2010 CANADIAN MARINE ECOSYSTEM STATUS AND TRENDS REPORT

Figure 1. Map of Canada delineated by the terrestrial, freshwater, and marine Ecozone^{plus} units for the 2010 Ecosystem Status and Trends Report.

Context

In 2001, the Canadian Councils of Resource Ministers (CCRM) named biodiversity reporting as a priority. As a result, the Biodiversity Outcomes Framework was developed to identify and link current and future priorities related to sustaining Canadian biodiversity, to engage Canadians on the planning and implementation of these priorities, and to report on progress. In 2006, the CCRM identified the completion of the Ecosystem Status and Trends Report (ESTR) as an early deliverable under the Biodiversity Outcomes Framework.

ESTR will report on the assessment of 25 Canadian ecozones (15 terrestrial, 1 freshwater, and 9 marine). Science-based technical reports which correspond to each of the ecozones have been produced and are a compilation of available scientific and technical information on the condition, trends, drivers, and stressors of Canadian ecozones.

Canadian experts met to examine the information compiled for each of the marine ecozones and identified key findings and themes. This science advice will be brought forward to Environment Canada for incorporation into the National 2010 ESTR under the Biodiversity Outcomes Framework, and will also aid in measuring Canada's progress towards the Convention on Biological Diversity's (CBD) 2010 biodiversity targets.

SUMMARY

- The status and trends of Canadian marine ecozones are changing owing to a suite of different factors.

- Biological and ecological effects (e.g. increased natural species mortality, species range expansions and contractions, and changes in fish size, assemblages, and community structure) are occurring; however their impact on ecosystems is not always well understood.

- Climate change and oceanographic variability are affecting most Canadian marine ecozones. In particular, ocean acidification is known to be impacting several ecozones and is an emerging issue in the others.

- A decline in many fish stocks has occurred on the Atlantic and Pacific coasts as a result of commercial overexploitation. Although management measures have been implemented for most species, recovery has been limited in most cases.

- Legacy contaminants, like polychlorinated biphenyl (PCB) and dichlorodiphenyltrichloroethane (DDT) for example, are decreasing, however the incidence of emerging contaminants (e.g. brominated flame retardants) are becoming an issue in most ecozones.

- Industry and development have, or are threatening to, impact most ecosystems. The coastal zone is particularly vulnerable and is of concern as these areas are considered highly productive ecosystems.

- Some marine mammals that were overexploited in the past are now recovering. For example: bowhead, beluga, and narwhal in the Arctic, and sea otters, stellar sea lions, harbour seals, killer whales, humpbacks, and gray whales in the Pacific.

- Populations of grey seals in the Gulf of Maine and Scotian Shelf ecozone and harp seals in the Newfoundland-Labrador Shelves ecozone have increased dramatically.

INTRODUCTION

In 2001, the Canadian Councils of Resource Ministers (CCRM) named biodiversity reporting as a priority. As a result, the Biodiversity Outcomes Framework was developed to identify and link current and future priorities related to sustaining Canadian biodiversity, to engage Canadians on the planning and implementation of these priorities, and to report on progress. In 2006, the CCRM identified the completion of the Ecosystem Status and Trends Report (ESTR) in 2010 as an early deliverable under the “Assess” and “Ecosystem” components of the Biodiversity Outcomes Framework.

In addition to domestic commitments, ESTR also delivers on part of Canada’s international obligation to the United Nation’s Convention on Biological Diversity (CBD) to assess progress towards the global 2010 biodiversity target “*to achieve by 2010 a significant reduction in the current rate of biodiversity loss…”.*

ESTR will report on the condition, trends, drivers, and stressors of 25 Canadian ecozones (15 terrestrial, 1 freshwater, and 9 marine) based on existing information (Figure 1). These ecozones are adapted from the National Ecological Framework for Canada which is a hierarchical classification system based on a combination of ecological, climatic, and topographic factors. The nine marine ecozones to be assessed in ESTR were approved by the Fisheries and Oceans Canada (DFO) Regional Science Directors as appropriate and are as follows:

- *Pacific Ocean* – North Coast and Hecate Strait, West Coast Vancouver Island, and Strait of Georgia;
- *Arctic Ocean* – Beaufort Sea, Canadian Arctic Archipelago, and Hudson Bay, James Bay, and Foxe Basin;
- *Atlantic Ocean* – Estuary and Gulf of Saint Lawrence, Gulf of Maine and Scotian Shelf, and Newfoundland and Labrador Shelves.

ANALYSIS OF CANADIAN MARINE ECOZONES

North Coast and Hecate Strait

Overview

The North Coast and Hecate Strait ecozone is a coastal region situated along the eastern boundary of the sub-polar northeast Pacific Ocean. This ecozone lies adjacent to the large-scale cyclonic circulation of the sub-polar gyre, in particular the sluggish Alaska Current which flows northward towards the head of the Gulf of Alaska. Within this ecozone, the circulation of the Hecate Strait and the broad shelf of Queen Charlotte Sound is dominated by seasonally-reversing, wind-driven flows, as well as buoyancy-driven currents due to the fresh water discharge at the coast. At the shelf break, downwelling winds dominate throughout much of the year, disrupted by a short period of upwelling during summer months. Mesoscale eddies form over the shelf and propagate westward to the deep ocean which leads to a significant exchange of fluid with the deep ocean, transporting nutrients from the shelf into the sub-polar gyre.

Key Findings

- Basin-scale changes on inter-annual to inter-decadal time scales dominate the variability of the physical environment.

Long-term records of sea surface temperature (Figure 2) show a period of colder surface waters from the period 1945–1978, switching to a long period of warmer surface waters from 1978–2006. The zooplankton community composition and several fisheries time series (e.g. salmon marine survival and sablefish recruitment) are correlated with large-scale climate signals (i.e. El Niño Southern Oscillation events and the Pacific Decadal Oscillation). In addition, sea surface salinity shows a continuous pattern of freshening through the full period of records.

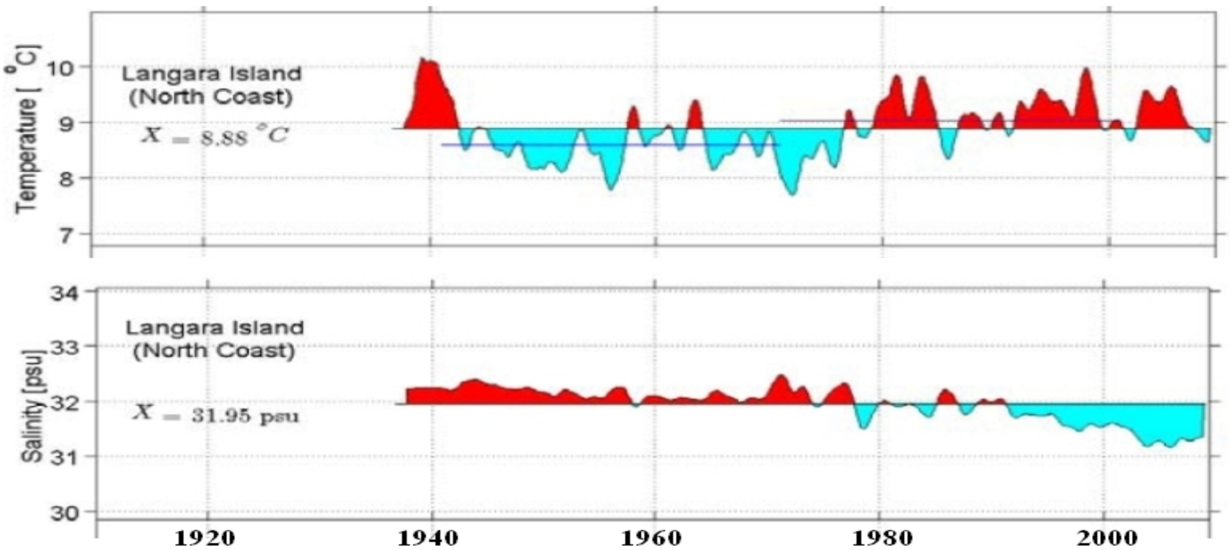

Figure 2: Long-term time series of annual-average sea surface temperature and salinity at the Langara Island light station in the North Coast and Hecate Strait ecozone.

- The transport of water masses in the North Pacific is an important driver of this ecosystem.

Declines in dissolved oxygen concentration, particularly in deeper waters (200-300 m) have been noted over the last 25 years. These changes may have affected the distribution of groundfish, but no "dead zones" (as have been observed on the Oregon and Washington coasts in some recent years) have been observed in this ecozone.

- Some herring and salmon populations are currently at low levels; however the trends for groundfish are variable.

Herring declines

Available time-series indicate that while the Prince Rupert herring stock remains at moderate levels of abundance, the Haida Gwaii stock has been depressed for the last decade (Figure 3). In addition, trends over the last several years indicate that the Central Coast stock is currently at record low levels of abundance.

Rivers Inlet Sockeye Salmon

Historically, the Rivers and Smith Inlet sockeye salmon stock formed one of the most valuable salmon fisheries in British Columbia, however it declined precipitously in the early 1990s (Figure 4). This decline is the result of poor marine survival during the migration through this ecozone and into the Gulf of Alaska; however the specific cause and location of this mortality is unknown.

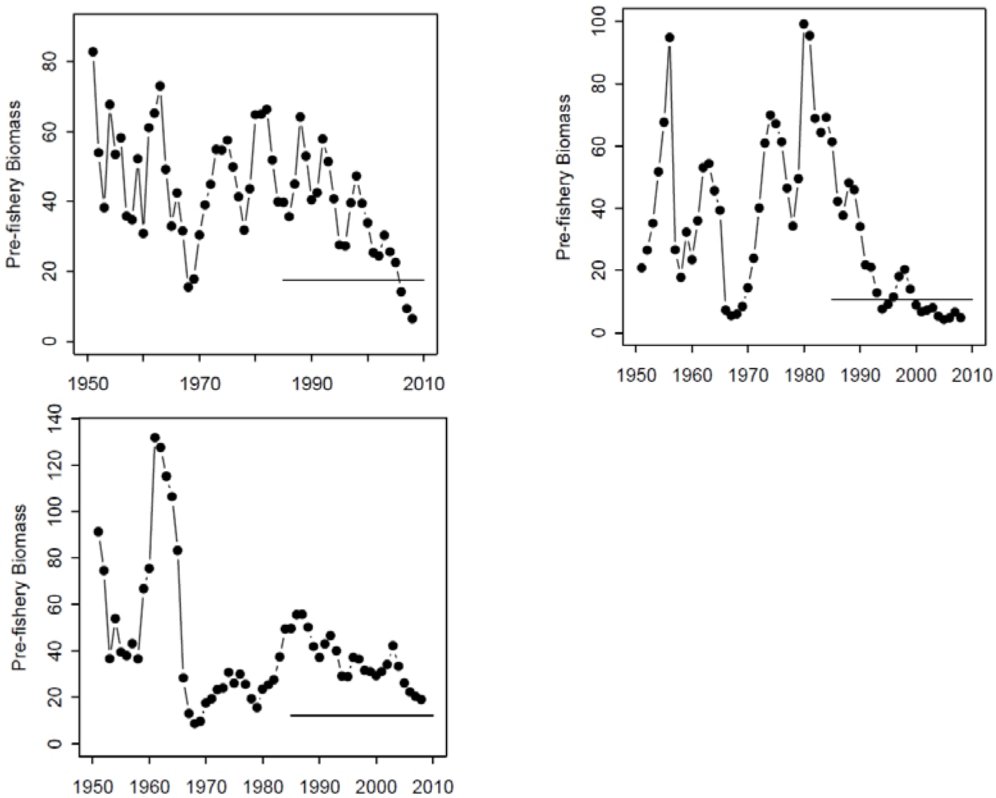

Figure 3. Pre-fishery biomass (in 1000s of tonnes) of Pacific herring in three subregions of the North Coast and Hecate Strait ecozone. The top left panel is for the Central Coast, the top right panel for Haida Gwaii, and the lower panel for the Prince Rupert District. The horizontal line represents the minimum spawning stock biomass.

Groundfish

In general, groundfish stocks in this area are recovering from a period of overexploitation in the early 1990s. Shorter-lived species (particularly some flatfish) show the highest recovery rates while some longer-lived species (notably several rockfish species) are still declining.

- Populations of most marine mammals that were overexploited are now recovering.

Populations of killer whales and stellar sea lions in this ecozone are recovering. The harbour seal population has increased rapidly since the 1960s and appears to have stabilized. Sea otters were once extirpated in this ecozone but have since been reintroduced; their populations have grown and the animals have extended their range.

- The breeding success of Cassin's and Rhinoceros Auklets is declining.

Breeding success for plankton-eating (i.e. Cassin's Auklets) and fish-eating (i.e. Rhinoceros Auklets) seabirds at major colonies on Triangle Island have declined. This decline is correlated with an increase in sea surface temperature in the spring.

