysis of survey results after the fact.

Aerial surveys can involve counts of all animals hauled-out along the shore at a time, or they may only count pups. Surveys that count all hauled-out animals provide a rough index of abundance, but must be corrected for animals that are in the water at the time the survey was flown to obtain a total population estimate. It is possible to develop a model of the proportion of seals hauled-out at the time of the survey in order to estimate total abundance. However, this may be complicated by seasonal changes in the haul-out behaviours of males and females, of adults versus juveniles, and environmental conditions such as tide, local wind, temperature and even local disturbance.

ing the number of adult females provides a means of estimating the number of adult males.

Juveniles usually cannot be estimated in this way because the relationship between juveniles and adults depends on population growth rate and the pattern of mortality among seals of different ages. Nevertheless, this final component of the population can be reasonably estimated by constructing a population model and comparing model estimates of pup numbers over time to the measured series of pup counts. A fitting factor that minimizes the difference between the model predictions and measured pup counts is used to estimate the number of juveniles. This basic approach is used to estimate total population size of harp seals and grey seals off eastern Canada.

Grey seal pup
Photo credit:
Jean-Francois Gosselin

Another difficulty with counting all age classes is that animals are often dispersed necessitating surveys over large regions. Counting all hauled-out animals is often used for species such as harbour seals or ringed seals, but has also been used on harp, hooded and grey seals.

Aerial surveys are effective if hauled-out animals can be detected easily and all concentrations are surveyed. However, if these conditions are not satisfied, then the counts will likely underestimate seal abundance.

In Atlantic Canada, where the most extensive aerial surveys are flown, the most practical method is to estimate seal pups born in a year from aerial surveys conducted in the spring, when the seals gather to have their pups. Estimates of total population are then based on a population model that incorporates independent estimates of pup production with data on reproductive rates (the age of sexual maturity and the proportion pregnant each year), and catches including Canadian and Greenland harvest, by-catch, and the number of seals killed but not landed, referred to as 'struck-and-lost'.

Although aerial surveys have proven to be effective, they are logistically expensive and challenging to execute. Future attempts to evaluate seal abundance will likely involve the development of new techniques or use of alternative observation methods. Currently the use of digital camera imagery is being examined and perhaps in the future, counting seals from satellites may be feasible.

Map representing a systematic aerial survey to estimate the abundance of beluga in the Western Hudson Bay. Each line represents the path taken by the plane to count belugas.
Credit: Pierre Richard

3.1.2 EVALUATING WHALE ABUNDANCE

AERIAL AND BOAT SURVEYS

Aerial surveys are an important tool to determine population numbers of whales because of their large range and rapid movements. Airplanes allow researchers the capacity to cover large areas in a short time, especially areas that would be difficult to navigate by boat. Unlike boats that are noisy underwater, whales barely react to airplanes flying overhead at 330 metres, which is the usual altitude for these surveys.

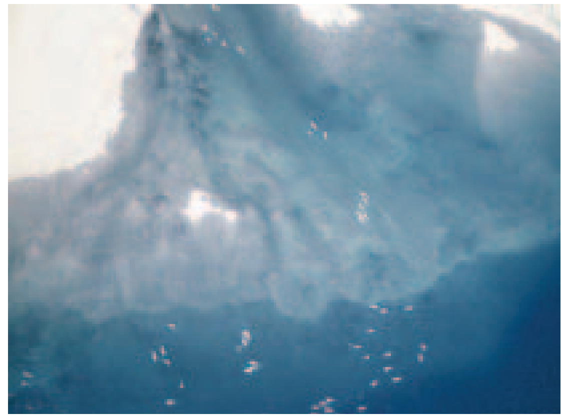


Photo credit: Pierre Richard

Pods of belugas as seen from the plane.

Photo credit: DFO Newfoundland

Observer in plane counting whales.

The aerial surveys use systematic survey lines that cover a fraction of the range of the animals (e.g., 1 sq km for every 10 sq km). To extrapolate the total population, estimates of the density of animals seen along the survey lines on both sides of the aircraft are multiplied by the total survey area. But such an extrapolation can only estimate the number of animals that were at the surface. That is where the dive data from the 'tagged' animals become useful for population assessment. (Please see section 4.1.2 Satellite Tracking for more details.)

Using the proportion of time whales spend at the surface, researchers can estimate the number of animals that were missed by observers because they were diving at depth. The surface estimate can then be expanded to correct for those diving animals. Finally, aerial surveys are also used to determine if animals are present in certain areas, where satellite tracking is impractical.

Boat surveys are carried out in the same basic manner as aerial surveys. Although they take a longer time to cover the same area, they have other advantages. For example, additional observers can participate, observers can use large magnification binoculars and the time during which each whale can be seen is longer.

Photo credit: Jack Lawson

Observers counting whales from a boat.

DID YOU KNOW THAT?

#2

MAKING A SPLASH FOR HUMPBACK WHALES

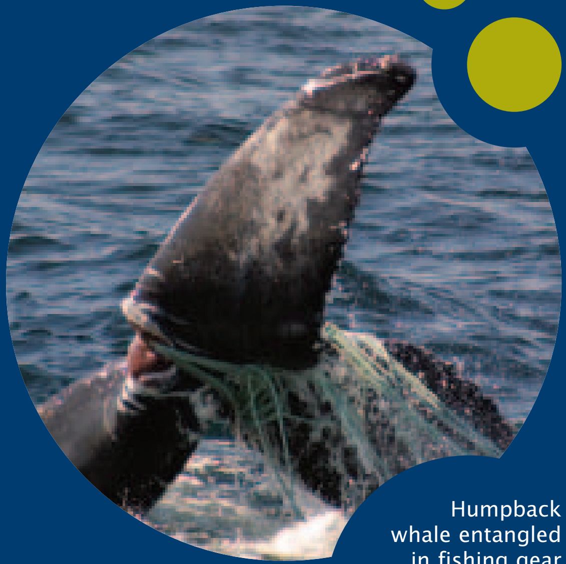
Humpbacks in the North Pacific are highly migratory whales that swim between calving grounds in Hawaii and Mexico, and feeding areas in nutrient-rich temperate and sub-Arctic waters.

During the early part of the 20th century, commercial whalers decimated the humpback whale population of the North Pacific from approximately 15,000 individuals to as few as 1,000. As a result, the International Whaling Commission placed the species under international protection in 1965.

While the major threat to the great whales – commercial whaling – has long been curbed, several other factors affect the recovery of this species. At present, entanglements in fishing gear and ship collisions appear to be the greatest sources of mortality. Noise disturbance, food availability, commercial whale watching, plus loss of prey and habitat may also play a role.

To gain a better understanding of all these factors, SPLASH (Structure of Populations, Levels of Abundance, and Status of Humpback Whales) was initiated in 2004. SPLASH is a collaborative international research project to examine the status, trends, population structure and human impacts on humpback whales in the North Pacific.

The collaborative effort is unprecedented in its international cooperation and geographic scope. The project involves researchers from the United States, Mexico, Canada, Russia, and Japan. Efforts are focused in the North Pacific wintering areas of the Hawaiian Islands, Japan, Mexico, Central America and the feeding areas of California, Oregon, Washington, British Columbia, the western Gulf of Alaska, southeastern Alaska, the Aleutian Islands, the Bering Sea, and the western North Pacific waters off Russia.



Humpback whale entangled in fishing gear

Photo credit: Provincetown Center for Coastal Studies, under NOAA Fisheries permit 932-1489, with authority of the US Endangered Species Act

Humpbacks lunge-feeding

Photo credit: John Ford

The project's primary objectives are to: a) estimate the overall abundance and determine the population structure of humpback whales in the North Pacific using genetic markers and photo-identification; b) better understand humpback whale wintering and feeding areas; c) provide information on trends in abundance; d) identify habitat and characterize use; and e) identify human impacts (i.e., entanglement, toxicology, etc.).

Scientists focus their effort mainly on collecting tissue samples by biopsy and taking identification photographs of the whales. Humpback tails are all slightly differently shaped, with patterns of pigmentation and scarring as unique as human fingerprints. With no two alike, researchers can use the tail photos to identify and track individual humpbacks, and to estimate the overall population.

To document the human impact on humpbacks, another important aspect of SPLASH is to record scarring caused from entanglement or collisions with vessels. Evidence is collected by photographing each animal's tail stock, tail surface and body where scars are typically seen.

Biopsy samples, obtained by darting the animal, are small cores containing both a layer of skin as well as a segment of blubber. The whole sample is about 5 cm long and 1 cm wide. In 2004, the DFO Pacific Cetacean Research Program provided SPLASH with photo-identifications of 410 unique humpbacks and 76 biopsy samples.

In 2004, the first year of the SPLASH effort, scientists catalogued more than 500 individual humpback whales in Pacific Canadian waters. Over 300 of these whales were new to the DFO catalogue of individual humpbacks. These photo-identifications will yield important new information on the abundance of humpbacks in British Columbia, as well as on other important details about their seasonal movements, preferred habitat and foraging ecology.

Humpback whale breaching

Photo credit: John Ford

Photo credit: John Ford

PHOTO-IDENTIFICATION

Photographic identification of individual whales through pattern recognition of natural markings is a widely used technique for determining population abundance, seasonal distribution, migratory destinations, site fidelity, and other important biological data. The technique for the photo-identification of killer whales in British Columbia (B.C.) was established in the early 1970s by a DFO researcher following the discovery that individual killer whales could be uniquely identified by their dorsal fin and saddle patch, which bear distinctive nicks, scars and other markings. This allowed researchers to develop a catalogue of identification photographs for all of the resident killer whales in B.C..

As the study of B.C.'s killer whales expanded over the years, photo-identification enabled researchers to determine ages of individuals, mortality and birth rates, movement patterns, and structure of social groupings. Patterns of association between animals quickly began to emerge, and several distinct populations of killer whales were recognized, now known as the northern and southern residents, transients and offshores.

Individual humpback whales can be readily identified by analysing photographs of the pigmentation patterns and markings on the ventral surface (underside) of the tail flukes, which are taken as the whale lifts its flukes before diving. Identification photos of humpback whales have been compiled into a catalogue for coastal waters of B.C., which now contains more than 1,500 unique individuals.

Photo-identifications collected during several sequential years can be used to estimate levels and trends in population abundance, fidelity of individuals to particular coastal locations and seasonal movement patterns. Comparisons to other regional catalogues can also yield important information on large-scale movement patterns associated with migration or feeding.

Humpback whale identifications collected in B.C. waters have also been submitted to the international SPLASH (Structure of Populations, Levels of Abundance, and Status of Humpback Whales) initiative, to yield important new information on population abundance, seasonal distribution, and migration patterns in the North

Photo credit: Véronique Lesage

Blue whale backs
Each individual whale is identified and catalogued using the unique markings on its back.

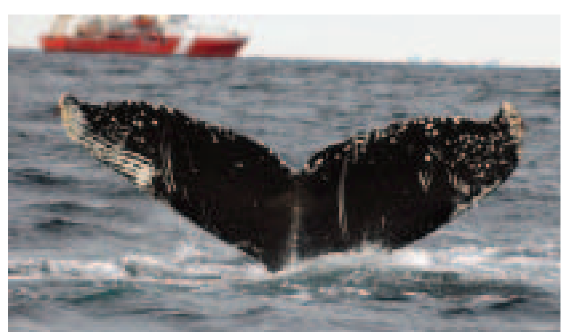


Photo credit: John Ford

Killer whales and humpback whales (shown here), are uniquely identified using the distinctive nicks, scars and other markings on their flukes.

Pacific. A similar catalogue of whale photographs is kept on the Atlantic coast. (Please see the info box 'Making a SPLASH for Humpback Whales for more information.)

The revolutionary advent of photo-identification allows researchers to determine population sizes either by directly counting all individuals, as done with killer whales, or by estimating abundance using the mark-recapture techniques described earlier, as done with migratory species such as humpback whales. Another valuable aspect of photo-identification is that the information gained by following individual whales over time can be used to determine important biological parameters such as life span, growth rates, age at sexual maturity, birth and death rates, and calving intervals.

Watching individual animals and their association patterns has also led to a greater understanding of whale social structure. The contribution that photo-identification has made to the understanding of cetaceans around the globe cannot be underestimated.

3.1.3 MODELS FOR CONSERVATION

Conserving the whales of Canadian ecosystems is a major responsibility of the Department. Although commercial whaling was banned in 1972, the hunting of whales by the Inuit, the indigenous people of the Arctic, is a traditional way of life and remains a significant source of protein.

A key question is whether continued hunting by the Inuit poses a risk to the recovery of depleted populations. To study this, given the uncertainties in the assessments, DFO uses risk models of whale population dynamics.

The models use information from aerial survey estimates of the population size corrected for uncertain biases in visibility from survey aircraft and the percentage of whales on the surface. Other parameters include an estimate of the rate of population increase in the absence of hunting and estimates of hunting losses. Originally, this rate was assumed, but it can now be estimated from time-series data on catches and population sizes. Most model parameters cannot be estimated with certainty. There are statistical uncertainties in each one of them so exact calculations cannot be done. Given those uncertainties, these risk analysis models evaluate the probability ('risk') that different levels of hunting will threaten recovery and, conversely, identify what catch level poses a negligible risk to a particular whale population's recovery.

These results are used as input to decision-making by co-management boards with Inuit groups and the Minister of Fisheries and Oceans Canada. Co-management boards involved in beluga management include the Nunavut Wildlife Management Board and the Inuvialuit Fisheries Joint Management Committee.


Photo credit: Kristin Laidre

Inuit hunters bring home a narwhal.

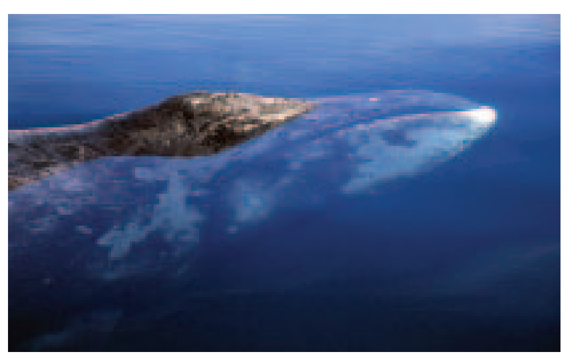


Photo credit: Larry Dueck

The eastern Arctic population of bowhead whales in the Arctic is currently estimated at 7,000 animals.

3.2 IDENTIFYING POPULATION STRUCTURE USING MOLECULAR GENETICS

When creating management strategies or conservation plans for a group of marine mammals, experts ask two questions: 1) how many stocks or populations are there? and 2) how do they interact? Knowledge about population structure is fundamental to the management of harvested species or species-at-risk. It is imperative to know not only the population size, but also the range limits and degree of population mixing when determining the allowable harvests or incidental harm for a species.

Although seemingly straightforward, the issues are quite complex. For example, most beluga whales migrate every year over long distances between their winter and summer destinations where they congregate in estuaries and near shore areas along coastlines.

Bowhead whales also travel long distances and often separate into groups based on age and sex. Walrus form groups on haul-out sites that may be based on complex social associations. This leads to even more questions about populations or stocks of marine mammals (e.g., what are the relationships among animals within a group? What are the relationships among animals found in different groups?)

One scientific tool used to answer these questions is the study of genetic patterns found in the animals' deoxyribonucleic acid (DNA). Although unique to each individual, the DNA code is more similar in animals that are related

DID YOU KNOW THAT?

#3

WHAT IS DNA?

Deoxyribonucleic acid (DNA) refers to the strands of genetic information passed from parents to offspring, which are found in cells of living organisms. These genetic instructions serve as a blueprint to build and maintain every part of a living organism.

The DNA code is a very long collection of chemical building blocks, including sets of nitrogenous bases. Letter labels are often used to represent these bases: A for adenine, C for cytosine, G for guanine and T for thymine. The sequence of these bases is 'read' and translated on a molecular level, and provides the instructions for different proteins to be built by the cells.

Small variations in this string of information can result in different individuals having different appearances, for example, different coloured eyes or hair. Larger variations are found when comparing the DNA code of animals of different species.

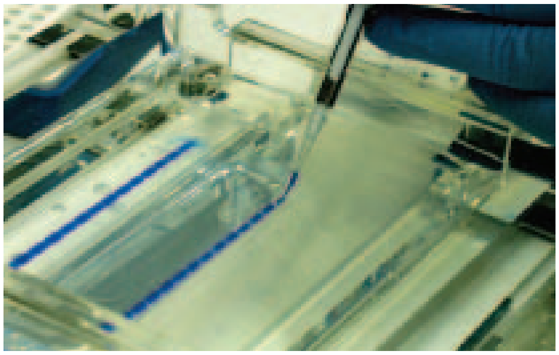


Photo credit: Lianne Postma

Loading DNA sample into an agarose gel in preparation for electrophoresis.

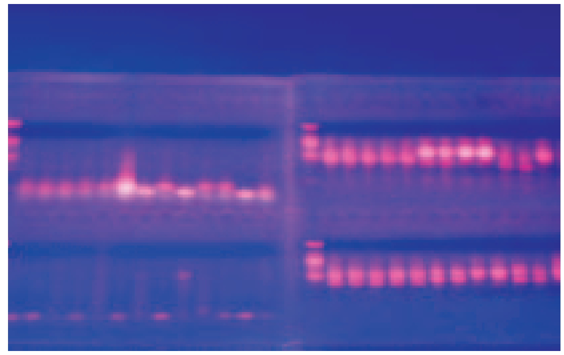


Photo credit: Lianne Postma

Visualization of DNA bands using UV light after agarose gel electrophoresis.