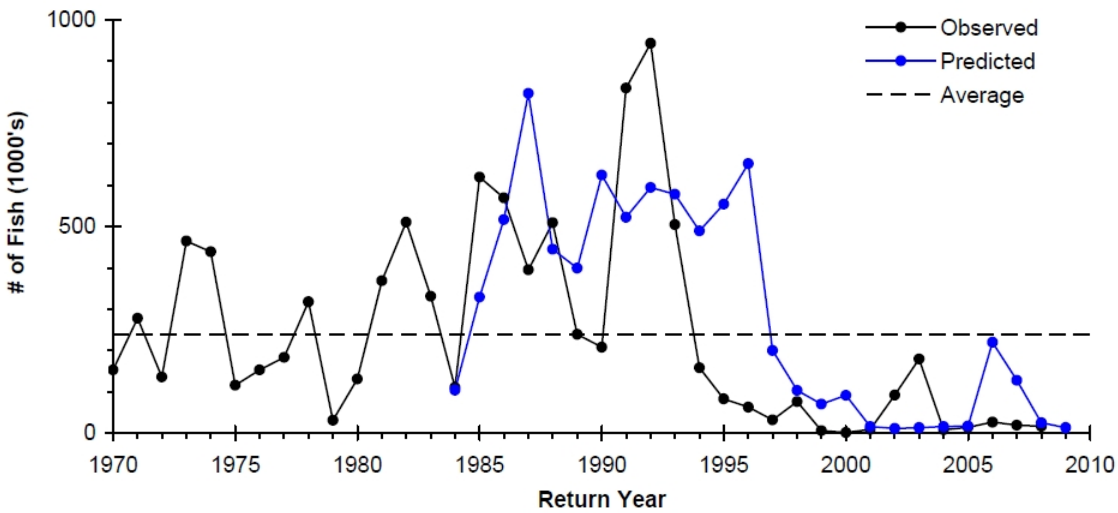

Figure 4: Returns and forecasts of Rivers and Smith Inlet sockeye salmon, 1970-2009.

Emerging Issues

- Renewable energy projects (e.g. wind turbines) may impact seabirds.
- The occurrence of globally-unique hexactinellid (glass) sponge reefs requires special conservation and management attention.
- Aquatic invasive species, primarily green crab (*Carcinus maenas*) and two species of tunicate (*Botryllus schlosseri, Botrylloides violaceus*), have the potential to cause serious impacts on marine and estuarine biodiversity, as well as impact the shellfish aquaculture industry.

Knowledge Gaps

- The source and mechanism of excessive marine mortality of some pelagic species (e.g. salmon, eulachon, and herring) is unknown.
- Plankton time-series are only available for the very southern edge of this ecozone and may not be representative of the whole ecosystem.
- Knowledge of ecologically significant species and community properties is lacking, especially for non-commercial species.

West Coast Vancouver Island

Overview

This ecozone generally includes the transition zone between two eastern boundary current systems (i.e. the California Current and the Alaska Current), on the west coast of North America. Over the mid and outer shelves, surface water flow is southward in the summer and northward in the winter in response to the large scale pressure systems and their associated winds. Over the inner shelf there is a northward flowing buoyancy current that is present throughout the year (i.e. the Vancouver Island Coastal Current) that brings nutrient-rich water into this ecozone from the Juan de Fuca Strait. In the subsurface waters, the California Undercurrent flows northward throughout the year.

Wind patterns cause upwelling (i.e. the transport of subsurface nutrient-rich water to the surface) during the summer and downwelling in the winter. This physical circulation drives both the chemical and biological systems in this ecozone. In addition, large basin-scale changes, such as a decrease in dissolved oxygen concentration and an increase in dissolved inorganic carbon in intermediate depth waters, may be transferred to the coast in this manner.

Key Findings

- Variability in the physical environment dominates this ecosystem.

Long records of sea surface temperature indicate a period of colder surface waters from 1945–1978, switching to a long period of warmer surface waters from 1978–2006. The zooplankton community composition and several fisheries time series (e.g. salmon marine survival, sablefish recruitment, herring production and offshore distribution, and sardine production and distribution) are correlated with the Pacific Decadal Oscillation as well as El Niño/La Niña events.

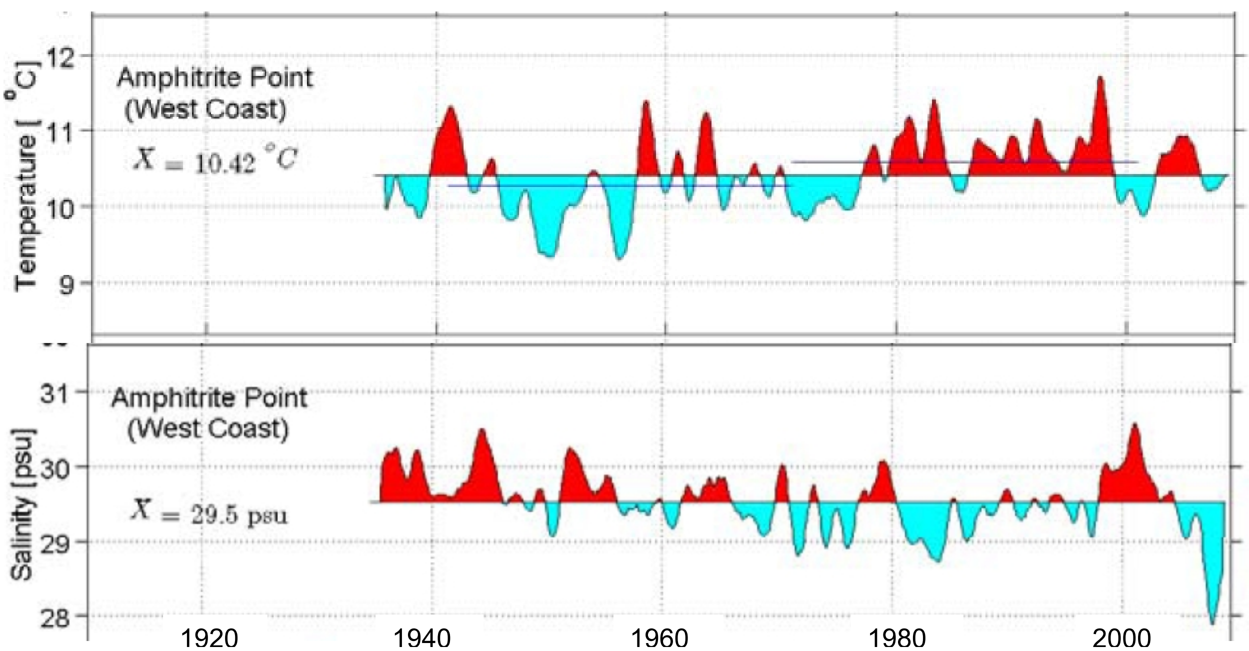

Figure 5. Long-term time series of annual-average sea surface temperature and salinity at Amphitrite Point, a coastal British Columbia lighthouse in the West Coast Vancouver Island ecozone.

- The transport of water masses in the North Pacific is an important driver of this ecosystem.

The north-to-south migration and transport of zooplankton and fish are important features of this ecozone. During warm periods, species more typically found off of Oregon and Northern California are found here with southern zooplankton having a lower nutritional value. Declines in dissolved oxygen concentration, particularly in intermediate depth waters (200-300 m) have been noted over the last 25 years. The cause of this change is unknown; however, changes in mixing and circulation in the western North Pacific likely play an important role. The decreased oxygen concentration may have restricted the distribution of groundfish, but no “dead zones” (such as have been observed off of the Oregon and Washington coasts in some recent years) have been observed in this ecozone to date. Stronger upwelling in this ecozone can bring low-oxygen water up onto the continental shelf.

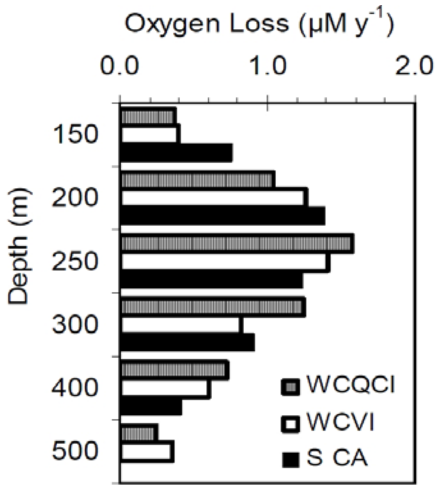

Figure 6. Oxygen trends at different depths along the west coast of North America. 'S CA' refers to Southern California, 'WCVI' refers to the west coast of Vancouver Island, and 'WCQCI' refers to the west coast of Haida Gwaii which is within the North Coast and Hecate Strait ecozone.

- The majority of exploited fish species in this ecosystem are collapsed or declining.

Pacific hake, herring, and Barkley Sound sockeye salmon (Figure 7) are at low levels. Size-at-age of the herring stock is also declining which is an issue of concern. Marine survival rates for some key index stocks of salmon have shown great variability over the last 20 years, but are at low levels now. However, some species (e.g. turbot and sablefish) are increasing in abundance. Pacific sardine, which collapsed coast-wide (from British Columbia to California) in the 1950s have return to their former full range in the California Current System.

- Populations of most marine mammals that were once over-harvested are now recovering.

Populations of killer whales, gray whales, humpback whales and stellar sea lions are recovering. The harbour seal population has increased rapidly since the 1960s and appears to have stabilised. Although previously extirpated in this ecozone, sea otters have been reintroduced and the populations have grown and have expanded to approximately 30% of their historical range (Figure 8).

Emerging Issues

- Emerging contaminants (e.g. brominated flame retardants) are known to be increasing in marine mammal tissues.
- There are potential bottom-contacting fishery impacts on deepwater corals and sponges at the shelf break.

Knowledge Gaps

- No long-term trend data are available for groundfish as trawl surveys have not occurred since 2004.
- Accurate population abundance estimates are lacking for many species.
- Information on status and trends related to coastal zones is largely unknown.

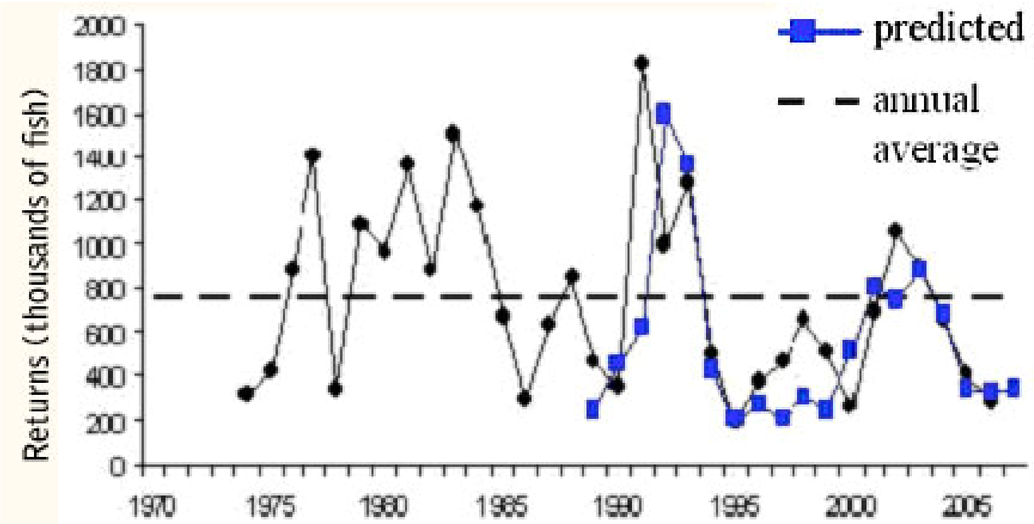

Figure 7. Trends in total returns (closed circles) and forecasts (closed squares) for the Barkley Sound Sockeye Salmon index stock, 1970 – 2006; the vertical axis represents returns in thousands of fish.

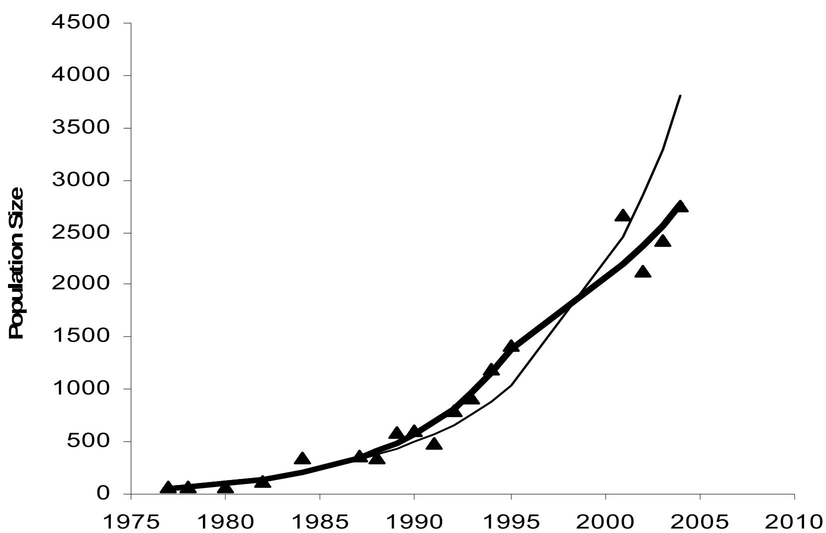

Figure 8. Annual sea otter abundance estimates (triangles) off Vancouver Island for 1977 to 2008. Population growth models estimate annual growth rates of approximately 15% (grey line) for the entire time series or approximately 19% for 1977 to 1995 and approximately 8% for 1995 to 2008 (black line).

Strait of Georgia

Overview

The Strait of Georgia is a semi-enclosed sea located between Vancouver Island and mainland British Columbia. Water circulation in the Strait is dominated by estuarine exchange (i.e. out at the surface, in at depth) and by tidal and wind mixing. The Strait is highly productive supporting commercial, Aboriginal, and recreational fisheries. It is also surrounded by a growing urban population, which is exerting a variety of pressures on this ecosystem.

Global climate change acts locally through variations in seawater and river temperatures, in the oxygen concentration and pH of inflowing deep water, and in the timing of river discharge. Other changes have resulted from local anthropogenic activities such as: shipping, fishing, the discharge of contaminants, and habitat destruction (including the construction of hard edges, which will interact with sea level rise). However, this ecosystem has shown resilience in the past, having recovered from numerous stressors and climatic variations.

Key Findings

- The Strait of Georgia is warming at all depths (1970-2006) and, in addition to other potential impacts, is effecting salmon populations.

  Unlike other ocean areas, the Strait of Georgia shows warming from its surface to 300 metres depth. This is due to the local warming of surface waters and the inflow of near-surface waters on the continental shelf into the interior of the Strait of Georgia. Rising summer temperatures in the Fraser River have caused substantial in-river pre-spawning mortality of returning adult salmon in some recent years.

- Zooplankton abundance is decreasing and the maximum biomass is peaking as much as 50 days earlier compared to the 1970s.

  The dominant species of zooplankton (*Neocalanus plumchrus*) is decreasing in abundance and the seasonal timing of its peak abundance in the surface waters is occurring approximately 50 days earlier than in the 1970s. The data suggests that this decline in abundance may be accelerating. Changes in the timing of events such as this increase the potential for a mismatch in the production cycles of various trophic levels and declines in higher trophic level productivity (Figure 9).

- The populations of several piscivorous fishes (e.g. coho and chinook salmon, lingcod, Pacific cod, and inshore rockfish) have significantly declined (1986-2006).

  There have been significant declines in the populations of some predominantly piscivorous (fish-eating) fish in recent decades (e.g. coho and chinook salmon, lingcod, Pacific cod) as well as some inshore rockfishes. In contrast, populations of pink and chum salmon, which are predominantly planktivorous (plankton-eating) have increased. In addition, the coho salmon which do remain in the ecozone are dominantly of hatchery origin (Figure 10). Declines in coho salmon are linked to declines in marine survival for both wild and hatchery populations.

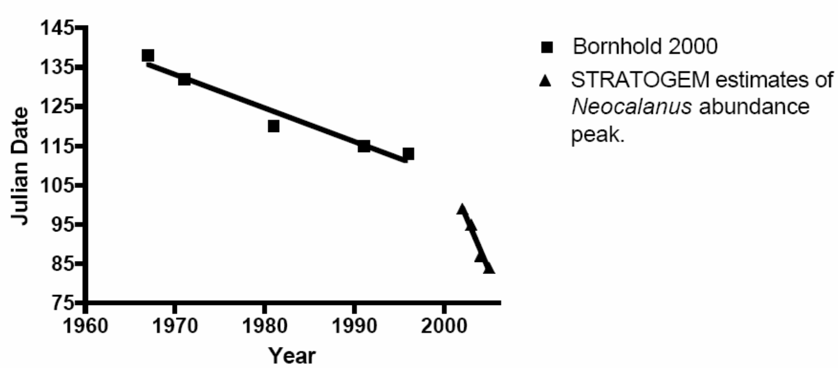

Figure 9. Temporal trend in the timing of peak zooplankton (Neocalanus plumchrus) biomass in the Strait of Georgia. Bornhold data (squares) are from back-calculation of the timing of the Neocalanus peak. The STRATOGEM data (2002-2005) are based on direct observations of Neocalanus stage composition in the Strait of Georgia.

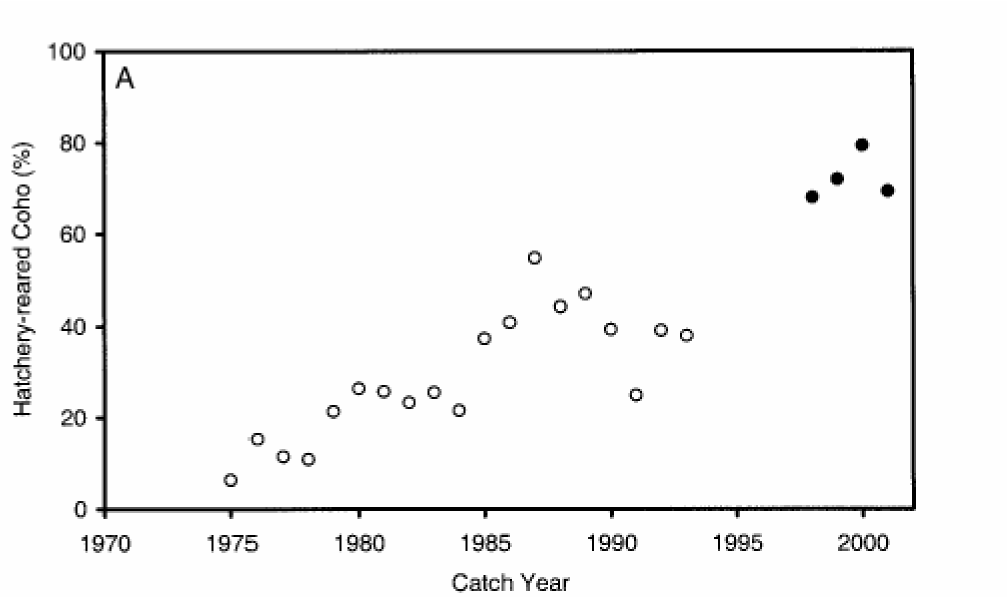

Figure 10. Percentage of coho salmon in the Strait of Georgia that were hatchery-reared (1975 - 2000). Open circles represent data collected from sport and commercial catches; filled circles, data from research cruises.

- There has been a significant change in the size of Pacific herring, a key forage species.

Similar to that of the West Coast of Vancouver Island ecozone, a decline in the weight-at-age of Pacific herring occurred from 1970–2006 (Figure 11). This decline is currently not explained and is a cause for concern.

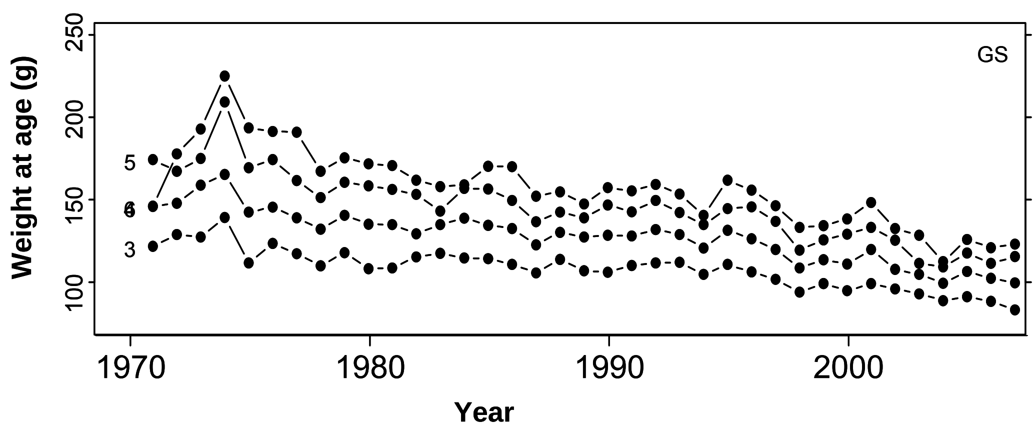

Figure 11. Estimates of weight-at-age (g) for 3-6 year old herring from 1970 to 2008.

- Coastal and estuarine zones are deteriorating in both extent and condition.

Coastal habitats, such as estuaries, salt marshes, and mud flats, are among the most biologically productive ecosystems. In general, in less developed coastal areas these systems are healthier than those in more developed areas. Those in developed areas are deteriorating in both extent and condition, often as the result of coastal erosion, contaminants from various land uses, alien invasive species, etc.

- The Strait of Georgia has two to three times the number of non-native species compared to other parts of coastal British Columbia.

There are 34 intertidal non-native species found in the Strait of Georgia, compared with 15 or fewer in other areas of coastal British Columbia. Concentrated aquaculture activities, local estuarine circulation patterns, and increasingly intensive shipping traffic have likely contributed to the high number of non-native species.

Emerging Issues

- The effects of emerging contaminants are starting to be documented but are not fully understood.

Knowledge Gaps

- The effects associated with changing deep water chemistry (e.g. changes in pH, decreasing oxygen, increasing CO_2) are unknown.
- Cumulative impacts in the coastal zone need further study.
- Time-series nutrient data are lacking.
- Status and trends of benthic and non-commercial organisms are generally unknown.
- The cause of change in the timing of zooplankton biomass peak and the potential impact on higher trophic levels are not well understood.

Beaufort Sea

Overview

The Beaufort Sea marine ecozone (BSME) is important for the subsistence and culture of communities within the Inuvialuit Settlement Region. The BSME is characterized by the Beaufort continental shelf, a relatively short ice-free season, increased sediment and freshwater loading from the Mackenzie River during the spring and summer, and the Cape Bathurst polynyas and associated flaw leads. The polynyas, flaw leads, and estuarine regions are considered to be areas of relatively high productivity and diversity. Water column salinity, temperature, and freshwater content are influenced by the outflow of the Mackenzie River and oceanic circulation patterns (i.e. the Beaufort Gyre). The continental shelf is a critical interface linking terrestrial and freshwater processes/impacts with this marine ecozone.

Key Findings

- There have been significant changes in the water mass characteristics of the Beaufort Sea which may impact species distribution and primary production.

The freshwater and heat content of the Beaufort gyre has significantly increased relative to the 1970s (Figure 12). The temperature increase has been related to a twofold increase in the temperature of the Atlantic water layer. This warmer Atlantic water enters the Arctic via the Fram Strait, and has contributed to the net warming of Arctic waters. The freshening of the Beaufort gyre is related to input from both Pacific waters and Arctic Ocean surface waters. Melting sea ice has contributed to the increasing freshwater content of the Arctic Ocean surface layer.

Water temperature and salinity are ecologically important because many species have narrow tolerances which may affect their spatial distribution. Thus, water temperature and salinity trends have important implications for range expansions of southern species into the Beaufort Sea. Changes in temperature and salinity also influence the stratification of the water column which is important for controlling the magnitude and timing of primary productivity.

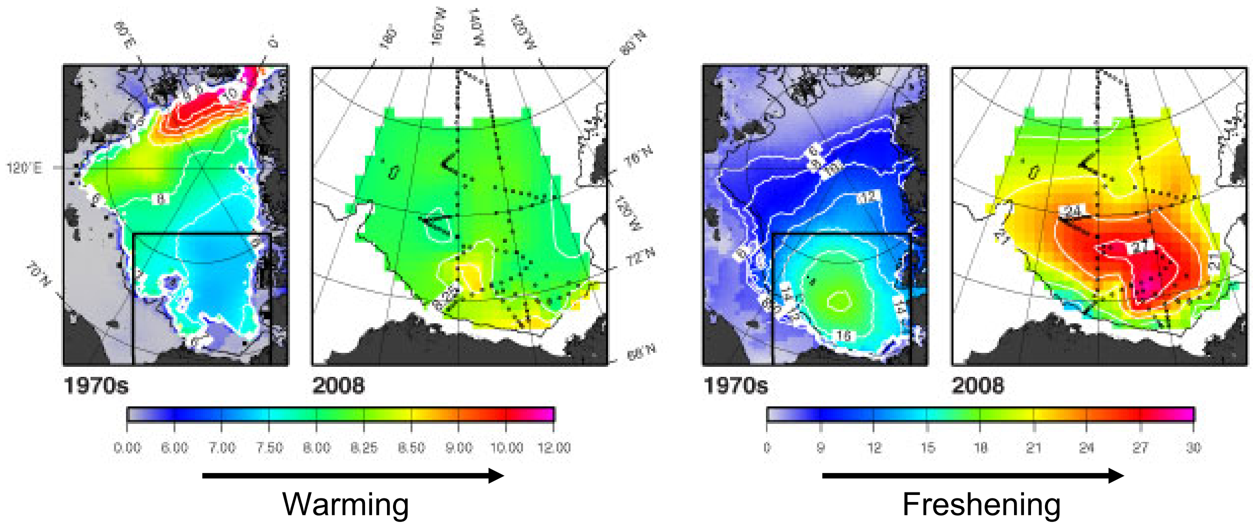

Figure 12. Warming and freshening of the Beaufort Sea in 2008 compared to the 1970s. The 2008 areas are outlined in black in the 1970s panels.

- There has been a significant reduction in the extent of summer sea ice which has multi-faceted effects on marine and coastal ecosystems.

The extent of summer (i.e. September) sea ice has declined at a rate of approximately 11.2% per decade between 1979 and 2009 in the Beaufort Sea/Arctic Ocean region (Figure 13). This change in sea ice has been accompanied by an earlier onset of ice melt (4.7 days/decade) and an increasing duration of the melt season (9.2 days/decade) as measured between 1979 and 2005. There is also much inter-annual variation in the spatial distribution of sea ice during the summer.