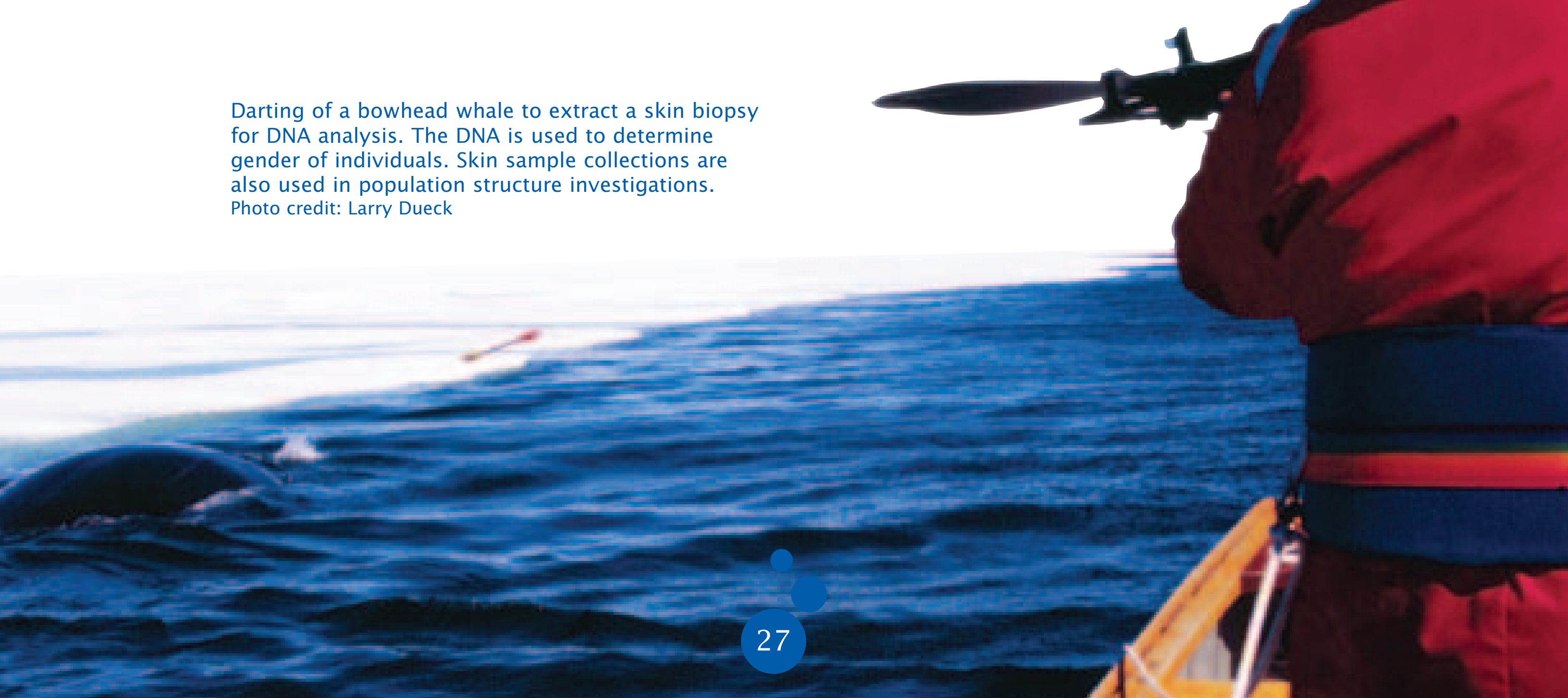
to each other than in those unrelated. Marine mammal researchers can exploit these differences and similarities to provide clues about the identity and dynamics of marine mammal populations.

In the oceans and waterways surrounding Canada, DFO researchers are looking for differences in the DNA information among different groups of marine mammals. This DNA may be obtained from tissue samples collected from marine mammals using a biopsy dart from harvested animals or from animals that have stranded or died.

This piece of tissue is then sent to the population genetics laboratories at the Freshwater Institute in Winnipeg, Manitoba, where the DNA is extracted. Once the DNA from the individual tissue sample has been isolated, it is processed using a variety of techniques that analyse the patterns of information contained in the DNA code.

When the genetic information contained in a collection of samples is compared, small differences are often revealed. These differences in genetic patterns can then be used to determine how many different stocks exist, how animals are moving along their migration routes (e.g., either as family groups or as some other segregated group), and to what degree the stocks are overlapping or mixing at different times of the year.

Along with other information provided from traditional ecological knowledge, satellite tagging studies and aerial surveys, molecular genetics can be a very useful tool for understanding the complex structures found in marine mammal populations.



Darting of a bowhead whale to extract a skin biopsy for DNA analysis. The DNA is used to determine gender of individuals. Skin sample collections are also used in population structure investigations.
Photo credit: Larry Dueck

3.2.1 POPULATION STRUCTURE OF HUDSON BAY BELUGA

During the summer, two known groups of beluga whales live in Hudson Bay. Some spend the summer along the western coast of Hudson Bay while the other group stays along the eastern coast of Hudson Bay. During the fall, both move into Hudson Strait and remain there, or in the northern part of Ungava Bay, throughout the winter. In spring, the group separates and returns to their respective Hudson Bay coastlines.

The Department is concerned that the population of beluga whales that lives in eastern Hudson Bay is declining. At the same time, the western Hudson Bay population is quite large, which allows harvesting to continue. To protect the declining population of whales, it is important to know how many of those being harvested belong to the eastern Hudson Bay population. To achieve this, Nunavik hunters collaborate with DFO researchers by providing tissue samples from whales they harvest. Biologists then analyse this skin sample for its genetic DNA, and can identify whether whales belong to the eastern or the western Hudson Bay population.

At the same time, if sampling is very good, researchers hope to identify the periods of the hunting season when hunters are more likely to harvest

Photo credit1: Jack Orr
Photo credit 2: Lisa Loseto

A scientist extracts a blubber sample for genetic analysis.

Photo credit: Zegrahm Expeditions

Belugas symbolize the Arctic for many people.

eastern Hudson Bay whales rather than the western ones. By shifting the hunt away from the small eastern Hudson Bay population towards the larger western Hudson Bay population, it is possible to maintain the harvest of whales by Nunavik communities without causing damage to the beluga population that spends the summer along the eastern Hudson Bay coast.

The genetic analyses of the skin samples provide more information on where the beluga spends the summer. In the sampling kit, DFO also asks for a tooth from the lower jaw. The tooth provides information on the age of the animals, which helps in monitoring whether the population is increasing or decreasing.

3.2.2 POPULATION STRUCTURE OF WALRUS

Walrus rest ashore or on ice for much of the time. Terrestrial resting places, called haul-outs, are used year after year, but not every haul-out in an area is used every year. As part of other ongoing studies, DFO collects skin biopsies from animals on haul-outs to determine the social structure of the walrus present.

At many haul-outs most of the mature animals are females. DNA analyses may determine if the walruses are related, such as whether they are all daughters, granddaughters and aunts of each other. Other questions include: are the fathers of the calves resting on other haul-outs? Does the group stay together when it leaves this haul-out and moves to others? While the answers to these and similar questions will be interesting in their own right, they will also help evaluate risks that the walrus population may face.

Climate change predictions include the possibility of significantly higher sea levels in the Arctic. Tourism and shipping may disrupt specific haul-outs. The impacts on the population as a whole could be different if a complete family line is disrupted than if the impact is spread across a broader genetic diversity.

Understanding the genetics of social organizations can also help evaluate the potential effectiveness of recovery strategies. If the number of animals is severely reduced in a location, they may increase faster than reproduction alone would allow if new animals move in from nearby areas. However, if the depleted group was mostly closely related animals, the probability of newcomers arriving is lower. Simply put, if a matrilineage (a group of animals closely related through the female line) has had largely exclusive use of an area, other matrilineages will also tend to remain in 'their' area and be less likely to discover newly available habitat.

3.3 REPRODUCTION AND MORTALITY

The direct driver of population dynamics (changes in the numbers, ages and sex ratio in a population over time) is the balance between the number of births and deaths. If more animals are born than die, the population size increases. If mortality exceeds reproduction, the population declines. Mortality can be either from natural causes such as predation or disease, or humans can cause it either directly (e.g., hunting) or indirectly (e.g., pollution). Usually, it is not possible to distinguish between indirect mortality and natural mortality. As a result, scientists and managers usually include human-induced indirect mortality in their estimates of natural mortality. We cannot change reproductive rates so influencing mortality is the only option left to managers wishing to influence population size.

Photo credit: Jack Orr

Photo credit: Don Bowen

Grey seal female gives birth on Sable Island.

Photo credit: DFO Newfoundland

Hooded seal mother and pup. The pup is also called "blueback".

3.3.1 SEAL REPRODUCTION

Understanding patterns and strategies of reproduction, as well as the ecological factors influencing them, is necessary to understand the population dynamics of any marine mammal species.

For example, hooded seals nurse their pups on unstable sea ice for only four days while some fur seal species continue to nurse their pups for up to three years. Some small, toothed whales remain in the same area year-round to feed and give birth, while an entire ocean basin separates the calving and feeding grounds of many large baleen whales. Most seal species give birth to a pup each year, while walruses and larger whales give birth every two or three years at most.

For species that are hunted or taken as by-catch, it is possible to examine the ovaries for the presence and size of particular structures (i.e., follicles and corpora) that provide information on the reproductive history of the individual animal. It is usually possible to tell whether the female is sexually mature, if she is currently pregnant and, in some cases, whether she gave birth in the previous one or two years.

For species that are no longer hunted and only rarely taken as by-catch, reproductive rates may be obtained from observations of known individuals. Recently, scientists have developed ways to analyse pregnancy hormone levels from blubber tissue obtained from a biopsy in order to determine if an animal is mature or pregnant.

One of the longest and most comprehensive data sets available on the reproductive status of a marine mammal population is on the harp seal. DFO has collected data on maturity and pregnancy rates since 1954 with annual information available from the mid-1980s to the present. Analysis of this long-time series of data indicates that female reproductive status varies as population

Female harp seal and pup.
The pup is also called a "whitecoat".
Photo credit: DFO Newfoundland

size and environmental conditions change over the years.

Estimates of the total number of harp seals in the Northwest Atlantic declined during the 1950s and 1960s to just under two million in the early 1970s and then increased steadily to around 5.5 million in 1996 where it has since stabilized. During this period, there was a general tendency for annual pregnancy rates to be higher (~90%) before the 1980s and lower (~70%) since the mid 1980s.

Similarly, the age at which females tended to become sexually mature also varies over time. During the late 1970s and most of the 1980s females tended to mature at a younger age (~4.5 years) while during the mid- to late-1960s and, since 1988, they matured later (~5.5 years).

Although the direction of these long-term changes in pregnancy rates are consistent with the changes in population size, from a statistical perspective, very little of the observed variability in these reproductive data are explained by population size. These findings suggest that other ecological or environmental factors such as changing oceanographic conditions and/or prey availability may have an important influence on harp seal reproduction.

3.3.2 WALRUS AND BELUGA REPRODUCTION

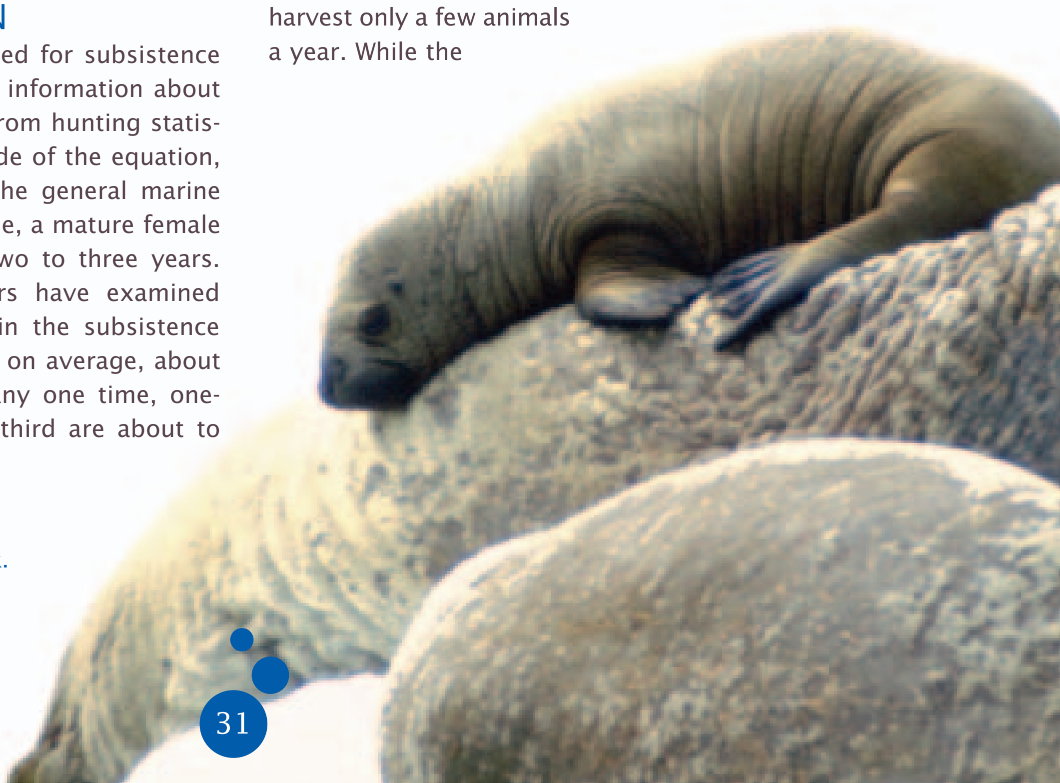
Walrus and beluga are hunted for subsistence in Arctic Canada, and some information about their mortality is available from hunting statistics. On the reproduction side of the equation, walrus and beluga follow the general marine mammal scheme. On average, a mature female will produce a calf every two to three years. DFO researchers and others have examined mature females harvested in the subsistence hunt and have learned that, on average, about one-third are pregnant at any one time, one-third are nursing, and one-third are about to become pregnant.

Photo credit: Caroline Guimont

Two beluga calves traveling with their parents. Baby belugas are grey and turn white as they mature.

These reproductive rates can be determined without knowing the age of the females. However, the age at which females start bearing young can make a large difference in how the population grows. Age of maturation can shift somewhat as a density-dependent response to changes in the relative amount of food available, but the shifts might be small. It requires a large sample to assess this shift and these data are hard to come by.

Hunters tend to avoid selecting walrus with calves and, in some areas, may harvest only a few animals a year. While the



Walrus pup on its mother’s back.
Photo credit: Jack Orr

age of maturation is generally between about 7 and 10 years for both walrus and beluga, scientists cannot resolve possible differences between two populations that may be quite different in their growth rates.

Although there are data available for harvest levels for each walrus or beluga population, estimates of natural mortality are more difficult to generate. DFO is examining the ages of harvested walrus to obtain an overall mortality curve. If this can be done, it should be possible to subtract hunting mortality and derive an initial estimate of natural mortality.

Another approach, in its infancy, is to use DNA to identify individuals (see section 3.2) to track the presence of animals in the population over time. This is a long-term project that lasts as long as the individual survives.

3.4 ROLE OF DISEASE IN MARINE MAMMAL POPULATIONS

Until recently, ecologists and wildlife managers assumed that infectious and parasitic diseases posed little or no threat to wildlife populations. While epizootics (disease outbreaks in animal populations) may cause massive mortalities, they were explained as cases where other factors had disrupted the ‘balance of nature’. Epizootics were considered as unusual exceptions to the general rule of ‘no effect’ at the population level. It was argued that diseases were unlikely to affect host populations; if diseases led to the death of the host, then the disease organism would die as well. This assumption has turned out to be incorrect.

It is now known that diseases can and do regulate wildlife populations. From this perspective,

These belugas are entrapped in ice and have nowhere to go. Ice entrapment is a natural cause of mortality.
Photo credit: M. Ramsey

Photo credit: Ole Nielsen

An abscess in an Inuit harvested narwhal from Grise Fiord, NT subsequently found to contain Brucella bacteria. Brucella is a known human pathogen.

Photo credit: Ole Nielsen

Hunters become concerned when they see animals with obvious abnormalities such as loss of hair on this harvested harp seal.

DFO scientists study diseases of marine mammal species in Canada including new or emerging diseases that may affect wild populations. This is an important area of research within CEMAM.

Events over the last few decades have shown that diseases caused by viral, bacterial and parasitic pathogens can have sudden and dramatic effects on marine mammals. The best documented case was the European Seal Epizootic that killed more than 20,000 animals and over 50 per cent of the North Sea harbour seal population in 1988 and 1989 (reappearing again in 2002 with a similar estimated number of dead). The responsible agent was found to be a distemper virus similar to the one that causes distemper in dogs. The virus had never been seen previously in marine mammals and is presumed to have evolved from the dog virus.

New and emerging diseases can have effects on wild host populations with no previous exposure to certain pathogens. Also, some diseases can have effects on the viability of their hosts. Brucellosis, a well-studied disease of livestock has long been known to cause reproductive failure and chronic disease in affected animals. Scientists now know that Brucella, the bacterium responsible for this disease, now infects marine mammals. Brucellosis may have the same harmful effects among species of seals and whales worldwide (including Canada) but further study is required. Mortalities due to natural or new and emerging diseases may contribute to marine mammal population declines previously attributed to habitat degradation, over-harvesting or ecological changes.

There are other reasons why the surveillance of marine mammal disease is important. Emerging diseases not seen until recently can appear and affect public health, the food supply, economies as well as the environment. Recent examples include avian influenza, HIV-AIDS, SARS, West Nile Virus - all zoonoses (diseases transmissible between animals and humans) and these diseases can have significant effects on human populations. Marine mammals are intimately connected to components of the marine and terrestrial ecosystems and can thus serve as indicators of the health of our environment. Marine mammals carry some zoonotic diseases, such as brucellosis, toxoplasmosis and trichinellosis, therefore, surveillance of animal diseases is critical in managing these infections and assisting public health experts in evaluating risks to consumers such as aboriginal groups.

4.0

HOW DO MARINE MAMMALS FIT INTO THE ECOSYSTEM?

Marine mammals are important consumers in continental and deep-ocean marine ecosystems off Canada's east and west coasts, and in the Canadian Arctic. As consumers, they may affect prey abundance and distribution, patterns of prey dispersal and behaviour.

Harp seals aggregate on the ice after weaning to moult. These aggregations are called "moulting patches".
Photo credit: DFO Newfoundland

Predation by marine mammals can also impact ecosystem structure and functioning through cascading effects on lower trophic levels, the so-called 'top-down' predation effects. This is perhaps best demonstrated in coastal ecosystems where predation by sea otters has profound influences on prey species and the structure of the physical habitat. In addition to their role as consumers, some marine mammals physically alter habitat through their effects on plant communities and the bottom surface.

Although marine mammal predation can influence lower trophic levels, changes in the physical environment (e.g., El Niño, North Atlantic Oscillation) and production at lower trophic levels can also influence the abundance and dynamics of marine mammals. Such events are called 'bottom-up' effects.

Bottom-up effects can alter the availability of prey, which in turn can alter the distribution of marine mammals and, in more extreme cases, result in increased mortality and reduced fertility or reproductive success. The timing of effects can vary widely from those that affect populations at a seasonal or annual time-scale to those that affect characteristics of the population over decades, such as age-structure and recruitment of young animals.