Changing sea ice conditions have multifaceted effects on the marine and coastal ecosystem in the Beaufort Sea. Sea ice plays a key role in protecting the subsiding shorelines from erosion caused by wave action, especially during storms. With increasing periods of open water on the coast as a result of reduced sea ice cover there is greater potential for increased coastal erosion in the Beaufort Sea ecozone. The increased exposure of surface water to more wind will also influence the physical mixing of the water column, which is an important process influencing primary production in the Beaufort Sea.

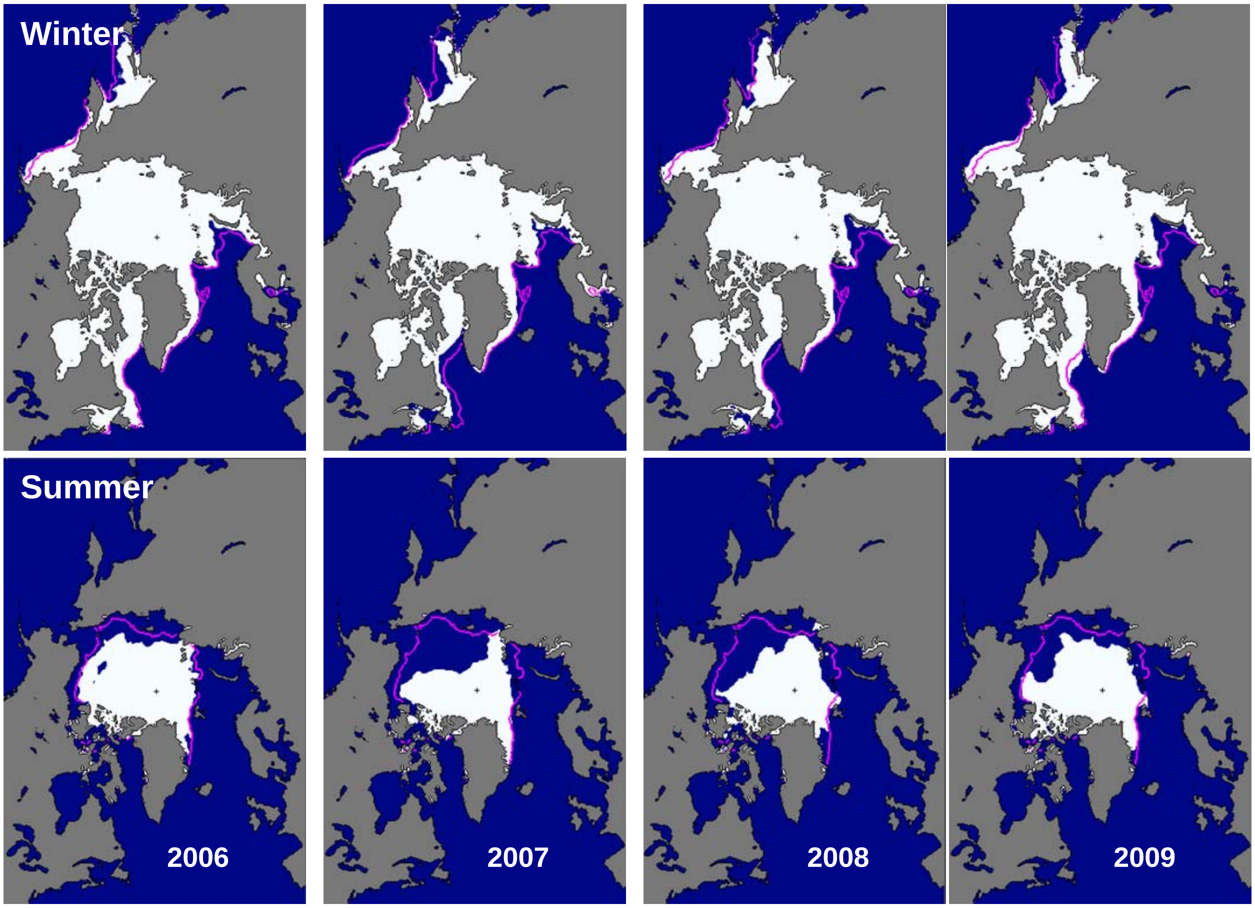

Figure 13. Trend in maximum (Winter; March) and minimum (Summer; September) sea ice extent between 2006 and 2009. Note: the magenta line indicates mean ice edge for the satellite record.

- There is an increasing trend in phytoplankton primary production which is linked to a longer growing season.

Satellite data from the last 20 years indicates an increasing trend in phytoplankton primary productivity, with 2007 and 2008 being the most productive years on record (Figure 14); this information is for the entire Arctic Ocean, including the Beaufort Sea. Phytoplankton is the major contributor to total Arctic primary productivity, although ice algae are an important early source of food for pelagic grazers and can stimulate benthic activity when they sink to the bottom. The increasing length of the growing season (i.e. annual mean open water area) is a key factor driving this trend in phytoplankton primary production. It is not yet known how changes in primary productivity will affect the direction (i.e. pelagic or benthic) or magnitude of organic carbon fluxes as well as food web linkages, especially on the productive shelf region. Inorganic carbon (e.g. CO_2) cycling will also be influenced by increased productivity, altering the carbonate system with feedbacks to processes such as ocean acidification.

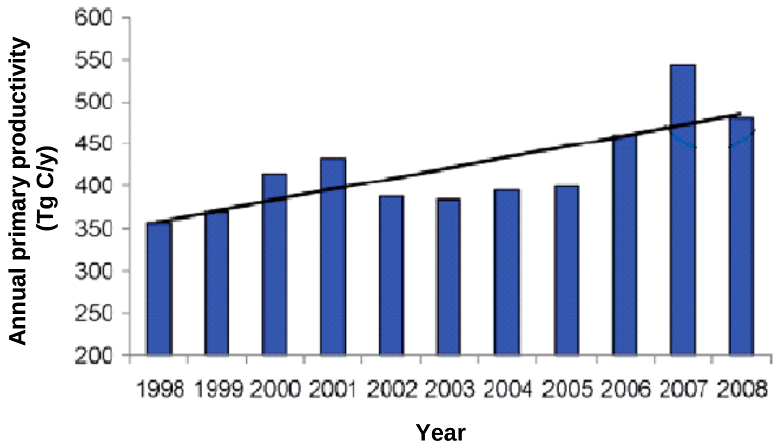

Figure 14. Trends in annual primary production for the Arctic (1998-2008).

- Bowhead whale populations are recovering from intense commercial whaling while beluga populations remain stable.

The western Arctic bowhead whale population in the Beaufort Sea was depleted by commercial whaling between 1840 and 1907. The historic population for bowhead was estimated between 10400 and 23000 but was reduced to approximately 3000 individuals. As of 2001, the population was estimated to be between 7700 and 12600 individuals, increasing at a rate of 3.4% per year between 1978 and 2001 (Figure 15).

The Beaufort beluga whale stock is one of the largest beluga stocks in Canada. These beluga aggregate in the warm estuarine waters of the Mackenzie River and are widely distributed offshore. Population estimates from 1992 indicate that there are between 15000 and 24000 individuals. This population is currently considered to be large and stable with subsistence hunting at sustainable levels.

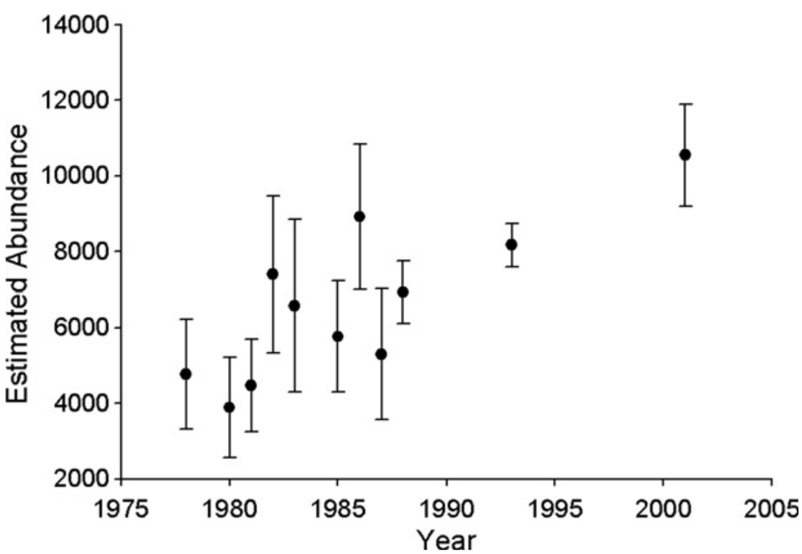

Figure 15. Abundance estimates and standard deviation for the western Arctic bowhead whale stock 1978 to 2001.

Emerging Issues

- Mercury concentrations in Arctic biota are substantially higher in Canada compared to other circumpolar countries and in some beluga, are approaching levels which could lead to health effects for these organisms.
- Ocean acidification is occurring more rapidly than anticipated which may have implications for some organisms and food webs.
- An increase in industrial development has resulted in seismic activity in preparation for drilling along the Beaufort Sea shelf break.
- Climate change appears to be facilitating the potential movement of new species (e.g. pink, sockeye, coho, and chinook salmon; Pacific zooplankton species) into the Beaufort Sea.

Knowledge Gaps

- The status and trends of seabirds in the Beaufort Sea are poorly understood relative to the Eastern Arctic.
- Temporal trends in the benthic community have not yet been assessed.
- Long-term trends in marine fish, zooplankton, and their food web linkages are not available.
- Sufficient information is not available to determine trends in the ecological integrity and sustainability of the near-coastal zone.

Canadian Arctic Archipelago

Overview

The Canadian Arctic Archipelago marine ecozone (CAA) is a major pathway for the exchange of heat and freshwater in the Arctic. Water is transported through Lancaster Sound/Barrow Strait, Jones Strait, or Nares Strait into Baffin Bay. The volume of water, freshwater content, and heat fluxes through the CAA has extensive seasonal and inter-annual variability. The CAA contains 50% of the total Arctic continental shelf area indicating that this area is important for total Arctic production. Productive regions and important habitats within the CAA include Resolute Passage, Lancaster Sound, and the North Water Polynya. The North Water Polynya is considered to be the most productive ecosystem north of the Arctic Circle and has been an important resource for the Inuit for at least 5000 years.

Despite its importance as an oceanic thoroughfare and its extensive shelf habitat, general status and trends of productivity, ecological diversity, and oceanographic processes are poorly understood compared to the other marine ecozones. The substantial ice cover of this ecozone makes it difficult to access, especially the northern portion where ice cover is extensive even in summer. The CAA encompasses the majority of remaining multi-year sea ice habitat in the Canadian Arctic, the fate of which is critical for understanding climate-driven changes to this Arctic marine ecosystem and will directly influence future accessibility of the Arctic.

Key Findings

- Changes in the age, distribution, and area of sea ice are occurring.

Between 1979 and 2008, first-year sea ice in the summer has been declining at a rate of 8.7% per decade, whereas the thick multi-year sea ice in the summer is being lost at an average rate of 6.4% per decade and over 20% per decade in some areas of the Canadian Arctic Archipelago (Figure 16). This decreasing trend in multi-year sea ice may be counteracted by the import of multi-year ice from the Arctic Ocean, or sustained by longer melt seasons that limit the promotion of first-year to multi-year sea ice. However, both of these factors have declined in recent years. Between 1979 and 2008 in the CAA, the longest melt season occurred in 2008 and there was a significant increasing trend in melt season duration (i.e. 7 days/decade). However, trends in ice disappearance and melt season are variable within this ecozone.

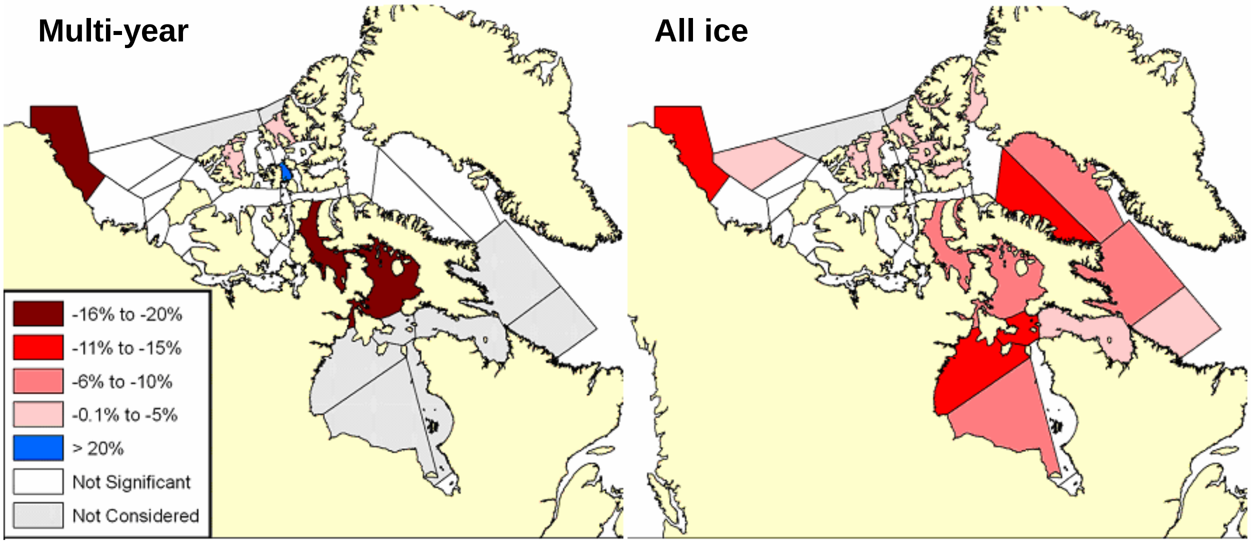

Figure 16. Percent per decade changes in multi-year ice and all ice types in the Marine Arctic Ecozones.