4.1 DISTRIBUTION

Marine mammals have wide distributions across the three oceans. Understanding their distribution requires a combination of methods. First, researchers tap the knowledge of the Aboriginal nations who have observed those animals for centuries and have a wealth of understanding of their seasonal occurrence in different areas of the oceans. This information, combined with observations gleaned from the scientific and popular literature form, is the basis of tracking studies and aerial survey design.

4.1.1 AERIAL SURVEYS

Aerial surveys provide invaluable information on the distribution and the abundance of marine mammals, and are used extensively by scientists of Fisheries and Oceans Canada (DFO). (For a detailed explanation of aerial surveys, please see sections 3.1.1 and 3.2.1.)

Photo credit: Don Bowen

Grey seal male emerging from the water.

Photo credit: Graeme Ellis

Aerial view of a sea otter raft. Sea otters like to rest in kelp beds which make counting difficult during surveys.

DID YOU KNOW THAT?

#4

HARP SEALS

There are three populations of this abundant species: the White Sea/ Barents Sea, the Greenland Sea and the Northwest Atlantic. The Northwest Atlantic stock off Canada is both healthy and the largest. Since 1970, it has tripled in size to 5.8 million based on the latest peer-reviewed survey in 2004.

The harp seal is a medium-sized seal that migrates annually between Arctic and sub-Arctic regions of the North Atlantic. The Northwest Atlantic population summers in the eastern Canadian Arctic and Greenland. In the fall, most of these seals migrate southward to Atlantic Canadian waters where they give birth on the pack ice in the Gulf of St. Lawrence or off northern Newfoundland during late February or March. Following moulting in April and May, the seals disperse and eventually migrate northward. Small numbers of harp seals may remain in southern waters throughout the summer, while others remain in the Arctic throughout the year.

Adult harp seal
Photo credit: DFO

DID YOU KNOW THAT?

#5

HOODED SEALS

The hooded seal is the second most abundant and largest seal species in the Northwest Atlantic. Adult males average 2.6 m in length and weigh over 300 kg; females are significantly smaller, averaging 2.2 m and 160 kg.Like harp seals, hooded seals give birth (whelp) on pack ice off the east coast of Greenland, off the coast of southern Labrador and in the Gulf of St. Lawrence. Hooded seals are seasonal migrants, spending most of the year in offshore waters. In the Northwest Atlantic, they spend their summer off south and west Greenland or in the Canadian Arctic, and migrate to whelping areas during the late fall or early winter.

The last survey in 2005 estimated a population of approximately 600,000 animals.

Male hooded seal
Photo credit: DFO Newfoundland

DID YOU KNOW THAT?

#6

GREY SEALS

There are two herds of this non-migratory species, with the main breeding concentrations being in the southern Gulf of St. Lawrence and on Sable Island off Nova Scotia.

The grey seal population was estimated to be about 195,000 in 1997. A new population survey completed in 2004 estimated approximately 200,000 animals on Sable Island and 50,000 in the southern Gulf of St. Lawrence and eastern Nova Scotia.

Female grey seal
Photo credit: Don Bowen

4.1.2 SATELLITE TRACKING

Tracking studies are used to obtain more detailed information on the seasonal distribution of whales and seals where they are less likely to be seen by coastal residents.

For most species, the animal must be captured in order to attach the satellite transmitter, or tag. For smaller species, this method involves the live-capture of these animals with nets of varying sizes depending on the bottom conditions and the behaviour of the animal.

Photo credit: DFO Newfoundland

Scientist captures a seal with a net before attaching a satellite tag.

Photo credit: DFO Central and Arctic

A scientist attaches a satellite tag on the back of a beluga to track its movements.

Photo credit: DFO Newfoundland

The satellite tag is glued on top of the head. The tag will fall off during the annual moult.

Surprisingly, it is relatively easy for several people in shallow water to restrain a beluga, which can be up to five metres long, to attach the tag to the dorsal ridge. For seals, a mild sedative is given to reduce stress after capture, and then a transmitter is glued to the surface of the fur.

Bowhead whales, which are too large to be captured or restrained, can be tagged with an implanted or tethered tag that is anchored in their very thick blubber layer. As well, blood samples and skin biopsies may be taken during capture for analysis of physiological condition, disease and stock identity.

Depending on the species and tagging method, the transmitter will stay in place from several weeks to more than a year, and can track movements at sea over hundred or even thousands of kilometres. Seals shed their tags during their annual moult, whereas whales may lose their tags because of water friction.

Transmitters attached to each animal send data to polar orbiting satellites. When a satellite passes over an animal at the surface, it receives the data, measures the frequency of the signals and relays all this information to the Service Argos processing centres via ground stations.

The position of the animal is computed using the Doppler shift on the transmitted signals. The Doppler shift is the apparent change in frequency perceived by an observer (the satellite) moving relative to the source (the animal). The classic example is the change in the sound you hear standing by the road when a car approaches

DID YOU KNOW THAT?

#7

SATELLITE TRACKING OF BELUGAS

Northern Quebec belugas are divided into three separate populations based on where they summer: Ungava Bay, eastern Hudson Bay and western Hudson Bay. In 1988, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated the eastern Hudson Bay population threatened and the Ungava Bay population endangered.

In an effort to better understand the movements of eastern Hudson Bay belugas and to provide a solid scientific basis for the management of northern Quebec belugas, DFO scientists, in co-operation with Makivik Corporation and the Nunavik Research Centre, launched a satellite-tracking program in 2002 to monitor the belugas.

In July 2003, 13 eastern Hudson Bay belugas were fitted with satellite transmitters. Once attached to the beluga's dorsal ridge, each device regularly transmits data to several satellites on the animal's diving activities and movements. The movements of a beluga between July 2003 and April 2004 can be seen on this satellite map of northern Quebec. The whale summered in southeastern Hudson Bay (at left on the map), then headed northward along the coast through Hudson Strait and into Ungava Bay (centre of the map), where it remained until November.

In December, it continued on its way to the coast of Labrador. The transmitter stopped sending data on April 15, 2004. Early aerial surveys had suggested that Hudson Bay belugas spent the winter in Hudson Strait. With the recent improvements in satellite tracking and new techniques for attaching the transmitters, it is now known that the belugas frequent a much larger area than previously believed and that part of the population over-winters along the coast of Labrador.

Scientists place a satellite tag on the back of a beluga
Photo Credit: Bill Doidge, Nunavik Research Centre

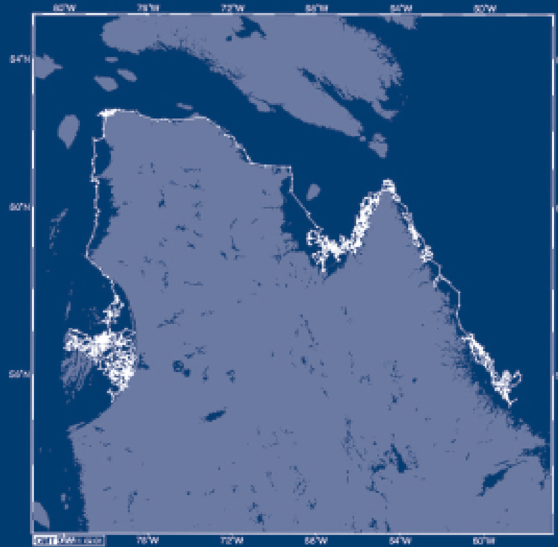


Photo credit: Mike Hammill

The movements of beluga between July 2003 and April 2004 can be seen on this map.

DID YOU KNOW THAT?

#8

OCEANOGRAPHER SEALS

The prolific diving of seals throughout the Northwest Atlantic is of great interest to Canadian physical oceanographers. This is particularly so because of the new technology that allows tags to sample temperature, salinity and depth with satellite transmission in near-real-time. Assuming a sufficient number of seals are in the Northwest Atlantic at a given time, this technology provides scientists with enough information to produce a three-dimensional snapshot of ocean observations.

This profile (water measurement with depth) information is particularly useful when linked to satellite information. Satellites provide a snapshot of the ocean's surface with constant horizontal resolution. The added profiles taken by the seals enable scientists to better interpret the satellite data and its inference on the state of the ocean beneath the surface.

Furthermore, when making an ocean forecast using a numerical ocean model, the inclusion of available at-sea data ensures that the ocean state (temperature, salinity, currents, etc.) described by the model are more accurate and realistic. This also allows the model to make better forecast predictions.

In 2004, seals 'took' 55,000 profiles! This is more than 10 times the amount taken from all other observation systems for the Northwest Atlantic combined. Scientific ships, ships of opportunity and Argo floats are the typical platforms used for taking ocean profiles, but now oceanographers can add seals.

Harp seal with satellite tag on top of the head. The seal will shed the tag during its annual moult. This tag measures temperature and depth of water. This information and location is relayed via satellite.
Photo Credit: DFO Newfoundland

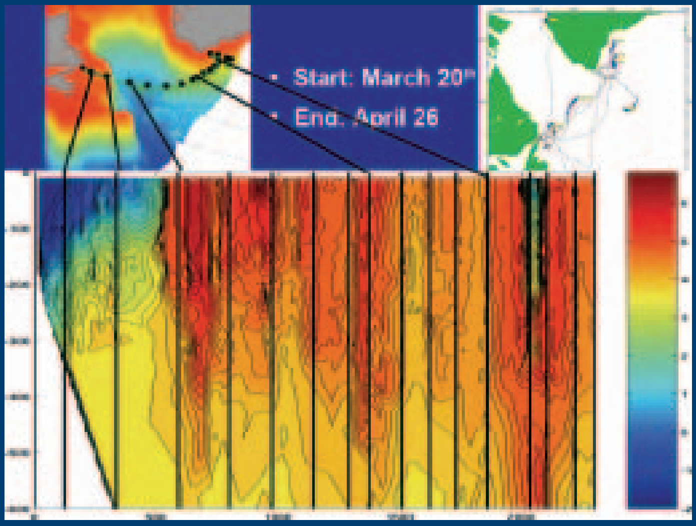


Photo credit: Fraser Davidson

Seals help provide information on temperature at depth in the North Atlantic.

(a higher pitch) and moves away (a lower pitch). Similarly, when the satellite 'approaches' a transmitter, the frequency of the signal measured by the satellite receiver is higher than the actual transmit frequency, and lower when it moves away.

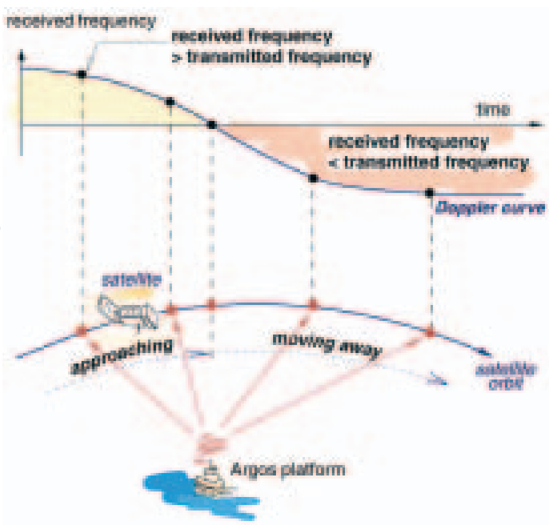


Photo credit: CLS Service Argos

The location of the Argos platforms (animals) is calculated using the Doppler shift on the transmitter signals.

The number of satellite passes each day depends on the latitude of the habitat used by a marine mammal, increasing as one approaches the poles. In temperate habitats, Service Argos receivers tracking marine mammal movements now routinely log seven to nine locations per day.

Some of these electronic tags also have a miniature computer that can transmit information on swimming speed, depth and duration of dives, as well as characteristics of the physical habitat (water temperature and salinity) used by the animals. This data can then help track migrations, measure the environment the animal prefers, and indicate how often an animal has to surface to breathe, or how deep and for how long it dives.

In this manner, scientists can identify critical habitat and ecologically sensitive areas or hot spots, better understand patterns of marine mammal predation, and address potential conflict between marine mammals and human activities in the ocean. All this information helps DFO scientists to better understand species' foraging behaviour, habitat requirements, seasonal distribution and dispersal that could not be addressed 15 to 20 years ago.

4.1.3 SEA OTTER DISTRIBUTION, ABUNDANCE AND CONSERVATION ON THE B.C. COAST

Historically, sea otters were found along the Pacific rim from Baja, California, to northern Japan, but were heavily hunted during the maritime fur trade of the 18th and 19th centuries. As a result, by the early 20th century, sea otters has disappeared from much of their range, including British Columbia (B.C). Between 1969 and 1970, 89 sea otters from Alaska were released into Checleset Bay on the west coast of Vancouver Island, in an effort to re-establish the species on the B.C. coast. Similar re-introductions were made in Washington, Oregon and southeastern Alaska.

Sea otters are rarely found beyond one to two kilometres offshore unless shallow areas extend further. Otters are not migratory. They feed on benthic invertebrates, such as sea urchins, clams, mussels and crabs. Most foraging occurs in depths of 30 m or less, although they are capable of foraging to depths of 100 m. Otters are gregarious and spend a considerable part of each day resting on the water in groups called rafts that can include as many as 200 animals. Rafts form habitually in the same locations,often

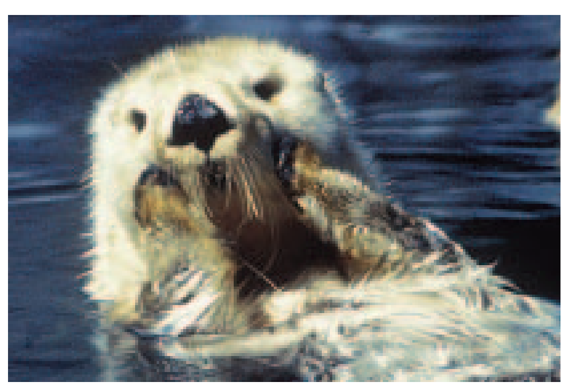


Photo credit: Bob Herger, Vancouver Aquarium Marine Science Centre

The sea otter is the smallest marine mammal in North America, averaging 1.2 m in length.

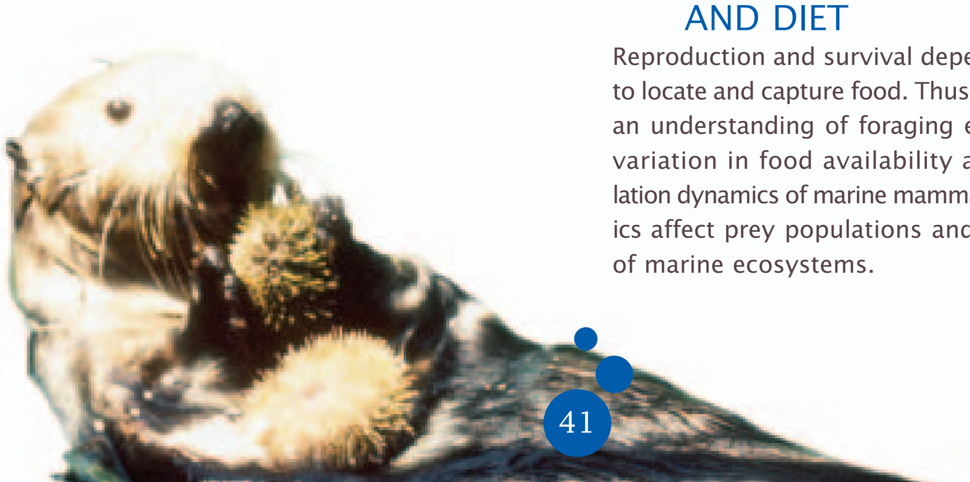
Photo credit: M. Lough

Scientists counting sea otters during a survey.

associated with specific reefs or kelp beds. Sea otters segregate by sex such that males and females form separate rafts. Population range expansion occurs by mass movement of a raft of males into new, previously unoccupied, habitat. Within a few years, female rafts move into these areas once the male raft has moved on.

In B.C., sea otters currently occupy areas with extensive rock reefs, kelp beds and associated shallow depths along rugged exposed sections of the west coast of Vancouver Island and the central mainland coast.

The first survey to count sea otters in B.C. was conducted in 1977. Population surveys are conducted from small boats and helicopter. Until 1987, sea otters were found in only two locations along the west coast of Vancouver Island. In 1990, sea otters were first reported in the Goose Island Group on the central mainland coast. By 1995, the sea otter population had increased to 1,522 otters.



Sea otter feeding on sea urchins.
Photo credit: DFO

Photo credit: Graeme Ellis

Sea otters live in rafts, all female or all male.

Since 1995, population growth and range expansion has continued along Vancouver Island and on the central mainland coast.

Between 1977 and 1995, the growth rate was estimated to be about 18.6 per cent a year on Vancouver Island. Although the population continues to grow, it seems to have slowed since 1995. The growth rate from 1977 and 2004 averages about 15 per cent yearly. Sea otters are a density-dependent species and populations are limited largely by food. Rapid initial growth followed by a decline in growth rate once the population expands to occupy most of the available habitat seems to be typical of re-introduced sea otter populations. The most recent population survey conducted in 2004 on the B.C. coast estimated a total of just over 3,000 animals.

The B.C. sea otter population is still relatively small, thus research is also underway to examine disease exposure, health and genetic diversity in the sea otter population to assess potential impacts to population recovery.

4.2 FORAGING ECOLOGY AND DIET

Reproduction and survival depend on the ability to locate and capture food. Thus researchers need an understanding of foraging ecology and how variation in food availability affects the population dynamics of marine mammals. These dynamics affect prey populations and the functioning of marine ecosystems.

Foraging ecology comprises such elements as: finding food (i.e., searching); choosing what to eat among the many species encountered and perceived; pursuit and capture of food; consumption; and digestion. These components are influenced by the age, sex, reproductive status, body size of the marine mammal, and by factors in the environment such as age and size of prey, prey anti-predator behaviour, abundance and distribution of alternative prey species, as well as variations in weather and climate.

Photo credit: Claude Nozères

Baleen whales feed primarily on planktonic crustaceans.

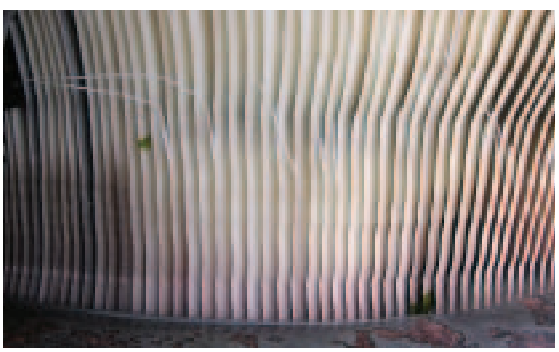


Photo credit: Claude Nozères

Baleen of a whale.

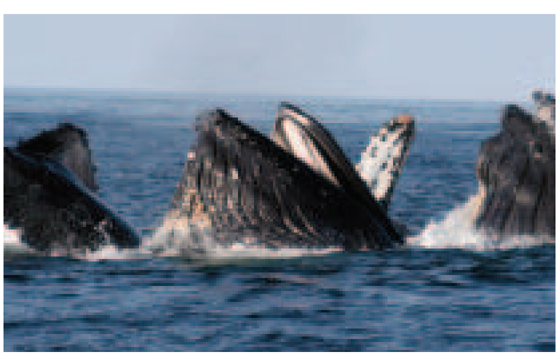


Photo credit: John Ford

Baleen whales (humpbacks) lunge feeding.

Baleen whales feed primarily on planktonic crustaceans such as copepods, euphausiids and amphipods. Although in some species such as humpback and minke whales, fish are important prey. All baleen whales require dense concentrations of prey, which they capture by engulfing or skimming.

Photo credit: Jack Orr

Belugas are odontocetes

Toothed whales (odontocetes) possess long rows of uniformly shaped teeth (homodonts) designed for grasping and holding prey such as fish or squid. Although primarily fish-eating, these species also consume significant amounts of squid and crustaceans. Pilot whales, which feed primarily on squid, have fewer (7 to 12 pairs per tooth row), but larger teeth. Another squid predator, the sperm whale, has 20 to 25 teeth in each lower jaw.

Photo credit: Claude Nozères

The different shaped teeth (heterodont) of seals allow them to consume a wider variety of food.

Pinnipeds (fur seals, sea lions and earless seals) have heterodont dentition (teeth of different shapes) and typically consume a variety of fish, squid and invertebrates. Pinniped diets are often notable for the large number of species that they eat.

For example, harp seals in the Northwest Atlantic eat more than 100 types of fish, squid and crustaceans. However, careful inspection reveals that usually less than five species and often only two or three, account for most of the energy ingested by pinnipeds at any one time and place.

Crustaceans are important prey of harp seals, particularly pups and young animals. Pinniped diets often show seasonal, yearly and spatial variation, presumably reflecting changes in prey availability. Thus, diets are dynamic and cannot easily be described by short-term studies at a single site.

The development of small telemetry devices and data loggers has dramatically increased our understanding of both the diving behaviour and movements of marine mammals during the past 10 to 15 years. Since most marine mammals must dive to encounter and capture prey, understanding more about diving behaviour has also meant a better understanding of foraging.

Studies on grey seals reveal strong seasonal patterns in their diving behaviour, and show that males and females exhibit quite different patterns. These patterns correspond to differences in the timing of energy storage in blubber (fat) and for reproduction.

Satellite telemetry provides detailed information on the spatial distribution of diving (i.e., foraging) and the search tactics used to find prey. It also provides new insight into the migratory behaviour of harp and hooded seals, and into the seasonal segregation of habitat use by adult males and females in non-migratory species such as the grey seal. This means that the habitats used by many species can be characterized and researchers can begin to understand why marine mammals eat the diets they do.

4.2.1 B.C. RESIDENT KILLER WHALE DIET PREFERENCE

Compared to many other mammals, the feeding habits of whales are very difficult to study. Feeding usually takes place below the ocean's surface, sometimes at great depths where it is impossible to observe. The diet of many of the large whales is known reasonably well from analyses of the stomach contents of animals taken in commercial whaling operations. However, for cetaceans that have never been hunted, such information is not available.

Killer whales are top predators in the ocean, and prey on a great diversity of marine fauna, from small schooling fish to the largest baleen whales. However, detailed knowledge of the diet of these animals has been very scarce.

In coastal waters of British Columbia, for example, killer whales have long been known to congregate in areas and at times of the year that coincide with high densities of migratory salmon, but actual direct evidence of predation on salmon was unavailable until recently.

To determine the actual diet of killer whales in B.C., annual predation studies are done concurrently with photo-identification censuses. These studies use surface observations of predatory behaviour, and collections of scales and prey fragments left at kill sites, as well as

Resident killer whales of BC.
Photo credit: Graeme Ellis

identification of prey remains in stomachs of beach-cast whale carcasses.

The results of these studies are quite surprising. Two different populations of killer whales in the area, known as 'residents' and 'transients', share the same waters yet do not mix, and have completely different diets. Residents feed primarily on salmon and other fishes, while transients eat marine mammals almost exclusively, especially seals, sea lions, porpoises and dolphins. Such dietary specializations between overlapping populations of a predator are extremely unusual.

Also surprising was the recent discovery that resident killer whales feed selectively on certain salmon species while ignoring other, more abundant salmonids. Chinook salmon is preferred over all others, probably due its large size and high fat content. Chum salmon, the second largest salmonid in the region, are also taken during their fall migration to spawning rivers.

An unexpected finding was that pink and sockeye salmon, which are by far the most abundant salmonids along the coast during summer, are not preyed on to a significant degree. This is likely due to their relatively small size and because chinook salmon are also abundant during their migration through coastal waters.

Chinook salmon appears to be the prey species of choice for resident killer whales throughout the year, though little information is available during winter. The whales may indeed be so specialized on chinook predation that their survival depends on adequate availability of this prey species. Several consecutive years of unusually high mortalities in resident killer whale populations during the late 1990s coincided with a sharp coast-wide decline in chinook salmon during the same period.

Future studies will be needed to determine if resident killer whale populations are, in fact, limited by the availability of chinook salmon. In the meantime, genetic analyses of chinook scales recovered from kills are underway to identify stocks that are particularly important to resident killer whales, in order to ensure the protection of what is clearly a vital food supply.

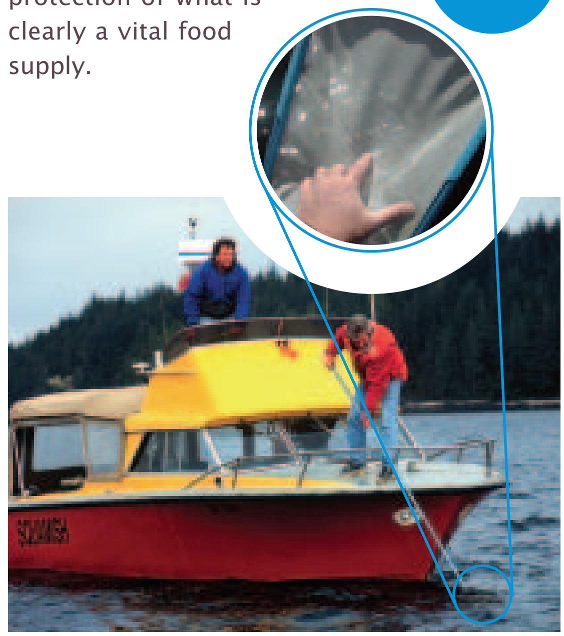


Photo credit: Roy Tanami

DFO scientist sampling a killer whale kill site to determine the prey.

4.2.2 ESTIMATING MARINE MAMMAL DIETS

Direct observation of feeding is feasible in a few species of marine mammals (e.g., sea otters), but most species inhabit remote areas for most of the year and feeding generally occurs at depths where observation is not possible. Thus, generally, indirect methods are needed to study the foraging ecology of marine mammals.

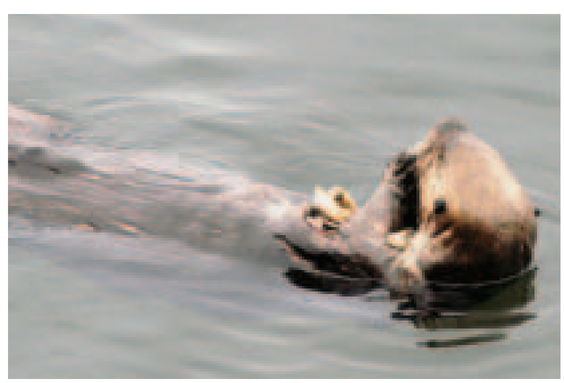


Photo credit: Linda Nichol

Sea Otter feeding on crab.

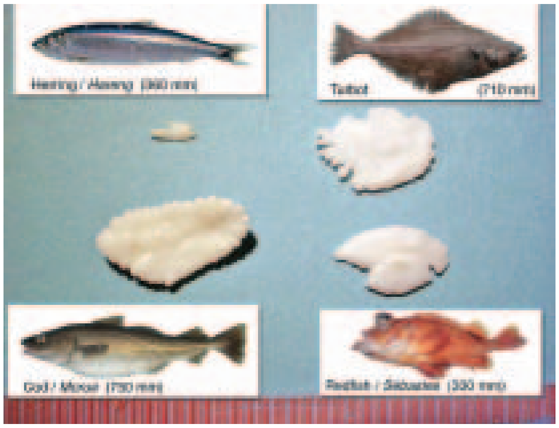


Photo credit: Claude Nozères

Examples of otoliths (ear bones): herring, turbot, cod and redfish.

Photo credit: DFO

Scientist taking a blubber biopsy for fatty acid analysis.

OTOLITHS AND OTHER HARD PARTS

The most common way to determine the diet of marine mammals is to identify the prey's 'hard parts' such as bones, scales and lenses that are resistant to digestion and can be collected from stomachs, intestines, or feces.

Otoliths (fish ear bones), shellfish carapaces and squid beaks can be used to determine the species of prey consumed as well as estimate the size and sometimes the age of the prey consumed. Information on prey size is important because scientists and managers are usually interested in the biomass and, ultimately, the energy intake associated with the consumption of prey.

Despite their widespread use in diet studies, using hard parts to determine the species composition and size of prey is subject to a number of biases, which may seriously limit the value of such information. One problem is that otoliths are present only if the head of the fish is consumed. Another difficulty is that hard parts erode during digestion, such that the size of prey consumed may be underestimated and, in some cases, identification may not be possible. Another potential difficulty in drawing conclusions from such data is that hard parts only provide information on recently eaten prey near the point of collection.

STABLE ISOTOPES RATIOS

Stable isotopes provide another means of estimating the diets of marine mammals. The carbon isotope ratio and the nitrogen isotope ratio of various animal tissues are useful in diet studies because they reflect the foods digested by the predator.

Stable isotope ratios provide a longer record of the diet than stomach or fecal contents and are not dependent on the recovery of hard parts. Enrichment of nitrogen occurs at each trophic level (position in the food chain) within a food web (interconnected food chains), thus nitrogen isotope ratio values provide a good indication of the trophic level at which the predator feeds. Although stable isotope values provide useful information on the broad-scale geographic source of the diet and the general trophic level of prey, they do not usually permit the identification of the species of prey being eaten.

FATTY ACIDS

To improve the understanding of diets, DFO scientists in collaboration with Dalhousie University researchers developed a new way to investigate diets over time, by analysing samples of lipids in tissues. The scientists have shown that the proportion of different fatty acids found in these tissues reflects the proportion of different fish species in its diet. The method is called Quantitative Fatty Acid Signature Analysis (QFASA).

Essentially, the fatty acid composition of prey (fatty acid signature) influences the fatty acid composition of the lipids of predators (fatty acid profile). Lipids in marine organisms are characterized by their diversity and high levels of long-chain and polyunsaturated fatty acids. Unlike other nutrients such as proteins that are readily broken down during digestion, dietary fatty acids are often deposited in predator lipid storage depots in predictable ways.

Fatty acids are identified and quantified using gas liquid chromatography. Blood, blubber (fat) and milk are used as each can provide information about foraging at different time frames.

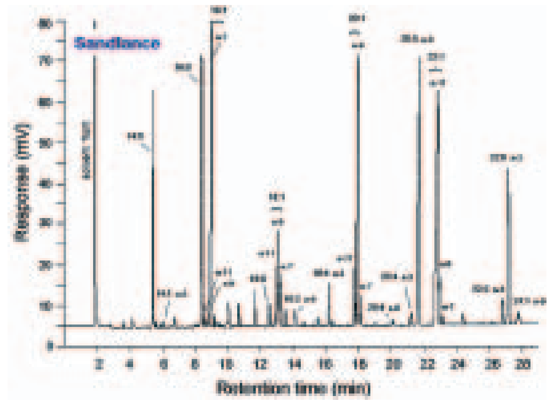


Photo credit: Don Bowen

Chromatogram of the fatty acids of sand lance, a commonly eaten marine mammal food.

Fatty acid signature analysis offers several advantages. First, samples can be obtained using relatively non-invasive techniques such as blood and tissue sampling. Thus, it is possible to conduct large area studies on individuals and to obtain data from rare or endangered populations that might otherwise not be possible. Blubber samples provide a longer-term picture of the diet and thus are less affected by the geographic location of sampling. In addition, the method is not dependent on the recovery of hard parts, so soft-bodied prey may be detected.

Potential disadvantages of using fatty acids are that all prey signatures may not be unique and that predator metabolism will alter the deposition of some fatty acids, which will bias estimates of diet. Thus, a good understanding of the lipid metabolism of marine mammals is required for the confident use of the method.

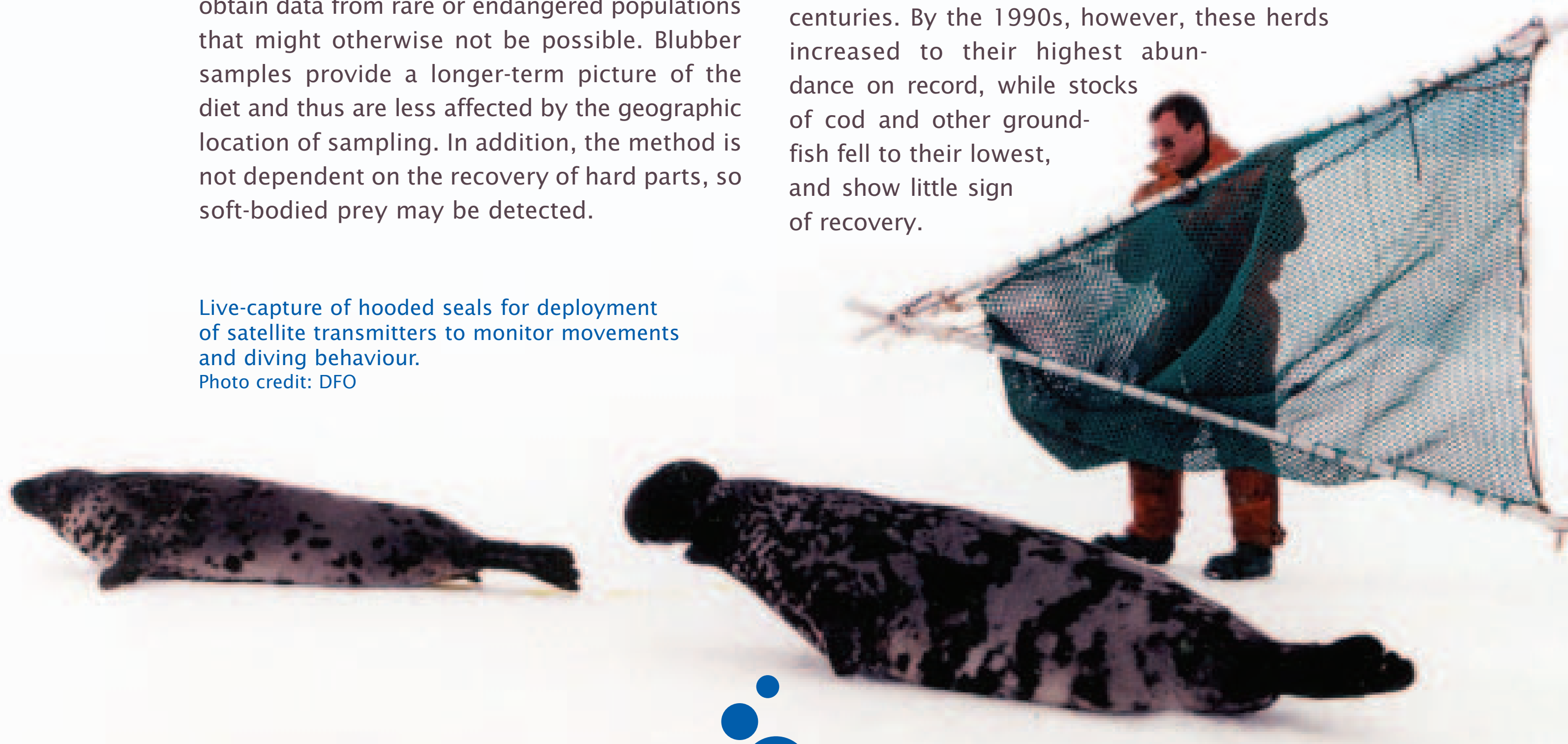
Finally, accurate identification of prey proportions in the diet requires the assembly of a comprehensive library of reference prey signatures. Species that are eaten, but are not represented in the library will not be identified in the diet.

4.3 PREDATOR-PREY INTERACTIONS

4.3.1 PREDATION OF SEALS ON COMMERCIAL FISH STOCKS

For decades scientists have considered the potential effects of upper trophic level predators, such as seals, on the dynamics of fish populations that are of commercial importance. These effects are also a continuing source of debate among fishermen, resource managers and ecologists.

Canada's Northwest Atlantic waters hold the biggest populations of harp, hooded and grey seals in the world. All of these populations were reduced due to hunting in the 19th and 20th centuries. By the 1990s, however, these herds increased to their highest abundance on record, while stocks of cod and other groundfish fell to their lowest, and show little sign of recovery.



Live-capture of hooded seals for deployment of satellite transmitters to monitor movements and diving behaviour.
Photo credit: DFO

Photo credit: J. -P. Sylvestre

Do harp seals consume large quantities of cod? This is one of the questions that the Atlantic Seal Research Program tries to answer.

Photo credit: DFO

Atlantic cod

The Fisheries Resource Conservation Council (FRCC), an advisory group of university scientists, government and fishing-industry representatives, are concerned that predation by the large seal herds may threaten the recovery of some groundfish stocks. Harp and hooded seals are already subject to a centuries-old, quota-controlled commercial hunt. The FRCC has called for further measures, such as seal exclusion zones in some areas, to reduce predation.

Many questions remain about how seals affect groundfish. To find answers, DFO launched the Atlantic Seal Research Project (ASRP) in 2003, to provide current information on the extent of predation by harp, hooded and grey seals on Atlantic cod.

A bioenergetics model is used to estimate the amount of cod eaten by seals as well as other depleted fish stocks and more plentiful species they eat. To use this model, information is needed on the energy requirements of seals of different ages and sexes, the number of seals in each age/sex category, how much time they spend in the area(s) of interest and what they eat in each area.