- Bowhead, narwhal, and beluga populations are considered stable or increasing.

The Eastern Canada-West Greenland population of bowhead whale was severely depleted by commercial whaling from the 1500s to 1910 and continues to be subject to subsistence hunting. The population is recovering as supported by both Aboriginal Traditional Knowledge (ATK) and scientific observations. The status of bowhead was reassessed by the *Committee on the Status of Endangered Wildlife in Canada (COSEWIC)* as 'Special Concern' in April 2009 from 'Threatened' (May 2005) and it is listed on the federal *Species At Risk Act (SARA)* as such. However, there are still concerns as to how the bowhead will respond to changes in their habitat due to climate change and increased industrial activities.

Narwhal populations in the CAA appear to be stable and have been assessed by COSEWIC as 'Special Concern' but are not listed on SARA. The very low genetic diversity of narwhal coupled with their specialized feeding characteristics indicates that they could be quite sensitive to changes in their habitat (e.g. sea ice cover) and/or diet.

The Cumberland Sound and Eastern High Arctic/Baffin Bay Beluga population in the CAA were assessed by COSEWIC as 'Threatened' and 'Special Concern', respectively but are not listed on SARA. The Cumberland Sound population may consist of only approximately 1500 individuals and the eastern high Arctic population is hunted in western Greenland. However, both beluga populations appear to be currently stable.

- The Ivory Gull population has declined dramatically (> 80%) since the 1980s however the cause is unknown.

The population of Ivory Gulls breeding in northern Nunavut (i.e. northern Baffin Island, Devon Island, and southern Ellesmere Island) that was formerly estimated at approximately 2000 pairs, declined by > 80% between the 1980s and 2005. The speed of the decline, the remoteness of their breeding sites, and their tendency to annually shift breeding sites have made it difficult to study the reasons for this decline. Consequently, we do not know whether it is related to changes on the breeding grounds or in their marine feeding areas. The latter seems most likely, but the specific change that affected them is unknown. For other species (e.g. Thick-billed Murres, Black-legged Kittiwakes) on Prince Leopold Island, the timing of breeding, reproductive success, and adult colony attendance have been linked to variations in sea ice conditions since 1975. In addition, other events on their wintering grounds may also influence seabird populations in this ecozone.

- Legacy contaminants (e.g. DDT, PCB) in marine biota have stabilized or are decreasing; whereas emerging contaminants (e.g. brominated flame retardants) continue to increase, as do mercury concentrations in seabird eggs.

The majority of contaminants found in Arctic marine biota have no Arctic sources. Legacy contaminants are the result of past use (e.g. DDT, PCBs) and their concentrations are now observed to be declining in Arctic marine biota (e.g. beluga tissues, multiple seabird species, Arctic char, and ringed seals). However, total mercury concentrations show increasing trends in seabird eggs (e.g. Thick-billed Murres) on Prince Leopold Island (Figure 17). In 2008, the highest mercury concentrations for Prince Leopold Island seabirds were found in Glaucous Gull eggs, whereas Kittiwake eggs had the lowest.

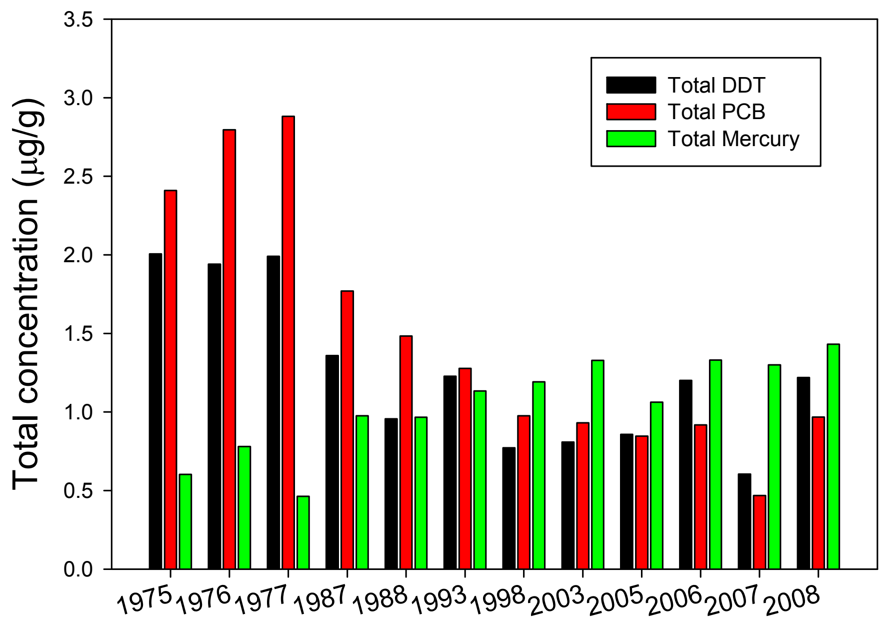

Figure 17. Contaminant trends for Thick-billed Murre eggs on Prince Leopold Island, 1975 and 2008.

Emerging contaminants have only been used industrially for the past 50 years and are found to be generally increasing in marine biota. For example, brominated flame retardants have shown increases in seabird eggs as well as beluga tissues. However, for the majority of contaminants year-to-year variability, tissues/sex effects, and the need for age-adjusted data complicate the interpretation of contaminant trends.

Emerging Issues

- New and developing commercial fisheries are important for Northern communities and are continuing to expand.

- Increased atmospheric CO_2 is expected to lead to more acidic surface waters which can adversely affect marine organisms.
- Industrial development (e.g. oil and gas exploration) and transportation could have significant impacts especially in an area such as Lancaster Sound that is a hotspot of diversity and productivity (e.g. breeding site for approximately three million seabirds).

Knowledge Gaps

- Data is lacking to for the determination of long-term ecosystem trends.
- Information regarding Arctic char biodiversity and marine habitat is deficient.
- The ecosystem impacts of reduced/removal of multi-year ice is unknown.
- Trends data for water column structure and circulation for assessing rapid changes in ecosystem structure and function..

Hudson Bay, James Bay, and Foxe Basin

Overview

Hudson Bay, James Bay, and Foxe Basin (HJBFB) is a unique semi-enclosed Arctic marine ecozone. The extreme southerly extent of Arctic waters and complete seasonal sea-ice cover creates habitat for Arctic marine mammals at latitudes equivalent to the Boreal Shield and Plain ecozones. Estuarine habitats are also important within the HJBFB due to the large volume of freshwater runoff, and unique coastal habitats are created by the continued rebound of land from the Laurentide ice sheet. Hydroelectric development and river flow alteration have had significant impacts on the coastal habitats of the HJBFB. This ecozone becomes completely ice free during the summer; however, the presence of winter sea ice is a critical platform for marine mammals and local communities.

The HJBFB is characterized by high biodiversity and contains multiple important habitats for seabirds, anadromous fish, and marine mammals. Coastal areas are key staging, breeding, and feeding areas for migrant birds and the largest aggregation of beluga in the world (> 40000 individuals) is located in western Hudson Bay. The HJBFB ecozone is also associated with approximately half the Inuit population of Nunavut and Nunavik. Thus, this ecozone is important for hunting and fishing, the transportation of supplies and goods (especially during the ice-free season), and for economic development.

Key Highlights

- Significant reductions in the distribution and extent of summer sea ice are having ecological effects.

Between 1979 and 2006, there has been a 19.5% per decade reduction in sea ice extent during the summer (July – September). This reduction is the highest among all the Arctic marine ecozones. The multi-year sea ice in the northern portion of this ecozone (i.e. near Baffin Island) is being lost at a rate of 6-15% per decade. There have also been significant shifts in the temporal distribution of sea ice, resulting in a longer ice free period. These changing ice conditions are expected to decrease the duration of, and influence the location of, polynyas, which are considered to be “hot spots” of production. The northern people, marine mammals, and birds that depend on polynyas will need to adapt to these changes.

A reduction in sea ice in Hudson Strait has facilitated the movement of Killer whales into this ecozone, particularly western Hudson Bay. The first individuals were observed approximately 50 years ago, with the number of killer whale sightings significantly increasing in recent years (Figure 18).

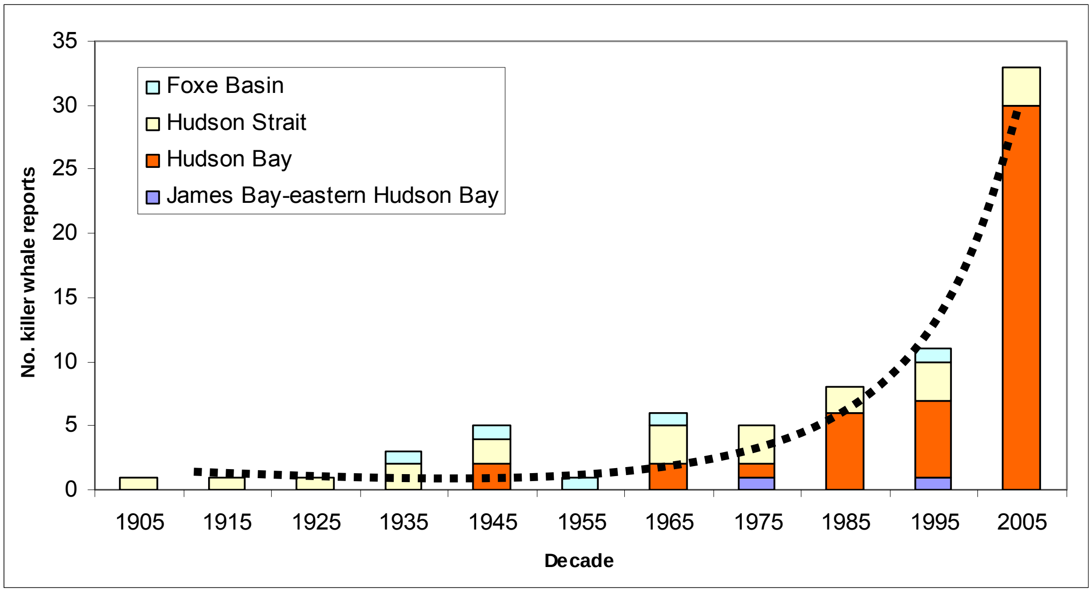

Figure 18. Trend in Killer whale reports in the HJBFB marine ecozone.

- There has been a decrease in freshwater inputs owing to a significant reduction in river inflow.

Between 1964 and 2000 there has been a 13% decrease in the annual flow of rivers into James, Hudson, and Ungava Bay. Of the 36 rivers investigated, 33 of them were not affected by dams. This decrease in river discharge is associated with a four day advance in peak river discharge. In addition, the increasing salinity of the surface waters, as a result of reduction in river inflow, has been correlated with surface water salinity increase in the Newfoundland and Labrador Shelves ecozone. This trend also highlights the linkage between terrestrial and marine ecozones.

- There are distinct populations of beluga whales showing varying population trends.

Genetically distinct stocks of beluga that show site fidelity are present in the HJBFB. Belugas are the only whales to commonly enter James Bay and south-eastern Hudson Bay, with the largest summering concentration in the world occurring around the Nelson River estuary. This very large population is part of the western Hudson Bay stock with 37700 to 87100 individuals (2004 survey) and has been assessed by COSEWIC as ‘Special Concern’ however it is not listed on SARA.

The eastern Hudson Bay population was reduced by approximately 50% and continues to decline. This population is considered by COSEWIC as ‘Endangered’ (2004) from their previous designation of ‘Threatened’ (1988), but is not listed on SARA. It is expected that this population could disappear in less than 10 to 15 years if appropriate mitigation measures are not implemented.

The Ungava Bay population is very small (<50 individuals) and could be extirpated, but their status is difficult to determine as other populations also utilize the area. This population was assessed as 'Endangered' by COSEWIC in 1988 and similarly reassessed in 2004; however it is not listed on SARA.

- Shifts in seabird diets indicate changing fish assemblages that are associated with changing sea ice conditions.

The diets of Thick-billed Murre nestlings at Coats and Digges Island have been monitored since the 1980s. Historically the diet at both colonies was dominated by Arctic cod, but since 1994 capelin have made up about half the diet at Coats Island, with cod falling to less than 20% after 2000 (Figure 19). The changes in diet reflect a reduction in the relative abundance of Arctic cod, likely linked to progressively earlier break-up of sea ice in Hudson Bay. The earlier break-up of sea ice has also been associated with earlier seabird breeding which demonstrates the potential cascading effects of sea ice reduction through multiple trophic levels/species.