Using the Quantitative Fatty Acid Signature Analysis method previously described (see section 4.2.2 Fatty Acids), the scientists showed that the proportion of different fatty acids found in the seal's blubber reflects the proportion of different fish species in its diet.

When used to examine the diet of grey seals on the Scotian Shelf, the new technique yielded some surprises, including less dependence on cod than expected. Fatty acid analysis confirmed that sand lance, a small and unfished species, was a staple food for grey seals. It also showed an unexpected degree of reliance on such species as redfish, skates and flounders.

The abundant grey seal population of Sable Island on the Scotian Shelf eats less cod than what was originally suspected.
Photo credit: Yves Morin

Even if a particular cod stock makes up only a small fraction of the ordinary seal diet, it would seem obvious that a large population of seals could still threaten that stock's existence. However, researchers point to other possibilities.

For example, seals might help cod by eating predators, such as herring, that dine on codfish eggs. Predation by seals must also be placed into the context of the total population of the prey species and the relative importance of other sources of mortality.

In their analyses, the scientists must take into account such interactions, some of which remain poorly understood, and would benefit from more knowledge of the fish themselves.

What if it appears that in some instances, saving a local groundfish stock would require the reduction or elimination of seal predation in that area? The Atlantic Seal Research Project in 2004 convened an international workshop on 'seal exclusion zones.' Experts discussed use of nets, sound barriers, culls and other measures, some of which might be practical for small areas, but would become highly expensive and impractical for larger ones.

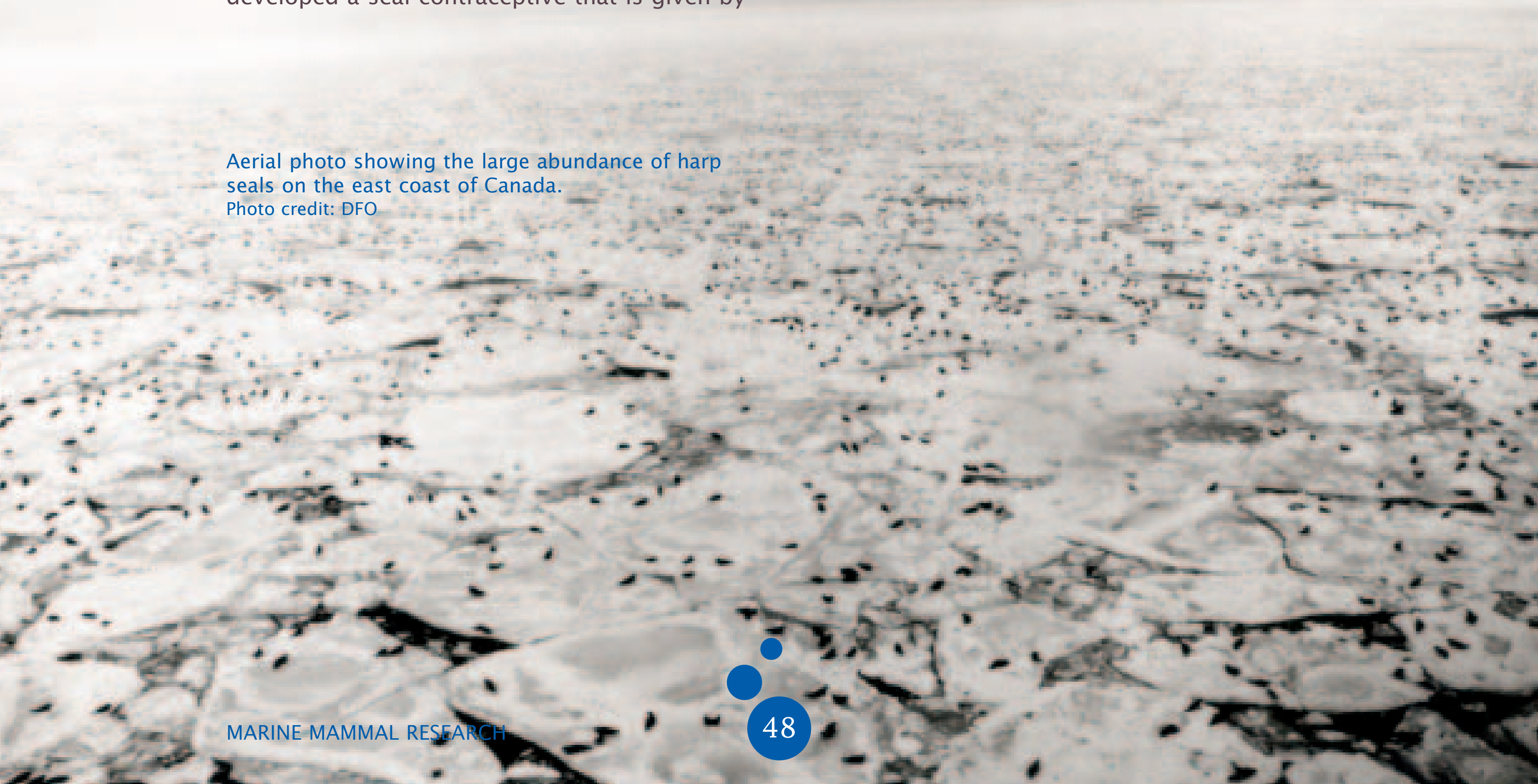
Meanwhile, back in the early 1990s, Dalhousie University and DFO -- in another world-first -- developed a seal contraceptive that is given by injection. This too proved workable in principle, but expensive and logistically difficult to apply on a large scale.

Complexities abound in the seal-predation puzzle. There is much more to learn about the impact of marine mammals on prey populations, but DFO long-term research is providing a better understanding that will assist in the development of policy and management options.

4.4 MARINE MAMMAL HABITAT

Marine mammal species exhibit a wide range of survival strategies and have specific habitat requirements to feed, reproduce, over-winter, avoid predation, and facilitate migration. There is now a growing global recognition that the worlds' oceans, including those bordering Canada's coasts, are under stress from ever-increasing resource use by humans. The long-term conservation of free-ranging marine mammals and other marine species is negatively affected by this trend.

For example, habitat issues are on the rise for beluga and narwhal due to increasing resource development in Canada's north. Mining, gas and oil developments and their infrastructure for extraction and transport raise issues regarding beluga and narwhal habitat alteration.



Aerial photo showing the large abundance of harp seals on the east coast of Canada.
Photo credit: DFO

Global climate change is also changing the quality of their habitat. For an increasing number of species, there is now a serious need to identify critical habitats, understand what makes these areas ecologically significant to the species in question, and to find ways of monitoring and protecting them.

Photo credit: Graeme Ellis

Pulp and paper mills release pollutants every day in marine mammal habitat.

In 1997, the Canadian Government passed the *Oceans Act*, which provides a framework for integrated ocean research and management in Canada. Three of the many new initiatives include the establishment of Large Ocean Management Areas and Ecologically and Biologically Significant Areas.

These initiatives are now facilitating new research on habitat-related concerns affecting marine mammals, sea turtles and other marine species, especially in cases where long-term conservation of the species is in jeopardy.

Integrated ocean management plans are proceeding for five Large Ocean Management Areas including the Grand Banks/Placentia Bay of Newfoundland, the Scotian Shelf, the Gulf of St. Lawrence, the Beaufort Sea and the Pacific North coast.

4.4.1 BOWHEAD WHALE IN THE EASTERN CANADIAN ARCTIC

Possessing a blubber layer that is up to 30 cm thick and having the capability of breaking through ice-covered water, bowhead whales are the only baleen whales evolved to exclusively inhabit the Arctic environment throughout the year.

With the longest baleen of all baleen whales, bowhead whales are highly adapted to exploiting the rich and abundant sources of Arctic marine zooplankton. Their migrations reflect their relationship with the ice; they retreat in winter to the southern limit of the Arctic ice margin or to regions of open water, and advance north into the Arctic Archipelago in summer with the melting ice cover. Although only few details are known, patterns of distribution and annual migration appear to be influenced by a combination of gender, reproductive status and age-class.

Bowhead whales are a species that touch on a number ofkey issues for the federal government, DFO, Aboriginal people and conservation groups. Bowheads in the eastern Canadian Arctic were subject to an intense commercial hunt during the 19th century, which reduced the population from an estimated 11,000 to a few thousand whales.

Based on recent evidence of increases in the numbers, COSEWIC upgraded the status of bowhead in this population from endangered to threatened in 2005. Under the *Species at Risk Act*, a recovery strategy and action plan must be drafted to ensure that the species continues to increase in numbers, and that critical habitat is identified.

The inception of the *Nunavut Land Claims Agreement* in 1993, provides the Nunavut communities entitlement to a bowhead hunt subject to conservation needs. Management of this hunt is conducted under a co-management agreement between Nunavut and DFO.

For management purposes, two stocks of bowhead whales are presumed to exist in the eastern Canadian Arctic, although recent satellite tracking and genetic studies provide increasing evidence that there is only one stock.

Due to the very close relationship of bowhead to an ice environment, bowheads are likely to be affected in some way by climate change. Possible climate variables that might have an impact on bowhead populations are reductions and changes in ice distribution, changes in prey abundance and distribution, and greater vulnerability to mammal-eating killer whales. The degree to which bowhead whales may be able to adapt through changes in distribution and migration patterns is unknown.

Habitat evaluation is required to determine what oceanographic processes currently influence bowhead distribution, so that critical habitat can be identified. Predictions as to how ocean processes will vary and how climate change will influence habitat may provide some insight into the potential impact of climate change on bowhead whales.

The bowhead whale gets its name from its large bow-shaped head and jaw.
Photo credit: Larry Dueck

4.4.2 HARBOUR SEAL HABITAT IN NEWFOUNDLAND

In a recent DFO project, harbour seals were used as an indicator species for monitoring contaminants in the upper-trophic level in Placentia Bay and surrounding area. Since the harbour seal is a coastal, non-migratory, apex (top-of-the-food-chain) predator that can be live-captured for biological sampling, it makes a good indicator species. Researchers hope to improve their understanding of contaminant pathways and trophic dynamics of Placentia Bay.

To increase their knowledge of current habitat use, scientists monitor seasonal distribution and relative abundance of harbour seals in Placentia Bay, key haul-out sites and coastal areas that may be negatively impacted by industrial developments related to offshore oil production and transportation. As well, they are using the local knowledge of fishermen and other community members to record any long-term/historic changes in harbour seal habitat use, seasonal distribution and relative abundance.

Finally, the researchers evaluate the harbour seals as indicators of marine ecosystem health in Placentia Bay and other coastal areas of Newfoundland. All these data are used to recommend how best to continue the collection and integration of local marine resource knowledge into integrated ocean management plans and marine ecosystem health assessments in the future.

Photo credit: Peter S. Ross

Harbour seal

Some key preliminary findings indicate that harbour seals sampled from Newfoundland waters were less contaminated by persistent organic pollutants than those from the St. Lawrence Estuary population and were generally similar to those from the southern Gulf of St. Lawrence.

For example, mirex (an insecticide) and total PCB concentrations were five to 10 times higher in the Estuary population while total DDTs and total chlordanes (another type of insecticide) were two to 5 times higher than in Newfoundland seals. Levels of total mercury, cadmium and selenium were generally consistent with literature reports from Alaskan harbour seals and with other northern seal species. However, cadmium concentrations varied geographically with the highest levels being found in seals sampled along the south and east coast of Newfoundland.

Based on local ecological knowledge interviews and a limited number of boat surveys and shore-based haul-out counts, it appears that the distribution and local abundance of harbour seals is generally consistent with observations made in the 1970s (which is the only comparative information available for harbour seals in that province).

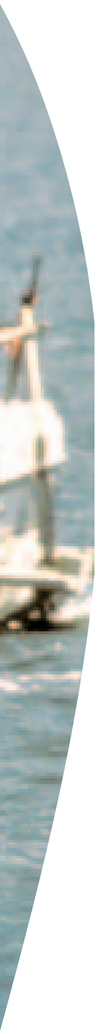
Scientists observing harbour seals.
Photo credit: DFO

When boats come too close, whale watching may interfere with normal resting, feeding and breeding activities.
Photo credit: John Ford

5.0

WHAT ARE THE HUMAN IMPACTS ON MARINE MAMMALS?

Humans have wide-ranging impacts on marine mammals. The most obvious is the harvest of marine mammals for commercial or subsistence purposes. Over-harvesting has reduced some marine mammal populations such as St. Lawrence beluga, blue whales and killer whales, to very low levels, resulting in concern for their continued existence. Marine mammals are also taken as incidental catches during commercial fishing activities.



Human activities such as marine mammal watching, petroleum exploration and commercial shipping may also affect marine mammals. Marine mammal watching, in cases where too many boats approach the animals, interferes with normal resting, breeding or feeding activities. Petroleum activity, such as seismic exploration, may cause physical damage to marine mammal hearing or interfere with their feeding, migration or communication. This may have short-term impacts on individual whales or longer-term impacts on survival if high sound levels limit access to critical feeding zones. Commercial ship traffic is also associated with very high noise levels and is responsible for much of the noise pollution found in the world's oceans today. Considerable work remains to be completed to explore these impacts more fully.

Industrial impacts need to be examined on a project-by-project basis, as well as cumulatively. For example, current areas off Nova Scotia are now known as some of the noisiest areas in the world for seismic exploration with constant, high sound levels recorded as far away as the mid-Atlantic during the summer months.

Coastal development also has an impact on marine mammals; increased marine traffic can cause the loss of habitat, such as seal haul-out sites or feeding areas. Finally, the dumping of waste into the environment results in the transfer to marine mammals of parasites normally associated with humans or terrestrial wildlife.

5.1 COMMERCIAL AND SUBSISTENCE HUNTS

In addition to its role in protecting marine mammals, DFO is also responsible for managing the commercial and subsistence hunt of some species. These hunts must be carried out in a way that is sustainable, humane and, in the

Photo credit: Tara Donaghy

Increased marine traffic can cause the loss of habitat.

Photo credit: Jack Orr

DFO ensures that the subsistence hunt is carried out in a sustainable way.

case of commercially exploited species such as harp seals, economically viable. The Minister sets quotas at levels that ensure the health and abundance of the population and these decisions are based on conservation principles and socio-economic considerations. Fisheries and Oceans Canada (DFO) also closely monitors the hunts to ensure humane practices and regulation compliance.

Photo credit: M. Plamondon

The seal hunt is closely monitored and tightly regulated. A fishery officer ensures that seals are killed humanely.

The role of DFO scientists is to advise resources managers with biological assessments of the exploited animals. These assessments provide estimates of the current status of the population. They also predict future changes in the state of the resource under various levels of exploitation by incorporating information on the age structure of past catches and reproductive rates with estimates of abundance into an assessment model.

5.1.1 THE PRECAUTIONARY APPROACH

The Precautionary Approach requires scientists and managers to identify clear management objectives and establish specific biological reference levels (defined as the value of a property of a resource that, if violated, is taken as evidence of a conservation concern). It evaluates the status of the resource with respect to the reference levels to identify specific management actions that would be triggered when a population approaches or falls below the reference levels. This approach attempts to incorporate a broader perspective, which is more consistent with the complexity of marine ecosystems.

Within the context of fisheries management, the Precautionary Approach strives to be more cautious when information is less certain. It does not use the absence of information as a reason to postpone or fail to implement conservation and management measures. In addition, it defines and implements limit and precautionary reference points, as well as defines in advance decision rules for stock management.

A key component of this approach is that at certain stages or levels of the population, specific management actions will be established, to aid in managing the resource. These levels can be referred to as Conservation, Precautionary and Target reference points, and scientific knowledge plays a key role in defining them.

5.2 MARINE MAMMAL BY-CATCH

The term by-catch refers to the incidental entrapment or capture of non-target species during a fishing operation. It is well known that even if the by-catch of a particular marine mammal species is a relatively rare event, over an entire fishery or within a specific type of fishing gear, by-catch rates may be biologically significant, particularly for species where there are conservation concerns.

The harbour porpoise is listed under SARA as “Special Concern”. The most important recent threat to the harbour porpoise is bycatch, particularly in bottom-set gillnets which are used to capture groundfish.
Photo credit:
Ari S. Friedlaender

Before the 1990s, relatively little scientific effort had gone into quantifying by-catch and only a few long-term studies had been conducted. Reports of by-catch, for the most part, were sporadic, gathered opportunistically and tended to focus on endangered species and on a limited number of large cetaceans and sea turtles. By-catches of small cetaceans and seals tended to be under-reported or not reported at all because they were considered nuisances by the fishing industry given the damage caused to fishing gear, and the perception that many species competed for limited commercial fish resources.

However, attitudes regarding the importance of by-catch are changing among all resource users

DID YOU KNOW THAT?

#9

SMART GEAR TO REDUCE BY-CATCH

More than 300,000 whales, dolphins and porpoises – or cetaceans – are estimated to die every year from entanglement in fishing gear worldwide. No wonder DFO and other scientists are looking for ways to fish smarter and finding ingenuous solutions to reduce by-catch.

A DFO marine mammal scientist, a chemist from Pennsylvania and a fisherman from Massachusetts collaborated to develop solutions to help marine mammals detect and avoid gillnets, as well as allow them to escape unharmed if they still become entangled.

The first type of gear, the 'weak rope', breaks at 50 per cent of the normal breaking strength, so large cetaceans – such as the North Atlantic right whale – may wrestle free of such nets.

The second innovation is 'filled gillnets', where barium sulphate is added to conventional nylon to produce nets that are stiffer and have a higher acoustic reflectivity. This means that small cetaceans that use reflection of sound to locate objects, such as the harbour porpoise and bottlenose dolphin, can detect the presence of the nets more easily. In addition, if they still hit the net, its stiffness will make it easier for them to get free.

Both filled gillnets and weak rope cost roughly the same as conventional gear, but last 20 per cent longer because the barium sulphate they contain reduces chafing and related wear.

The team is currently working on a sinking ground line between lobster pots that will maintain a low profile in the water column. Whales will be less likely to become entangled when sinking line is used instead of floating line between lobster pots. Field tests are underway to measure a sinking line's vertical profile and durability under fishing conditions. It is hoped that this mitigative measure would reduce the large unnecessary amounts of highly buoyant rope in the ocean.

It's a win-win situation for both fishermen and ocean resources!

DFO scientist preparing barium sulfate gillnet and weak rope for experimental field trials in the Bay of Fundy.
Photo credit: Suzanne Taylor

Photo credit: DFO Newfoundland

A young harp seal has been caught in a crab pot; however seals are more likely to be taken in gillnet fisheries such as the lumpfish fishery.