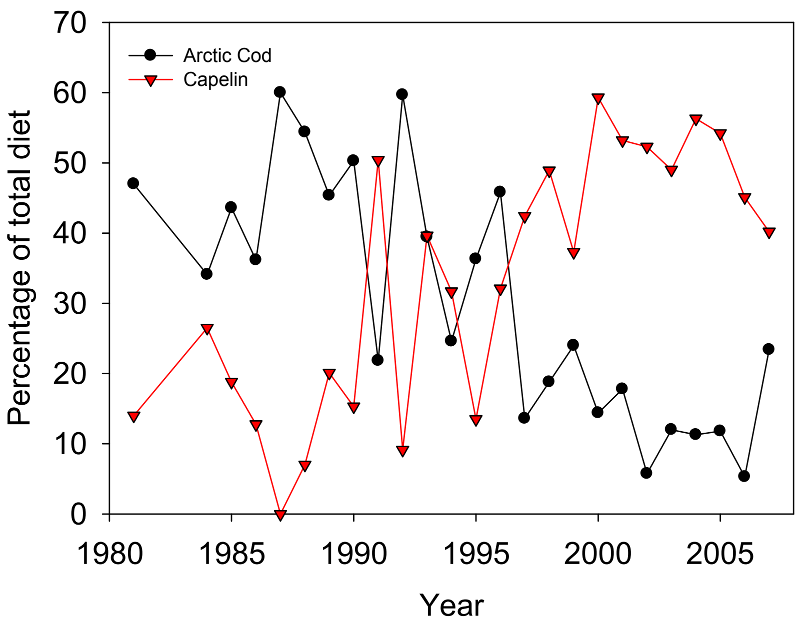

Figure 19. Proportion of Arctic cod and capelin fed to nestling Thick-billed Murres at Coats Island between 1981-2007.

Emerging Issues

- Industrial development and transportation could impact the coastal zone of this ecozone.

Knowledge Gaps

- Local and large-scale ecosystem effects of decreasing river inputs are not fully understood.
- The ecosystem effects of the introduction of a new apex predator (killer whale) are unknown.

Estuary and Gulf of Saint Lawrence

Overview

The Estuary and Gulf of Saint Lawrence (EGSL) represents one of the largest and most productive estuarine/marine ecosystems in Canada, and in the world. With a drainage basin that includes the Great Lakes, the St. Lawrence marine ecosystem receives more than half of the freshwater inputs from the Atlantic Coast of North America. This ecosystem is also strongly influenced by ocean and climate variability in the North Atlantic, of both Arctic (Labrador Current) and tropical (Gulf Stream) origin. As a result, the EGSL exhibits large spatial and temporal variations in environmental conditions and oceanographic processes. This unique setting provides the conditions for a highly diverse and productive biological community and trophic structure.

Key Findings

- The structure and food-web dynamics of fish and invertebrate communities changed dramatically in the early 1990s.

In the northern Gulf, the ecosystem structure shifted from one dominated by groundfish (e.g. cod, redfish) and small-bodied forage species (e.g. capelin, mackerel, herring, shrimp) to one dominated only by small-bodied forage species. Despite a 15-year moratorium on groundfish harvesting, the ecosystem structure has not returned to its previous state.

In the southern Gulf, large-bodied species such as Atlantic cod, White hake, and American plaice have generally declined whereas smaller-bodied taxa (e.g. sculpins, shannies) have increased in abundance. The biomass of shrimp (i.e. close to 20 species of decapod shrimp) has increased continually since the early 1980s and at an accelerated rate beginning in the early 1990s. Furthermore, the biomass of numerous other invertebrate taxa, including jellyfish, has also generally increased since the late 1980s.

The changes in community structure and food-web dynamics observed in both the northern and southern Gulf followed a period of heavy groundfish exploitation. These changes also coincided with an exceptional influx of cold water at depth starting around 1990 and continuing to the late 1990s. Although the physical parameters have returned to their previous state, the changes in upper trophic levels have persisted.

- Average sea surface temperature increased approximately 2°C between 1985 and 2008.

Using the monthly average surface air temperature as a proxy to determine trends in sea surface temperature prior to 1985, and scientific ship surveys and remote sensing technologies from 1985 to present, the data indicates that the two warmest years since 1945 have occurred in the last decade (Figure 20).

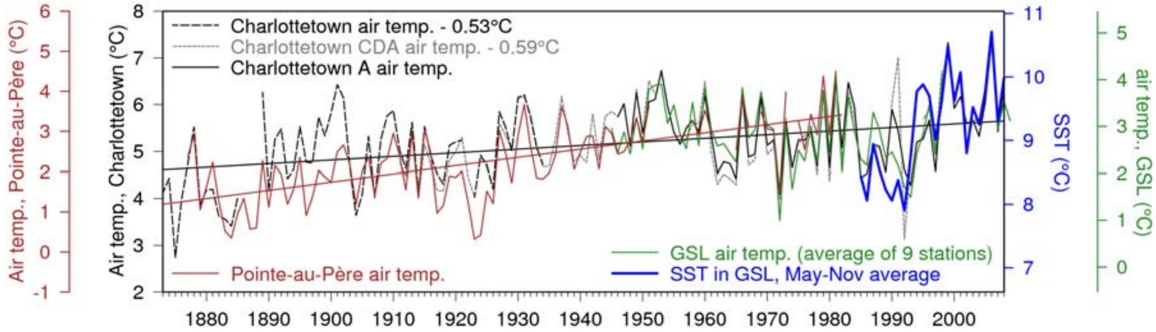

Figure 20. Sea surface and air temperature records for the Gulf of St. Lawrence. Sea surface temperature averages for the Gulf of St. Lawrence from May to November, from 1 km^2 resolution NOAA AVHRR imagery, are available since 1985 (blue line) and show a 2ºC warming trend between a cooler and a warmer period centered around 1993. The series is well correlated with the average air temperature at nine stations selected around the Gulf available since 1945 (green line), with air temperature data from Charlottetown available from three stations since 1873, and with air temperature data from Pointe-au-Père collected since 1876.

- Hypoxia (< 30% O_2) is resulting in severe physiological stress in marine organisms.

The deep waters of the Estuary were briefly hypoxic in the early 1960s and have consistently been hypoxic at < 30% saturation since 1984 (Figure 21). Reduced oxygen levels have been attributed to two primary factors: i) changes in the ocean circulation pattern of the northwest Atlantic, which is possibly linked to climate variability through the North Atlantic Oscillation, and ii) an increased flux of organic matter to the sea floor. The increased carbon flux could be ascribed to natural variability in surface productivity, but it could also be related to human activities (e.g. municipal effluent discharge, increased use and leaching of fertilizers leading to eutrophication, soil erosion, and deforestation).

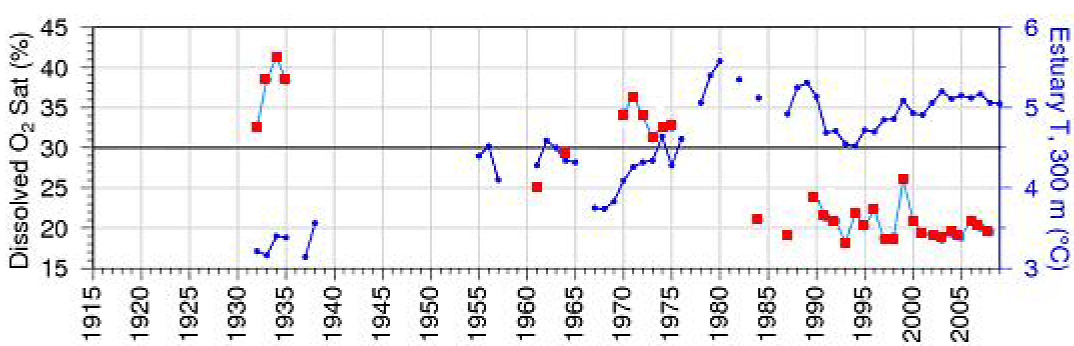

Figure 21. Dissolved oxygen saturation (red square) and temperature (blue dot) between 295 m and the bottom in the deep central basin of the St. Lawrence Estuary. The horizontal line in the oxygen panel at 30% saturation marks the threshold of hypoxic conditions.

This reduction in oxygen content is indicative of major changes in ecosystem dynamics in the Lower St. Lawrence Estuary including abundance, diversity, and activity of benthic and demersal species. By 2005, the abundance of several groups of benthic species (e.g. polychaete worms, echinoderms, and crustaceans) had declined substantially compared to the 1970s and 1980s. In addition, laboratory studies on cod demonstrated a reduction in growth, negative swimming effects, and an increased mortality at oxygen levels similar to those found in the natural environment.

- The coastal zone is deteriorating in both extent and condition owing to a wide variety of anthropogenic pressures.

The coastal zone includes a number of ecosystems of small extent that have high biodiversity value and consequently are important for wildlife and people. The cumulative effects of anthropogenic pressures are having ecological consequences which may be widespread; however their interactions and relative contributions are not well understood.

The primary human pressures in the coastal zone are: aquaculture, alien invasive species, habitat destruction/modification, the addition of nutrients and contaminants, modified freshwater inputs, shipping, and commercial fishing.

Emerging Issues

- An influx of species (e.g. macrozooplankton, Arctic hyperiid amphipods) through and from the Arctic have unknown consequences.
- Declines in primary producers and resulting changes in their community structure are an indicator of coastal eutrophication and water column stratification.
- Observed changes in macrozooplankton may impact higher trophic levels (e.g. ichthyoplankton and recruitment of fish species).

Knowledge Gaps

- The significance of changes in zooplankton is not fully understood.
- Coastal production and the overall contribution to the productivity of the ecozone require further investigation.
- The extent and significance of coastal eutrophication are unknown.

Gulf of Maine and Scotian Shelf

Overview

The Gulf of Maine and Scotian Shelf ecozone is bounded by the Hague Line to the southwest (defining the international border with the United States) and by the southern edge of the Laurentian Channel to the northeast. It includes coastal portions of Nova Scotia and New Brunswick, and extends beyond the edge of the continental shelf to the 200 nm limit of the Canadian Exclusive Economic Zone. The North Atlantic Oscillation is the dominant atmospheric pattern in the North Atlantic Ocean and a significant large-scale abiotic driver of this ecozone. The circulation patterns on the Scotian Shelf are governed largely by its complex topography and the influence of three major currents: i) the warm, salty Gulf Stream over the continental slope to the south, ii) the downstream influence of the cold Labrador Current from the north, and iii) the cool, fresh Scotian Shelf Current derived from the outflow of the Gulf of St. Lawrence.

Key Findings

- A major shift in ecosystem structure has impacted all trophic levels.

An evaluation of numerous (64) indices of species, processes, and conditions on the eastern portion of the Scotian Shelf has demonstrated that nearly all have undergone significant changes since the 1970s. The transition period most typically occurred between 1985 and 1990. The magnitude of change was rapid and was reflected in a community shift from a large-bodied, groundfish-dominated system to a pelagic (i.e. fish, seals, phytoplankton) and macroinvertebrate-dominated system. This shift was preceded by a change in environmental conditions which are reflective of what has been termed a “trophic cascade”. This trophic cascade was reflected in the concurrent increases in seals, decreases in groundfish, increases in small pelagic fish and benthic macroinvertebrates, decreases in zooplankton, and increases in phytoplankton. A moratorium on the commercial groundfish fishery was implemented in 1993, with only limited recovery of some groundfish species since that time. However, zooplankton and phytoplankton abundance are now closer to long-term averages.

- There has been a decline in the size and condition in a number of groundfish species.

There has been a reduction in the size of some groundfish species (e.g. haddock, cod, pollock, and silver hake) since the start of the time series in 1970 (Figure 22). This decrease in size has been observed both on the Eastern Scotian Shelf, where decreasing water temperature may have had an influence on growth in the late 1980s through early 1990s, but also on the Western Scotian Shelf, where temperatures remained relatively stable over this same period. A change in the average size of exploited species can be related to long-term fishing pressure if larger individuals are removed selectively from the population. The trend of reduced size on the Scotian Shelf has persisted despite the current low population levels of groundfish and low exploitation rates, suggesting that the population dynamics (or genetics) of these species has been altered.

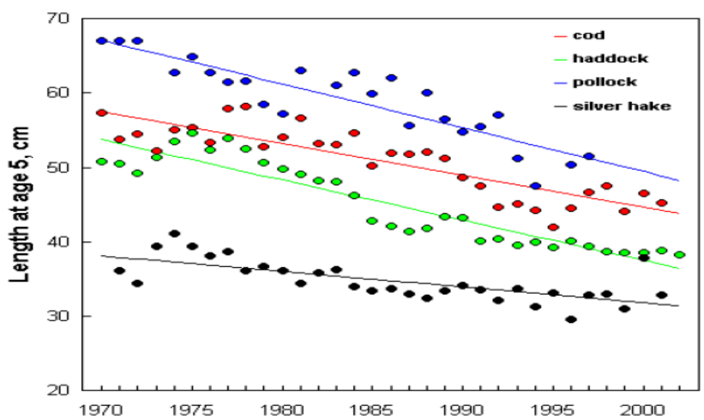

Figure 22. Length of five years of age for Atlantic cod, haddock, pollock, and silver hake. Regression lines are shown (all significant at $p < 0.01$).

There has also been an overall decrease in the condition (weight at length) of many groundfish species during the aforementioned timeframe (Figure 23), with some stabilization or increases in recent years. Condition is likely related to the availability of prey and environmental conditions; changes in the diet of some species have been noted.