Credit: NOAA

Marine mammal caught in a fishing net.

as the problem gains worldwide recognition. DFO has several ongoing marine mammal and sea turtle by-catch projects in Canadian waters.

One of the longest and most comprehensive projects provides annual estimates of the number of harp seals taken in the lumpfish fishery in Newfoundland and Labrador. Lumpfish migrate from deep-water areas to shallow coastal areas during April to May to spawn. The fishery uses long strings of large-mesh monofilament gill-nets that are hauled every two to three days to catch female lumpfish for the roe market. The use of these nets and the timing of the fishery contribute to the harp seal by-catch problem because the fishing season overlaps geographically with the spring migration of seals.

To address this problem, a By-catch Logbook Program was initiated by DFO in the 1980s. Lumpfish fishermen around the coast of Newfoundland were requested to record fishing effort, the amount of lumpfish roe landed, and the number of seals caught on a daily basis during the season.

The Program is an ongoing success. Generally, results indicate that in the early 1980s, harp seal by-catch remained below 5,000 seals, but by the late 1980s and early 1990s, by-catches had doubled. Peak by-catch levels occurred from 1992-96 with an average take of approximately 30,000 seals annually.

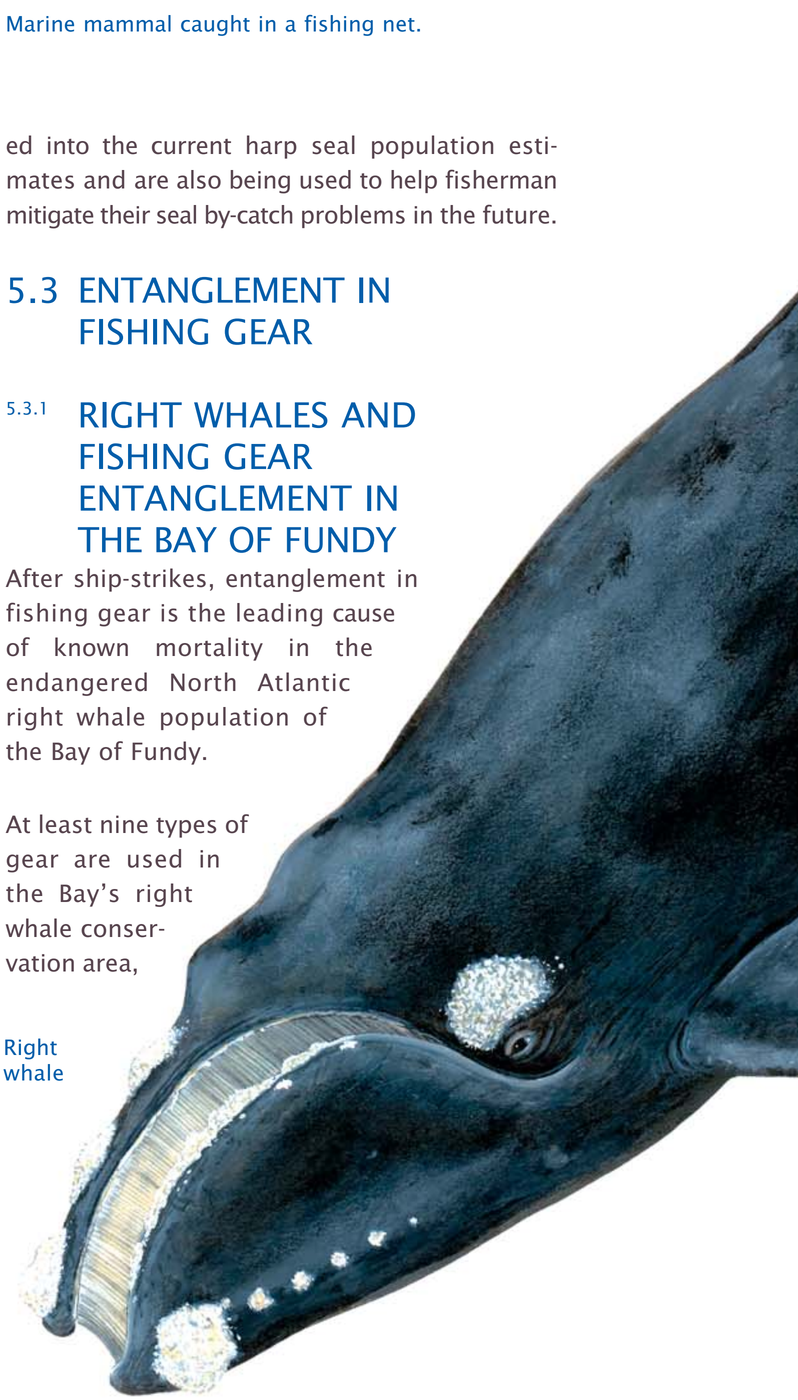
Although by-catches have been variable recently, they have dropped to less than 10,000 seals. These by-catch estimates have been incorporated into the current harp seal population estimates and are also being used to help fisherman mitigate their seal by-catch problems in the future.

5.3 ENTANGLEMENT IN FISHING GEAR

5.3.1 RIGHT WHALES AND FISHING GEAR ENTANGLEMENT IN THE BAY OF FUNDY

After ship-strikes, entanglement in fishing gear is the leading cause of known mortality in the endangered North Atlantic right whale population of the Bay of Fundy.

At least nine types of gear are used in the Bay's right whale conservation area,



Right whale

where as much as two-thirds of the whale population can reside in summer. Some gear may not pose a risk to the right whales due to design, deployment, or spatial and seasonal distribution. Other gear types may impose severe risk and have been documented as entangling right whales.

Researchers are quantitatively analysing the time and space variation in fishing gear type and deployment in the right whale conservation area. Using the New England Aquarium sightings per unit effort database, the researchers can then quantify the time-space probability of gear and whale coming in close proximity to assess risk.

The work involves collaboration with Dalhousie University, which initiated some of these analyses in 2000, along with similar analyses related to ship-strike risk based on vessel traffic in the region.

The analysis will reveal when and where, and which fisheries and gear sectors pose the greatest risk to right whales. The results will be used to advise industry and management on actions that would minimize the risk to right whales, while at the same time attempting to minimize disruption of the commercial fisheries in the region.

5.4 IMPACT OF NOISE AND WHALE WATCHING

5.4.1 FIELD INVESTIGATION OF 'DISTURBANCE' OF RIGHT WHALES

On a typical summer day in the Bay of Fundy there is considerable vessel traffic near right whales. This traffic includes whale-watching operations, recreational boaters, research vessels, fishing boats, and commercial ships.

Photo credit: "Provincetown Center for Coastal Studies, under NOAA Fisheries permit 932-1489, with authority of the US Endangered Species Act"

Right whales get entangled in fishing gear such as gillnets and the floating line used between lobster pots.

Some of these boats, such as whale watchers and research vessels, are specifically searching for right whales, while others are just passing through the area. These vessel activities may adversely affect the right whales by disturbing feeding or nursing, disrupting surface-active groups, and/or causing undue stress.

Photo credit: Lei Harris

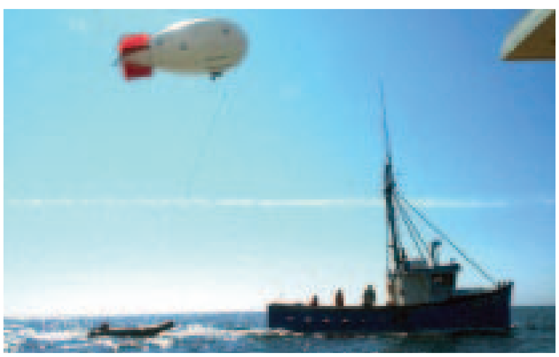
Whales are increasingly subjected to noise generated by vessel traffic such as whale-watchers, recreational boats, commercial shipping, fishing boats and research vessels.

Although most of these traffic groups make an effort to be respectful and not disturb whales, there is neither clear definition of disturbance nor a quantitative description of what will cause disturbance.

To determine how whales respond to oncoming vessels, and which cues elicit a response, a collaborative field study is underway to record whale behaviour. A remotely operated video camera system was suspended from a 10-metre aerostat tethered to an observation boat to observe and record whale behaviour. This overhead video system provides real-time information, increased accuracy of behavioural data, and a unique perspective.

Due to the overhead positioning of the aerostat relative to the whales, the research vessel did not have to get close to the whales. The scientists recorded the whales' surfacing, ventilation, dive patterns, course and orientation, aggregation, as well as activity level both in the presence and absence of other vessels. With this information, the scientists developed a draft classification scheme to quantify the interactions of right whales with research vessels, which is currently being evaluated.

Photo credit: Mike Power



Aerostat and vessel used for field study of right whale disturbance.

5.4.2 DFO AND MAKIVIK STUDY ON NOISE DISTURBANCE OF BELUGA

Estuaries are considered to be a very important habitat for beluga: they are usually ice-free in the spring, their warmer waters reduce heat loss for the young and they may help beluga to moult their skin.

During the last 15 years, the number of beluga observed in the Nastapoka Estuary has declined sharply. Many think that this is due to disturbance caused by the noise of boat traffic, while others attribute it to the decline in numbers due to heavy hunting pressure.

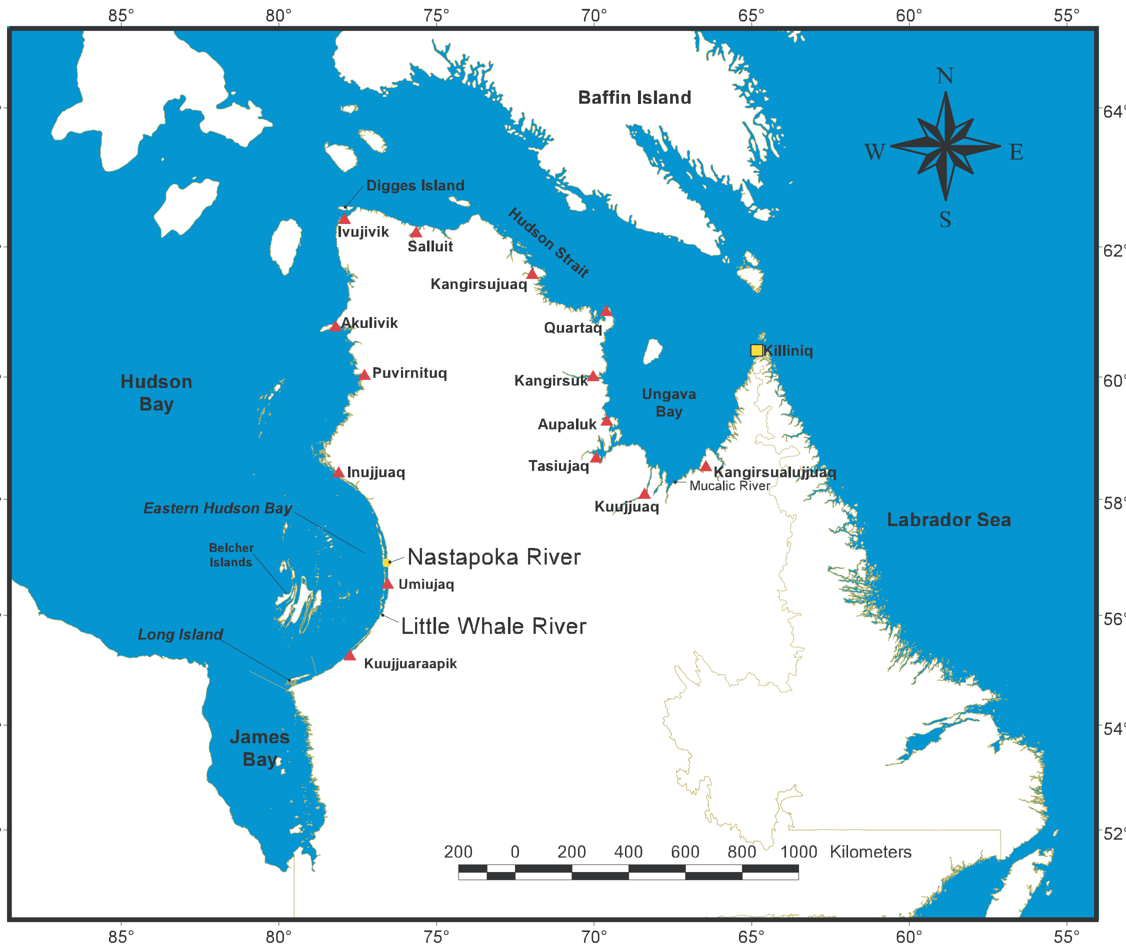
It has been noted that beluga flee from the estuaries of eastern Hudson Bay whenever there is boat traffic in the area. Since sound travels further in water than in air, the area of impact from vessel noise may be greater than had previously been thought.

Since 2000, the Nunavik Research Centre (Makivik Corporation), in partnership with the Umiujaq Hunting, Fishing and Trapping Association and DFO scientists, has been studying the use of eastern Hudson Bay estuaries by whales and the degree of disturbance by humans. Makivik and the federal Canada Habitat Stewardship Program funded this project.

The results of the 2000 and 2001 studies show that the beluga stay away from the Nastapoka Estuary longer than from the Little Whale River. This may be due to a reduction in the number of beluga that frequent the river or it may be caused by the noise from outboard traffic being greater within the enclosed area of Nastapoka Sound. Also, the Little Whale River enters Hudson Bay in a region of open coast whereas the Nastapoka flows into Nastapoka Sound. The Sound may act to trap vessel noise, amplifying the disturbance effect, whereas noise at Little Whale may be dissipated into the open waters offshore.

To test this hypothesis, a second study was undertaken in July 2002. With the help of Umiujaq Inuit, the noise generated by a 40 hp (30 kW) outboard-equipped freighter canoe (typical transport of the Inuit of Hudson Bay) was measured at various locations near Little Whale and Nastapoka rivers, along with the GPS position of the vessel as it approached, left and passed by the estuaries.

The distance at which beluga perceived noise from outboard motors was calculated by applying published audiogram

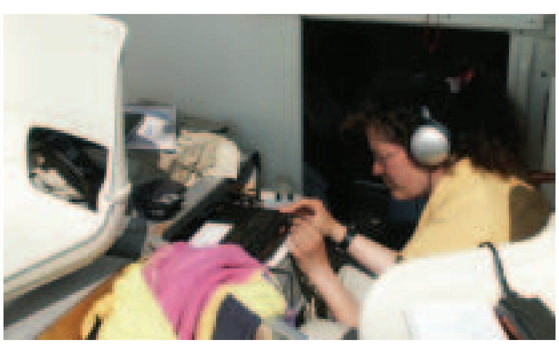


The study on noise disturbance of beluga took place in the Nastapoka and Little Whale estuaries in the Eastern Hudson Bay.

data to the sound spectra recorded in the Nastapoka and Little Whale estuaries, and adjacent offshore waters. Bathymetry (water depth) greatly influences noise levels; perception distances were shortest when belugas were in estuaries and farthest when in offshore waters. Field measurements indicated that beluga would hear boats farther away at the Nastapoka (1220-1750 m) compared to Little Whale (790-950 m). These perception distances varied with boat direction (shorter when boat is travelling away) and ambient noise level.

Further analysis of sound spectra levels with distance and bathymetry are underway. The results from this study will be used to better

Photo credit: Bill Doidge, Nunavik Research Centre



DFO scientist records underwater noise.

Photo credit: W. Klenner

Beluga

understand the noise that belugas experience in their habitat and will provide information that can be used to minimize disturbance by boat traffic.

5.5 SEISMIC SURVEYS AND NAVY SONAR

Human activities in the ocean often transmit sounds underwater and some of these sounds can affect marine mammals. The sounds can have a range of effects from no response to small behavioural changes, or masking of hearing to temporary or permanent changes in hearing sensitivity, to non-auditory injury such as hemorrhage and direct fatality. More subtle, but still potentially important, these sounds can cause physiological stress which may compromise immune response or affect reproduction. One of the objectives of Canada's *Species at Risk Act* is to mitigate such impacts to listed species.

Besides large vessel noise, other underwater sound sources are of concern in Canada. Seismic exploration and military SONAR are particularly troublesome for marine mammals, partly because of their relatively high source levels (Table 1).

To date, there is no evidence that either acute or chronic physical impacts have occurred through exposure to seismic sounds, although studies of such effects on wild marine mammals would be very difficult to conduct. These effects might only occur for marine mammals exposed at close range for unusually long periods, or when the seismic sound is strongly channeled with minimal propagation loss, or when the animals are unable to avoid being near the seismic sources.

Effects of seismic sounds on marine mammal behaviour are inconsistent. Some studies show that toothed and baleen whales as well as seals sometimes react to seismic sounds (and other loud human-made sound) with changes in their behaviour patterns. If there are changes, these can range from deflections around a seismic source during migration to small increases in the distance between seals and the seismic-source vessel when it is operating.

These same studies also show that these displacements are short-lived, lasting hours to a day and the mammals soon return to their previous patterns. Other behavioural changes, such as calling rates, diving patterns and group behaviour also show short-term modification.

Vessel pulling seismic equipment
for oil and gas exploration
Photo credit: Jack Lawson

Some marine mammals react at relatively low-received sound levels whereas other individuals or species do not overtly react even at relatively high-received levels. However, for many of these studies there is little long-term follow-up, or baseline research, so it is difficult to assess anything but obvious changes.

Military SONAR systems are designed to transmit and receive high-intensity sound energy. Although there are many different kinds, SONAR systems can be subdivided into low- (<1 kHz), mid- (1-20 kHz) and high-frequency (>20 kHz) types.

Low-frequency active SONARs are designed to allow submarine tracking up to thousands of kilometres, and their loud sounds could potentially travel over broad areas of the ocean, and be received by many marine mammals.

Mid-frequency tactical SONARs are designed to detect submarines over tens of kilometres, while high-frequency SONARs are incorporated either into weapons (torpedoes and mines) or weapon countermeasures and have short ranges; these types are highly directional and use pulsed signals.

It was previously assumed that exposure to a few SONAR impulses would not be sufficient to cause significant auditory or significant behavioural impacts. However, there is evidence that for some marine mammals, such as deep-diving beaked whales, reactions to military SONAR exposure may be vigorous enough to cause them to surface in a way that would result in injuries followed by stranding. If these injured whales had not stranded, this potential source of SONAR-induced injury would not have come to light.

Due to the unpredictable nature of marine mammal behaviour and exposure conditions, much research remains to be done to assess the potential impacts of seismic and SONAR sounds on marine mammals, particularly for less apparent behavioural and/or long-term effects.