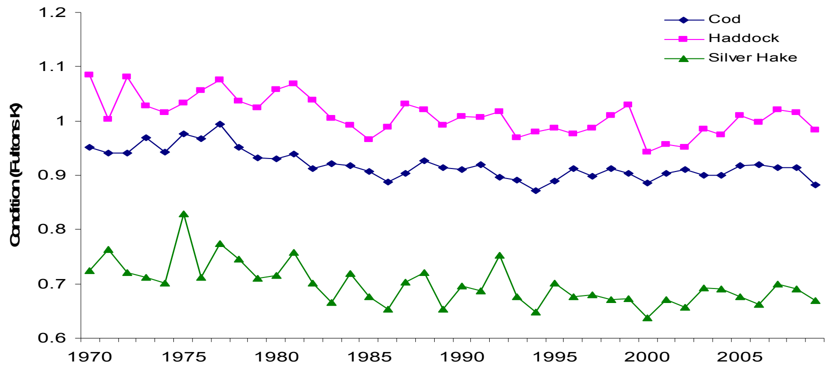

Figure 23. Condition of Atlantic cod, haddock, and silver hake on the eastern Scotian Shelf.

- After an exponential increase in grey seal abundance for the last 30-40 years, the rate of increase has slowed considerably.

Over the past 30 to 40 years, the numbers of grey seals in the Gulf of Maine and Scotian Shelf ecozone have increased dramatically. The greatest increase is associated with the Sable Island colony, the largest worldwide, near the edge of the continental shelf in the central Scotian Shelf. Population numbers of the Sable Island colony increased exponentially at an annual rate of 13% per year until the late 1990s. Since that time there is evidence of a significant slowing in the rate of increase to about 7% per year through 2007 (Figure 24). A reduction in the rate of increase in pup production coupled with an increase in the age at first birth indicates that the population is approaching resource limitation.

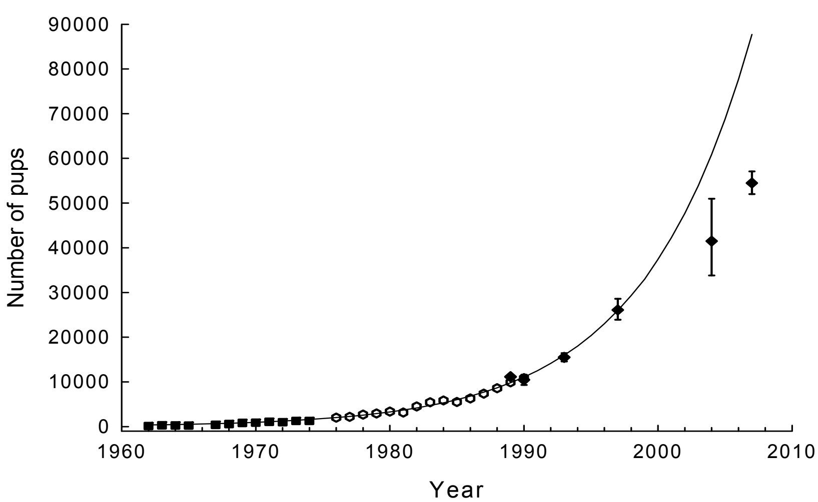

Figure 24. Observed trends (symbols) in the number of pups and exponential model estimates (solid line) of the number of grey seal pups born at the Sable Island colony between 1962 and 2007.

- The average 0 to 50 m stratification index has increased resulting in reduced nutrient and energy flow between bottom and surface waters.

Seawater density depends on temperature, salinity, and pressure, and increases with depth in the ocean. The density difference between water at two depths is referred to as the density stratification which inhibits vertical mixing and can reduce the flow of nutrients and energy between bottom and surface waters. In addition, marine stratification can influence both phytoplankton and benthic production.

On the Scotian Shelf, the average 0 to 50 m stratification index has increased since 1960 but most significantly in the 1990s. From the mid to late 1990s, the index was at or near its maximum over the 50-year record. Stratification in 2008 was the fourth strongest in 49 years. Important changes in stratification have also been noted in the eastern Gulf of Maine and Georges Bank, with increasing temperature and changes in salinity. Stratification has increased steadily from the mid-1980s on Georges Bank and in the eastern Gulf of Maine.

Emerging Issues

- Ocean acidification will affect primary productivity and higher organisms, particularly those forming calcium carbonate shells.
- Ecosystem effects resulting from reductions in the average trophic level of fisheries (i.e. "fishing down the food web").
- The potential impacts of new alien invasive species (e.g. tunicates and green crab) are displacing native species, altering community structures, and fouling fishing gear.

Knowledge Gaps

- The ecology and trends in the deepwater beyond the Scotian Shelf have not been studied in detail.
- Information on the status and trends of coastal zones is lacking.
- The status and trends of non-commercial species are largely unknown.
- The impacts of climate change are not well understood.

Newfoundland and Labrador Shelves

Overview

The Newfoundland and Labrador Shelf Ecozone (NLSE) extends off the eastern coast of Canada, and encompasses one of the largest areas of continental shelf in the world. Ranging from the northern tip of Labrador south to the Grand Banks, and bounded by the Canadian Exclusive Economic Zone, the total area of the NLSE is greater than 2.5 million km^2 and exhibits significant variation in seabed structure and habitat that is represented by extensive coastal forms, offshore banks, slopes, and canyons. In combination with influences mainly from the southerly-flowing Labrador Current, but in unison with other drivers, the waters off Newfoundland and Labrador are some of the most productive in the world. Given its temperate nature the NLSE supports an impressive diversity of marine life, including various species of coldwater corals, plankton, fish, mammals, amphibians, and seabirds.

The North Atlantic Oscillation (NAO) has been a dominant factor in recurrent atmospheric oscillations in the North Atlantic and the NLSE, and exhibits considerable variability at approximately biennial and decadal time scales. Variations in the NAO are related to many climatic, oceanographic, and ecological features in the marine ecosystems of Newfoundland and Labrador, including iceberg flows, ocean temperatures, the strength of the Labrador Current, and the distribution and biology of many species. The NAO provides a useful index of ocean conditions related to warm and cold periods in the North Atlantic and Newfoundland and Labrador waters.

The NLSE has supported various types of exploitation dating back multiple centuries, with the most notable being that of commercial fisheries. As in many other large marine ecosystems, overexploitation of fisheries has been identified as the principal source of change within the NLSE over time, although fluctuations in the ocean climate can also been implicated.

Key Findings

- Water temperature has a very important influence on the dynamics of marine organisms in this ecozone.

During the 1950s and 1960s water temperatures were above average (Figure 25). Subsequent cooling occurred during the mid-1980s that culminated in a major cold water influx in the early 1990s, resulting in large-scale ecological changes throughout this ecozone. Since the early 1990s, significant warming has occurred, resulting in a notable 61-year high in water temperature in 2006 and below average sea ice extent and duration.

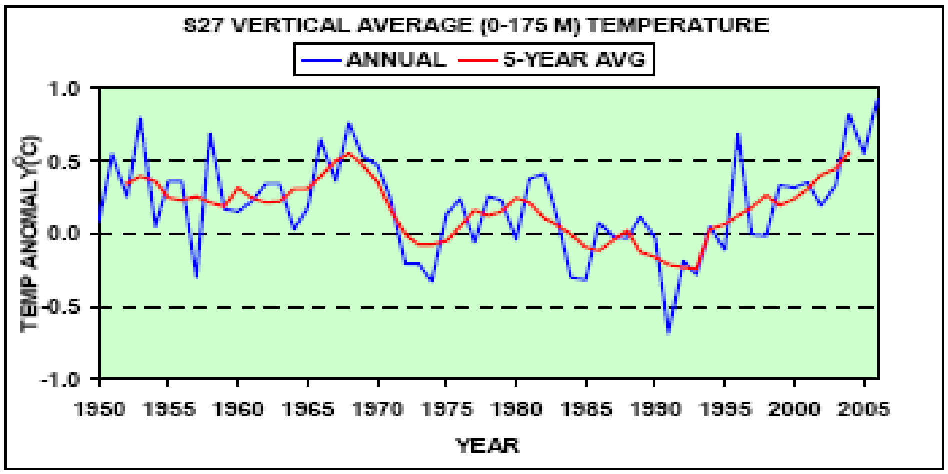

Figure 25. Time series of the vertical average temperature at Station 27, outside of St. John's.

- In the early 1990s, a major shift in species composition and community structure occurred along the entire shelf.

The changes in species composition and community structure that occurred in this ecozone during the early 1990s were characterised by a decrease in target and non-target groundfish abundance (e.g. Atlantic cod, redfish, skate) (Figure 26). In addition, a dramatic increase in the biomass of invertebrates (e.g. crab and shrimp) has occurred coupled with the loss and lack of recovery of capelin, a key forage species. Unlike changes that occurred in the adjacent Scotian Shelf ecozone, these changes were not accompanied by an observed[†] decrease in zooplankton or an increase in small forage species.

The harp seal population declined during the 1960s, reaching a minimum of less than 2 million in the early 1970s. Following the introduction of a quota system in the 1970s, the population tripled by the mid-1990s to a very high level (~ 5.5 million). Since that time, the population has continued to increase at a slower rate (likely due to large harvests in recent years) of approximately 1.5% annually up to its last assessment in 2009, where Northwest Atlantic harp seals numbers were estimated at 6.9 million (95% CI=6.0 to 7.7 million) (Figure 27).

The reasons for the aforementioned changes in community structure are still under debate, but overexploitation of groundfish, climate change (e.g. cooler water temperatures), and

[†] Revised October 2010

trophodynamics (e.g. predation release) are some of the hypotheses used to explain them. However, the scenario likely involves some combination of all these driving forces.

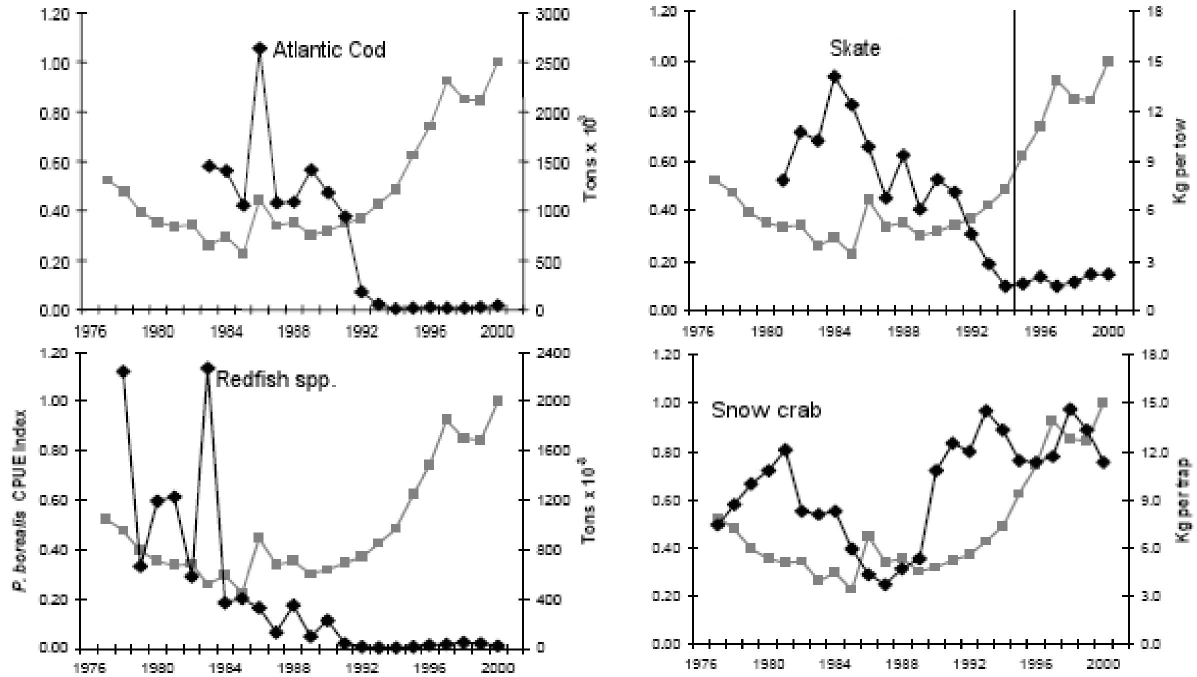

Figure 26. Population trends for northern shrimp (Pandalus borealis) and key predators off eastern Newfoundland and Labrador. The biomass series for shrimp (■, left Yaxis) is represented by the CPUE index for NAFO Division 2HJ3K. The biomass series for fish predators (♦, right Y-axis), obtained from published documents in most cases, are given as tons x 10-3 or kilograms per tow from annual research trawl surveys.