There have been few studies of either marine mammal hearing sensitivity or the effects of underwater sounds on their hearing sensitivity

Photo credit: Véronique Lesage

Photo credit: Jack Lawson

Photo credit: Lisa Spaven

Seismic guns (middle panel) are used to explore the geologic structure below the ocean floor. They produce "explosions" of air at regular intervals which can generate sounds of up to 240dB. This noise can potentially interfere with the natural behaviour of whales such as blue whales (top) and fin whales (bottom).

or behaviour. This is especially true for baleen whales both on an individual and population level.

How reliably these effects occur, the magnitude of these effects, the range of recovery times after effects are detected, as well as the factors that seem to influence probability, magnitude and time of effects, are all types of data that remain absent or limited for almost all marine mammals.

A review can be found at **www.dfo-mpo. gc.ca/csas/Csas/publications/ResDocsDocRech/2004/2004_121_e.htm.**

Precautionary approaches are warranted when seismic or military SONAR sources are planned for use in areas where marine mammals might be exposed to them.

TABLE 1.

COMPARISON OF NATURAL AND HUMAN-MADE UNDERWATER NOISE SOURCES*

UNDERWATER NOISE SOURCE	SOURCE LEVEL [DB RE 1µPA @ 1M]	REMARKS
Sea floor volcano eruption	280	Steam explosions
Undersea earthquake	272	Magnitude 4.0 on Richter scale
Air gun array (seismic)	240-255	Loud at many frequencies (broadband); variable output depending on configuration
Military AN/SQS-56 SONAR	245	6.8 and 8.2 kHz in narrow band
Multi-beam echo sounder	230+	12-100 kHz in narrow band
Low-frequency active SONAR	230+	Mostly low-frequency; 2-minute signal; very long propagation distances
Military AN/SQS-53C SONAR	223	2.6 and 3.3 kHz in narrow band
Fin whale call	200	Mostly low-frequency
Ice breaking	193	Broadband
Humpback whale	190	Fluke and flipper slaps
Super tanker (350 m long, 20 knots)	190	Broadband with low frequency
Bowhead and blue whale calls	188-189	Low frequency vocalizations
Offshore drill ship	185	Broadband noise
Container ship (274 m long, 23 knots)	181	Broadband with low frequency
Depth sounder SONAR	180	12-200 kHz
Fishing trawler (12 m long, 7 knots)	158	Low frequency, continuous
5 m Zodiac boat	156	More high-frequency content
Acoustic deterrent (AquaMark 300)	132	Short duration and high frequency
Jet ski recreational vehicle	75-125	Broadband noise
Open ocean ambient noise	120	Noisiest conditions

* *Based on studies of terrestrial mammals, if a sound intensity level is measured in water, 62 dB must be subtracted from its value to get an equivalent value in air. This may not be directly applicable to marine mammals since the way that underwater sounds lead to ear damage may be different than in air.*

5.6 MARINE MAMMALS AS SENTINELS OF ENVIRONMENTAL CONTAMINATION

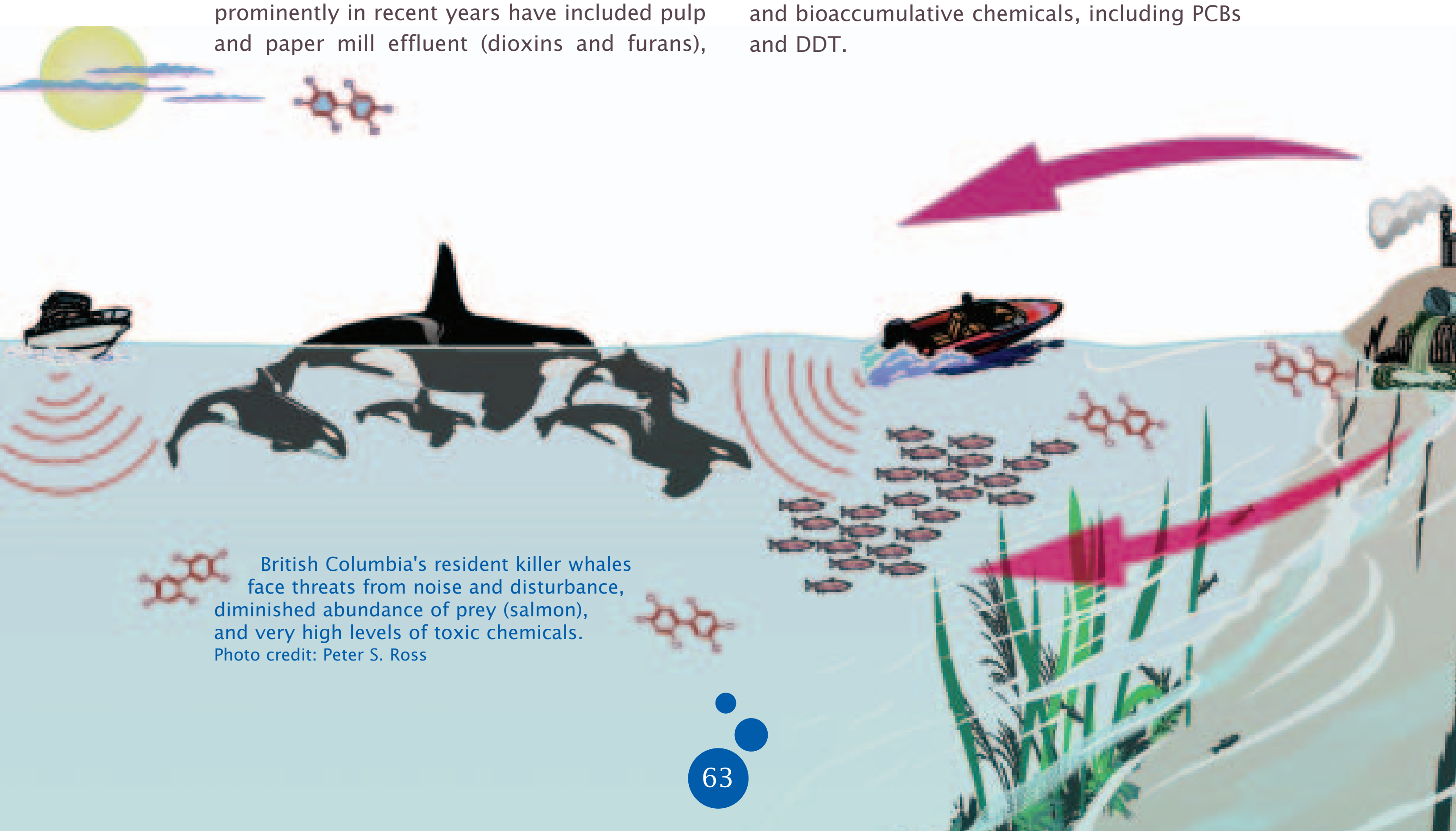
The varied feeding habits and life histories of the many seals and whales that inhabit Canada's three oceans make it difficult to generalize about their ecological role. However, it is becoming increasingly clear that marine mammals can tell an important story about the state of our oceans.

Environmental contaminants provide a case in point. As long-lived and often high-trophic level species, marine mammals as top predators, can accumulate high levels of contaminant through bio-magnification. They can effectively provide an 'integrated' signal of those contaminants that persist in the environment and amplify in marine food webs (a series of interconnected food chains). In addition, their charismatic nature provides marine mammal researchers with an outreach tool that is understood and respected by many stakeholders and members of the public.

While Canada is known internationally for its remote and spectacular natural landscapes and seascapes, it is not immune to problems of environmental contamination. Local contamination concerns in coastal regions that have figured prominently in recent years have included pulp and paper mill effluent (dioxins and furans), mines (acid mine drainage and metals), agricultural runoff (organochlorine pesticides), industrial discharges (PCBs), anti-foulant paints (organotins), oil transport (PAH) and municipal discharges (organic waste and a myriad of chemicals).

In many of these cases, source control and/or regulations have been enacted subsequent to research programs that characterize the source, transport and fate features of the pollutant in question. As a result, local sources are relatively easy to document from a science perspective and to mitigate from a management perspective. However, since many chemicals are persistent and can travel great distances, the cumulative effects of multiple sources can result in the contamination of the environment on a global scale.

Marine mammals represent perhaps the ultimate biological 'sink' for these pollutants. Canada learned this lesson the hard way when it was discovered that the Arctic food web, which supports a traditional Inuit way of life, had become contaminated with a wide variety of persistent and bioaccumulative chemicals, including PCBs and DDT.



British Columbia's resident killer whales face threats from noise and disturbance, diminished abundance of prey (salmon), and very high levels of toxic chemicals.
Photo credit: Peter S. Ross

Marine mammals have provided Canadian scientists with a means to 'sample' the marine food web. Seals have been used extensively to document contaminant trends, over time and space, in Canada's oceans. Species that have been well-studied include harbour and grey seals in the Atlantic and Gulf of St. Lawrence, ringed seals in the Arctic, and harbour seals in the Pacific.

Whales have been used to characterize poignant concerns about marine environmental quality, as Canadian scientists grappled to understand why the endangered St. Lawrence belugas and British Columbia killer whales had become some of the most contaminated marine mammals in the world.

Although marine mammals provide important information to managers and stakeholders on the presence and trends of different contaminants, it is the toxicity of these pollutants that drive the ultimate concern about their presence in the environment.

The risk of adverse health effects is of particular worry to those concerned with marine environmental quality, species at risk and mitigative measures. Establishing cause-and-effect relationships between exposure and effect is very challenging in marine mammals. Logistical, ethical and legal constraints preclude invasive research with many species. In addition, the highly complex mixtures of contaminants to which marine mammals are exposed make it difficult to assign blame to one chemical class for an observed effect. Laboratory-based studies are more amenable to such mechanistic research.

Photo credit: L. Mos

DFO scientist with a young harbour seal, conducting research on the effects of persistent organic pollutants on marine mammal health. This work involves the live-capture, sampling, and release of seals.

Nonetheless, the evidence highlights the risks associated with exposure to high levels of environmental contaminants in marine mammals. Contaminant-related effects on reproductive, immune function, endocrine and developmental health are increasingly viewed as conservation issues in marine mammal populations that are contaminated through either local or global contaminants.

As wildlife that occupy high positions in marine food webs, marine mammals can deliver an integrated signal of marine environmental quality to decision-makers and stakeholders. In working with marine mammals, contaminant scientists have, in essence, an effective tool to better understand the environment in which we live.

Photo credit:
J. -P. Sylvestre

5.7 STRANDINGS AND MORTALITY EVENTS

5.7.1 MARINE MAMMAL STRANDING AND UNUSUAL MORTALITY EVENT INVESTIGATION

Though DFO maintains very active research programs for living marine mammals of all species, it also realizes the importance of monitoring the causes and patterns of mortality in these animals.

Researchers within DFO and Canadians generally are becoming concerned that oceans are under increasing pressure from human activity (pollution, global warming, harvest, boat strikes and the introduction of new and emerging diseases) and therefore they must be protected and monitored. In order to assess the extent and impact of these assaults, the investigation of dead stranded animals provides valuable information.

In many areas, DFO scientists often in conjunction with other interested people, maintain a modest stranding investigation program, by international standards, focussed mainly on species at risk. Provincial veterinary personnel and laboratories do most of the testing, while DFO personnel oversee sample collection, logistics, reporting and funding.

Photo Credit: Margeret Butchler, Vancouver Aquarium Marine Science Centre

A veterinarian investigates the stranding of a fin whale.

Information obtained from these investigations is ultimately used to identify threats to survival of stocks and/or populations of animals. Government wildlife managers and Inuit wildlife management organizations use this information, along with the other information provided by scientists, to develop management and recovery strategies, and set quotas based on a sustainable harvest in species where hunting is permitted.

A DFO fishery officer standing beside a stranded blue whale.
Photo credit: DFO Quebec Region

At a grassroots level, information obtained is also sent to the hunter or member of the public who originally identified the stranding, thus educating the public regarding the underlying causes of death and making them full partners in the program.

This ‘early warning’ surveillance program has also provided information regarding infectious diseases that are of interest to other federal departments who are responsible for animal as well as human health.

Internationally, DFO provides stranding information and results to the U.S. government with regard to migratory species that are shared by both countries. In addition, it collaborates on a variety of emerging marine mammal-specific disease projects with American government scientists and with university researchers from around the world.

Canada is a vast country with a huge coastline and a wealth of marine mammals within its waters. Threats to the long-term survival of a number of mammal species are real and, in some cases, poorly understood. Understanding the components of mortality is the first step in establishing trends in population decline with the ultimate goal of reversing them.

5.8 CLIMATE CHANGE

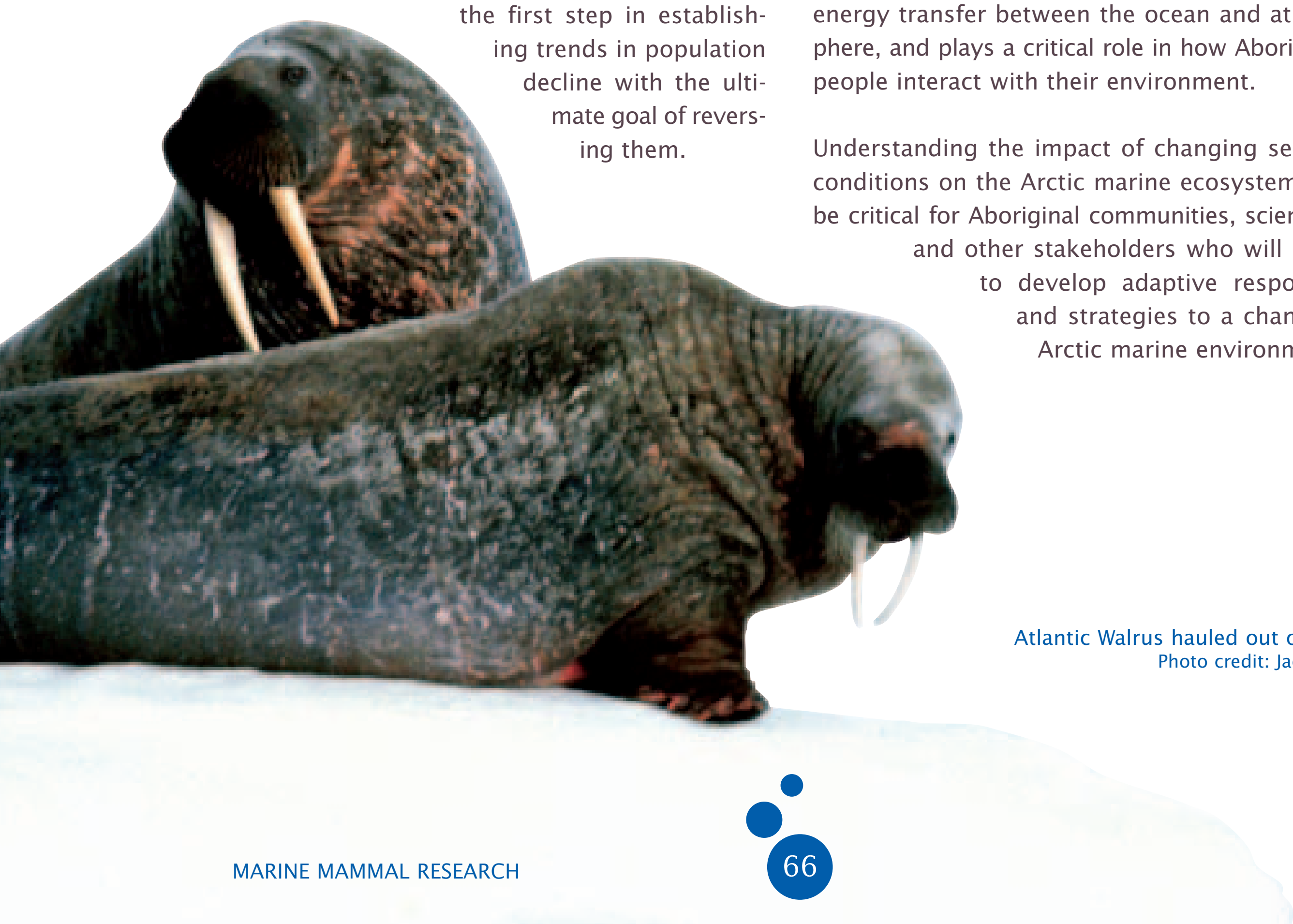
Current research on the response of Arctic marine ecosystems to climate change and/or variability suggests that effects will be significant and, in the opinion of many researchers and local residents, are already detectable in many regions.

Photo credit: A. Kristofferson

Climate change is causing ice to melt in some areas of the Arctic.

Sea ice is a pivotal component of the Arctic marine ecosystem because it provides a habitat platform for a diverse range of flora and fauna, influences many aspects of marine productivity, moderates energy transfer between the ocean and atmosphere, and plays a critical role in how Aboriginal people interact with their environment.

Understanding the impact of changing sea ice conditions on the Arctic marine ecosystem will be critical for Aboriginal communities, scientists and other stakeholders who will need to develop adaptive responses and strategies to a changing Arctic marine environment.



Atlantic Walrus hauled out on ice
Photo credit: Jack Orr

Photo credit: Jack Orr

Ice platforms are important
to walruses.

Photo credit: M. Plamondon

This harp seal pup sheds its white coat at
2-3 weeks of age.

5.8.1 IMPORTANCE OF ICE FOR MARINE MAMMALS

Seals move and forage in water, but must return to a solid platform, either on land or on the ice to give birth and nurse their young. While hauled-out, seals are vulnerable to surface predators such as bears, foxes and even aerial predators like crows and eagles. To avoid predation, seals often haul out in isolated areas that are difficult for surface and aerial predators to find or reach.

There are two main types of ice associated with seals. Fast ice is the ice that is normally attached to land and remains in place throughout the winter. Pack ice, or drift ice, is ice that may form along land but breaks off or forms in offshore areas. This ice can be quite thick and consists of ice pieces or pans that vary from only a metre to several hundred metres across.

Atlantic Canada harp, hooded and grey seals are usually found on pack ice. Harp and hooded seals always breed on pack ice. The Northwest Atlantic populations of these species give birth, nurse their young and breed during early to mid-March in the Gulf of St. Lawrence, and during mid- to late-March off the northeast coast of Newfoundland.

A stable ice platform is needed to breed,
give birth and nurse seal pups.
Photo credit: J. -P. Sylvestre

Photo credit: DFO

Harp seals hauled out on ice pans in the Gulf of St. Lawrence.

After birth, the young pups of all three species grow rapidly, with the hooded seal pup showing the most rapid growth increasing from 22 kg at birth to 44 kg at weaning in 3.8 days. The harp and grey seal pups increase from about 10 kg and 17 kg at birth to 30kg and 50 kg after 12 to 14 days and 16 days respectively.

In all cases, animals breeding on the ice require a stable platform, where the female and pup are capable of remaining out of the water, where the pups are unlikely to be crushed, or where the ice won't break resulting in separation of the female from the pup. The ice must also be solid enough for the female and pup to lie on it for nursing.

The type of ice varies between each of the three species. All appear to prefer ice that is around 50 to 100 cm thick, with pans that are 10 to 100 m across. All seem to avoid very tight, closely packed ice, which limits the movement of animals between pans, or the ability of animals to move in and out of the water. They also tend to avoid thin pans and areas with large spaces between pans because they can easily break and the animals can be swept off by waves during storms. These are only general characteristics since animals must make do with what is available, and storm and drift activity can change the shape of pans very rapidly.

In all three populations, the preferred pupping areas are usually found in ice retention zones. In these areas, due to a combination of land features and water current characteristics, the ice drifts slowly and is not ejected directly into the open ocean. The combination of good ice and slow ice drift zones provide areas of stable ice, where females can nurse their pups and where the pups are able to rest during their post-weaning fast before they have to swim.

Harp seal peeking out of the water.
Photo credit: DFO

5.8.2 SEAL PREDATION PRESSURE ON ATLANTIC SALMON

Regional climate-change models indicate that the rate and severity of change across Canada will vary with some areas experiencing more extensive impacts than others. The western Arctic and Hudson Bay have received considerable scientific and media attention given the importance of sea ice in the ecology of these marine ecosystems and the relative immediacy of change that has already occurred and been predicted.

However, it is important to note that other more temperate regions of Canada are also going to be affected in ways that may be complex and somewhat unexpected. One area of active research is determining how climate change/variability may contribute to the mismatch, either in space or in time, between an animal and its key food source.

For example, in marine systems, the spring bloom of algae initiates a complex suite of food chain interactions – if the bloom occurs significantly earlier, will all species of the affected food chains be able to adapt equally well? For most marine ecosystems, the answer to this question, and many more like it, are largely unknown.

DFO, in collaboration with the Climate Change Impacts and Adaptation Program and Memorial University of Newfoundland, recently initiated a project to examine the relationship between climate change and seal predation pressure on salmon in Newfoundland and Labrador rivers. Salmon stocks in Newfoundland and Labrador have a long history of subsistence and recreational exploitation.

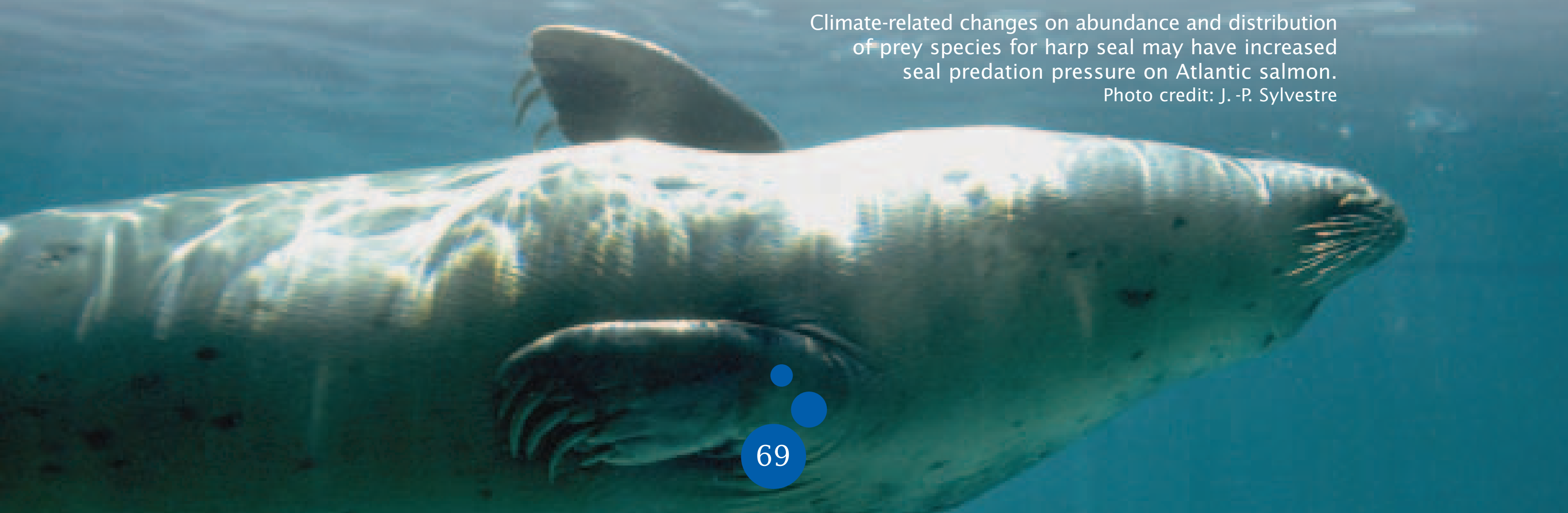
Photo credit: DFO

The abundance of Atlantic salmon has declined significantly since the early 1990s and it is not known why. Many fishermen believe increased seal predation may be a contributing factor.

The significant decline in Northwest Atlantic salmon since the early 1990s has resulted in progressive river closures and fishing restrictions. The reasons for this decline are unknown, but many fishermen cite increased seal predation in rivers and estuaries as a cause. Yet there is virtually no seal information available to evaluate the potential problem.

This project looks at whether climate-related changes have influenced the distribution and abundance of schooling fish species, i.e. capelin and herring, which are key prey species for harp seals. It also looks at whether these changes have influenced seal foraging behaviour such that there may be increased seal predation pressure on salmon. The research team will also evaluate whether a better understanding of changing inshore fish distribution could be useful for predicting the occurrence and severity of seal/salmon fisheries interactions in an increasingly variable coastal marine environment.

If this is the case, these data would facilitate the implementation of more timely mitigative actions and fisheries management decisions for rivers and estuaries that may have serious problems.



Climate-related changes on abundance and distribution of prey species for harp seal may have increased seal predation pressure on Atlantic salmon.
Photo credit: J. -P. Sylvestre

5.8.3 RINGED SEALS IN HUDSON BAY

Climate models predict that Hudson Bay will be ice-free within the next 50 years. Recent evidence of declining polar bear reproduction and condition in western Hudson Bay has raised conservation concerns. This knowledge has kindled interest in understanding the possible ecological changes that are occurring in the Hudson Bay marine ecosystem.

Ringed seals are the primary prey of polar bears and are one of the most important marine mammals harvested by the Inuit. Yet, little is known about ringed seal population ecology, particularly the factors responsible for successful reproduction and survival.

Given that ringed seals require certain sea ice conditions to successfully over-winter and rear a pup, it is likely that they are sensitive and perhaps vulnerable to any climatic variability that alters these required habitat characteristics.

Ringed seal pups are born in a snow cave (lair) constructed by the female near a well-drifted pressure ridge known as an ice hummock. The lair protects the pup from predation as well as provides much needed shelter from the wind and cold temperatures.

Adequate snow cover and appropriate ice roughness are important to the survival of ringed seal pups in the High Arctic.

Pup survival can be jeopardized in years where there is less snow, more freezing rain or early spring ice break-up.

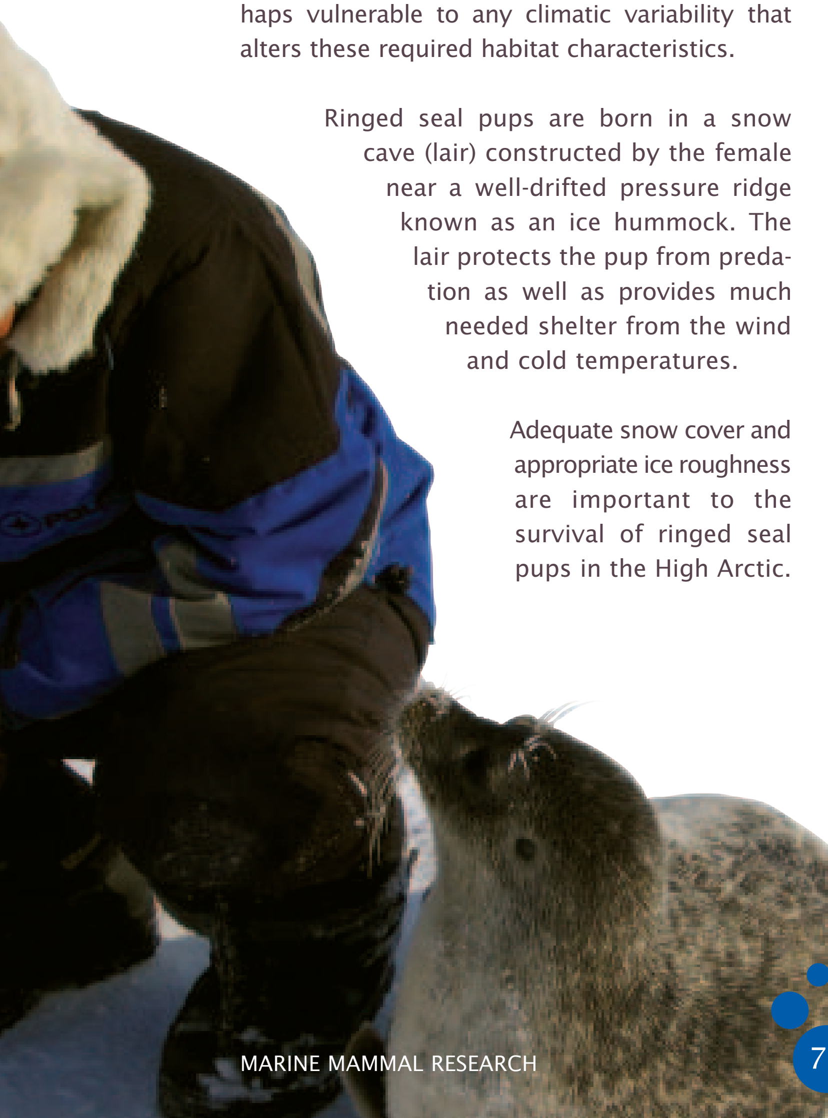
Generally, it is assumed that there are enough ringed seals to satisfy the needs of people and bears, and that seal population sizes are large and stable. However, hunter knowledge in western Hudson Bay indicates that the number of ringed seals has declined in recent years.

This knowledge also had some support from science: the pregnancy rate in seals from Arviat in Nunavut appeared to be low in the early 1990s and the density of ringed seals basking on the sea ice off Churchill in late spring declined from the mid- to late-1990s. In recent years, fewer pups have survived to become adults in Hudson Bay signaling a possible future reduction in ringed seal distribution and abundance.

After reviewing the evidence, DFO started a study to uncover the cause of the ecological changes. In this study, scientists use samples from harvested seals to provide information on genetics, disease, contaminants, food habits, reproduction and survival. They also tag seals to monitor movements and dive behaviour. The goal is to understand the dynamics of population change and provide management options to protect ringed seal populations through future reductions in sea ice extent as forecasted by climate change models.

Photo credit: Steve Ferguson

Scientists weighing a ringed seal.



I'll be watching you... This ringed seal was satellite tagged to track his movements.
Photo credit: John Moran, University of Alaska Southeast

Photo credit: Steve Ferguson

Scientists collect samples from seals harvested by Inuit communities to provide information on genetics, disease, contaminants, food habits, reproduction and survival.

Ringed seals are numerically, nutritionally and economically the most important marine mammal species to Inuit communities of Hudson Bay. They are also the primary prey of polar bears. Given their importance, it is critical to anticipate changes rather than wait for ringed seals to start disappearing.

5.8.4 RINGED SEALS IN LABRADOR

In collaboration with the Northern Ecosystem Program of Environment Canada, Memorial University, the Nunatsiavut Government and the Canadian Ice Centre, Fisheries and Oceans Canada has an ongoing Labrador ringed seal and sea ice project.

The project has four objectives related to climate change: 1) to develop the use of satellite imagery as a tool to identify, classify and quantify the available habitat for breeding ringed seals; 2) to determine the ecological linkages between ringed seal productivity and changing land-fast ice conditions; 3) to develop consistent sea ice and ringed seal monitoring protocols that will integrate the Labrador project with ongoing and future climate change studies in other Arctic regions; and 4) to establish a community-based sea ice/ringed seal research network in the communities of Rigolet, Hopedale and Nain in Labrador.

Photo credit: John Moran, University of Alaska Southeast

Photo credit: Canadian Ice Centre

A satellite view of eastern Lake Melville in Labrador during March. The image documents ice conditions on the Lake with relatively smooth areas showing up darker and rougher ice showing up as white braided ridges and rafted pans. Ringed seals require moderately rough ice that creates snow drifts large enough for females to excavate a birthing lair for the pup.

Generally the availability and quality of ringed seal pupping habitat appears to be better in parts of Lake Melville, near the community of Rigolet, when compared to the northern coastal areas of Labrador (Nain and Hopedale study sites). This is primarily because of greater snow accumulation and snowdrift development in the Lake Melville area.

Photo credit: Becky Sjare

A hunter examining a collapsed ringed seal birthing lair in March near the community of Nain, Labrador. The snow cover over the lair was so thin that wind action eroded the roof and exposed the newborn pup to the cold and to predators such as polar bears, wolves and foxes.

6.0

HOW TO CONTRIBUTE TO A MARINE MAMMAL SIGHTINGS NETWORK

Canada's large areas of fresh and marine waters contain a complex and, in places, abundant collection of animals, including marine mammals such as whales, dolphins and seals. To manage these marine mammal populations, Fisheries and Oceans Canada (DFO) requires knowledge of where they are and how many are there, particularly for those animals listed under the federal *Species at Risk Act*.

Humpback whale
Photo credit: NOAA

DFO scientists employ a variety of ways to collect information on the locations of marine animals: ship-based or aerial surveys, monitoring of underwater sounds made by the animals, and sighting records gathered aboard scientific vessels. The cost of undertaking surveys specifically for whales is prohibitive and therefore, opportunistic data sources are of great importance. Although opportunistic sightings do not provide all of the information that directed surveys can, all information on whales is useful in studying migrations, distributions and feeding habits.

Currently, the Department participates in a number of data collection and management programs for marine animal sightings across Canada. For example, DFO's Pacific Biological Station and the Vancouver Aquarium created the B.C. Cetacean Sightings Network to collect and compile sightings reports submitted by the public. The objective of this Network is to increase public awareness of B.C. mammals and the conservation concerns affecting them.

Photo credit: Jack Lawson

Narwhal in Spaniard's Bay, Newfoundland.

The Network encourages the public to become active stewards and report sightings of cetaceans in B.C. waters.

Scientists enter sightings reported by the public into a database and use the data to answer key questions on cetaceans at risk, such as understanding what habitats are most important for these species. The information helps researchers target their conservation efforts more effectively.

Anyone can join the hundreds of participants from all over the West Coast in helping conserve B.C. cetaceans. Not only does it increase personal awareness of whales, dolphins and porpoises, it also helps the Network scientists learn more. More details on the Network can be found on its website at http://www.pac.dfo-mpo.gc.ca/species/marinemammals/report-sight_e.htm.

On the east coast of Canada, the *Species at Risk* Group in St. Andrews, New Brunswick, maintains a sightings database for large whales in the Bay of Fundy and on the Scotian Shelf. The database allows scientists to input sightings records from a variety of sources including: whale watchers, scientific researchers, fishermen and fisheries observers. It can also house information on other large marine animals such as basking sharks and sea turtles. The database contains 'interaction' codes for cases where whales and marine animals are impacted by human activity.

Photo credit: Jack Lawson

Northern Bottlenose whale in Newfoundland

Photo credit: Barry Peters

B.C. killer whale

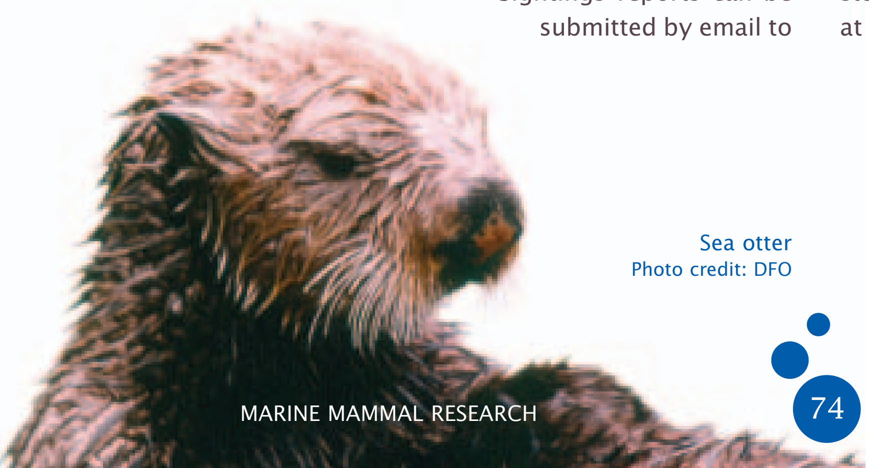
Ongoing components of the project include training of data collectors and the development of data products for those involved in data collection. A whale identification course and data collection kit has been developed and is being distributed to interested parties. The facilitation of data exchange is an important part of the whale sightings database project.

In Quebec, DFO maintains a survey database for cetaceans and pinnipeds in the Gulf of St. Lawrence and northern Quebec. The Central and Arctic region has a sightings database covering the Arctic, with much data for the eastern regions.

Finally, the Marine Mammal Section in DFO's Newfoundland and Labrador Region maintains a survey and reporting database of more than 15,000 sightings (mostly marine mammals) collected over the last 50 years. Sightings reports can be submitted by email to whalesighting@dfo-mpo.gc.ca for evaluation and inclusion in the sightings database.

Although most of the sightings databases maintained by DFO contain large and small whale, dolphin/porpoise, and seals records, some also include data for marine turtles, sharks, sunfish, and so on. The various databases are compatible, both with each other and with other whale databases in the United States, Canada and overseas.

Given the high cost of dedicated surveys, the areas and time periods covered by such efforts are usually only a small proportion of the region of interest. With such a huge area to cover -- and the large number of fishermen, and industrial and recreational users on the water every day -- these DFO sightings databases could benefit from public input. So, if you see a whale, seal or turtle please send in your report! – Environmental stewardship begins at home!



Sea otter
Photo credit: DFO