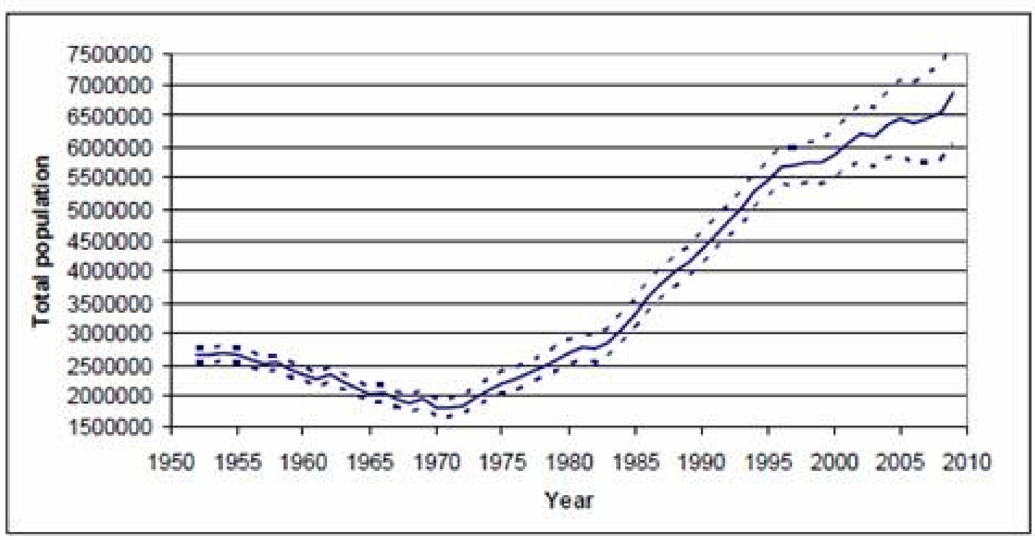

Figure 27. Estimates of the total population of northwest Atlantic harp seals for 1952-2009 (± 1SE) using the visual estimate of pup production at the Front in 2008.

- Groundfish stocks, after a prolonged period of heavy exploitation, suffered a catastrophic decline in the early 1990s.

Many historically dominant groundfish species (including those of commercial importance) have declined to a small percentage of their former levels; an example of a characteristic decline curve is shown in Figure 28. Management efforts, primarily through fisheries closures, have not resulted in significantly increased populations and the remaining individuals are often smaller at maturity. As a result of this decline, some species have reached levels that have resulted in their consideration as a 'Species At Risk' by COSEWIC.

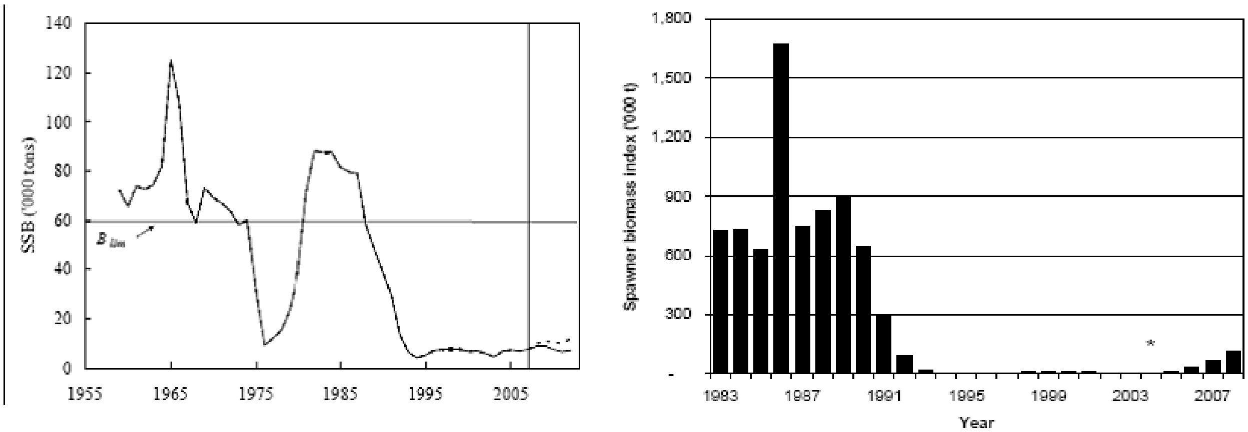

Figure 28. Trends in spawning biomass of "Grand Bank" Atlantic cod in NAFO Divs. 3NO (left; NAFO 2007) and trends in offshore spawner biomass index for Atlantic cod (NAFO Division 2J3KL) from autumn bottom trawl surveys (right). Asterisks indicate partial estimates from incomplete survey coverage in NAFO Division 3L in 2004.[‡]

- The abundance of capelin, a key forage species, was high in the 1980s, decreased dramatically in the early 1990s, and has remained low ever since.

Although there is an increasing trend in offshore capelin abundance in the most recent years (2007-08), abundance still remains considerably less than that observed pre-decline (Figure 29). This decline has not been ascribed to overexploitation but continues to reflect other trends that occurred in the early 1990s. For example, individuals continue to be smaller and changes in behaviour include later[†] spawning times and a decrease in the extent of diurnal migrations.

Emerging Issues

- The potential increase in eel grass beds could lead to improved recruitment of fish.
- The occurrence and impact of alien invasive species in selected areas of the ecozone could have ecosystem impacts.

Knowledge Gaps

- Information on the status and trends of coastal zones is lacking.
- Trophic pathways and interspecies relationships are poorly understood.
- Population dynamics and the distribution of capelin and other small pelagic species are largely unknown.

[‡] Revised October 2010

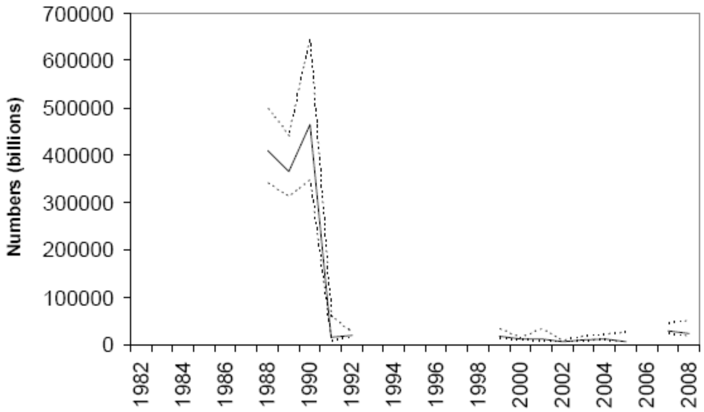

Figure 29. Simulated spring offshore abundance estimates for capelin (solid line) with 95% confidence intervals (broken lines) for an index area comparable to NAFO Division 3L on the Grand Bank of the Newfoundland-Labrador Shelves ecozone.

Recurring Themes among the Canadian Marine Ecozones

The key findings and emerging issues that have been identified for each of the Canadian marine ecozones are compiled in Table 1.

Changes in Phenology

A major ecological issue in all ecozones is the developing mismatches in seasonal cycles between predators and their resources. This appears to be an important trend in plankton, fish, birds, and marine mammals. It may be the reason for declines of some species and the failure of others to rebound from periods of overexploitation. The underlying causes are complex, likely involving poorly documented food web interactions, but ultimately depend on environmental and physiological responses to climate change.

Changes in Fish Size

Body size-at-age in many poikilotherms is often taken as an indicator of cumulative growth as well as the state of each individual relative to its conspecifics. Year-to-year variations in size-at-age can be a simple reflection of fluctuations in food availability or the energetic demands placed on a population as a result of variations in the state of the environment. These short-term changes may be of importance to the formation of particular year classes or the success of a particular fishery, but may not sufficiently persist to be a cause for concern. However, of potentially greater significance to the assessment of ecosystem status and trends are instances where there are persistent medium to long-term (i.e. five years or more) changes in size-at-age, typified by declines in the average size of individuals in the population.

Despite the apparent health of a population measured in terms of the overall abundance or biomass of a stock, such persistent changes in size-at-age may be a harbinger of declining condition, reproductive capacity, or the ability to withstand additional anthropogenic or environmental stressors. Declines in size-at-age have often been precursor indicators of impending population collapse. Persistent decreases in size-at-age can result from changes in ecosystem structure whereby prey types or abundance do not allow maximal growth rates to be achieved or, more seriously, they may reflect the cumulative effects of selective removal of fast growing individuals from the population which can lead to alterations of the genetic structure and reproductive potential of a stock. In several Pacific and Atlantic biogeographic units, this review noted long-term declines in size-at-age that may be indicators of significant changes in population productivity and resilience which should be a cause for concern and investigation.

Climate Variability and Oceanographic Changes

In any evaluation of status and trends in marine ecosystems, climate variability must be carefully considered. Climate variability occurs at a variety of time scales from inter-annual through decadal and longer. The climate "forcing" of the ocean is often described using regional or ocean-basin indices, such as the El Niño-Southern Oscillation, Pacific Decadal Oscillation, Arctic Oscillation, or North Atlantic Oscillation. Variations in climate, as shown by these indices, have been demonstrated to be correlated with changes in sea ice extent, ocean currents and water properties, primary productivity, seasonal timing of important biological events, recruitment success, growth and distribution/migration of marine species and many other properties of marine ecosystems. The presence of substantial variation on time scales of a decade and longer make it more difficult to separate long term (secular) changes/trends from decadal variation, especially when most marine ecosystem time series are relatively short (< 30 years), compared with the meteorological "forcing" time-series, which are typically a century long or longer . This problem is particularly acute for Arctic marine ecosystems, where long time series are very scarce.

Coastal Habitats

Coastal habitats, such as rocky coastlines, estuaries, salt marshes, and mud flats, are among the most biologically productive ecosystems. These ecologically important habitats are arguably also the most likely to be directly impacted by cumulative impacts of human activities. Habitats in developed areas are often subject to direct and indirect habitat modification or destruction, increased coastal erosion, sea-level rise, eutrophication, harvesting, contaminants from agriculture and other industries, alien invasive species, etc. Moreover, activity in these habitats is expected to increase in the future, likely increasing the pressure on them. Thus, these habitats are, in general, healthier in less developed coastal areas than those in more developed areas. It would appear that many such habitats are deteriorating in both extent and condition. Information on these areas and their status is needed.

Unfortunately, the available information on these habitats is in disparate sources, such as student theses, technical reports, primary publications, etc., much of which is only available if the interested person knows of the existence of the references as many such works are not indexed in searchable collective databases. Moreover, there is a paucity of structured or recurrent monitoring of these habitats and the majority of monitoring that does occur (e.g. clam surveys in intertidal locations) is targeted towards species of economic or other interest and do not include other assemblages that live in association with the target species (e.g. worms living in sediments with clams). In addition, relevant indicators have not been developed to monitor the condition of these habitats, and information on the physical condition (e.g., temperature, salinity) of coastal areas is lacking. These are important indicators of, for example, the vulnerability of different areas to invasion by exotic species, which may be modeled if information at the appropriate spatial scale was available.

Table 1. Summary of key findings and emerging issues for each of the marine ecozones. Key findings are represented by a checkmark (√) and emerging issues by an 'E'.

	PACIFIC			ARCTIC			ATLANTIC		
Key Findings & Emerging Issues	**North Coast/Hecate Strait**	**West Coast Vancouver Island**	**Strait of Georgia**	**Beaufort Sea**	**Canadian Arctic Archipelago**	**Hudson Bay, James Bay, Foxe Basin**	**Estuary and Gulf of Saint Lawrence**	**Gulf of Maine and Scotian Shelf**	**Newfoundland and Labrador Shelves**
Climate and Oceanography									
Climate Variability	√	√	√	√	√	√	√	√	√
Oceanographic Changes	√	√	√	√			√	√	√
Sea Ice Reduction				√	√	√	√		√
Ocean Acidification	E	√	E	√	E	E	√	√	E
Primary Production Changes			√	√			E		√
Hypoxia Impacts	√	√	√				√		
Freshwater Input Changes			√			√	√		
Species									
Recovery of Marine Mammals[1]	√	√	√	√	√	√	√	√	√
Seabird Declines[2]		√	√		√			√	√
Collapse of Commercial Fish Stocks	√	√	√				√	√	√
Zooplankton Declines	√	√	√				√	√	√
Forage Species Declines	√	√							
Salmon Declines	√	√	√				√	√	√
Increasing Commercial Invertebrates							√	√	√
Presence of Alien Invasive Species		√	√				√	√	√
Discovery of Corals and Sponges	√	E	√				E	√	√
Contaminants									
Declines in Legacy Contaminants	√	√	√		√		√	√	
Increases in Emerging Contaminants	E	E	E	E	E	E	E		
Increases in Mercury				√	√				
Industrial Impacts & Development									
Bottom-contact Fishing Impacts	√	√					√	√	√
Increasing Offshore Industrial Development	E			E	E	E	E		E
Developing Fisheries					√		E	E	√
Coastal Zone Cumulative Impacts									
Aquaculture	√	√	√				√	√	√
Habitat Alteration							√	√	√

	PACIFIC			ARCTIC			ATLANTIC		
Key Findings & Emerging Issues	**North Coast/Hecate Strait**	**West Coast Vancouver Island**	**Strait of Georgia**	**Beaufort Sea**	**Canadian Arctic Archipelago**	**Hudson Bay, James Bay, Foxe Basin**	**Estuary and Gulf of Saint Lawrence**	**Gulf of Maine and Scotian Shelf**	**Newfoundland and Labrador Shelves**
Biological and Ecological Effects									
Incidence of Disease in Marine Mammals				√	√	√			
Increased Natural Mortality	√	√	√				√	√	√
Changes in Fish Size		√	√				√	√	√
Change in Fish Assemblages and Community Structure			√			√	√	√	√
Biological Seasonality Changes		√	√	E	E	√	√	√	√
Species Range Expansions		√	√	E		√	√	√	

[1]Marine mammals are recovering in all ecozones. In the Pacific, most species are recovering, while only Bowhead whales are noted for each of the Arctic ecozones. In the Atlantic, pinnipeds and humpback whales are most notable.
[2]Seabirds are known to be declining in several marine ecozones: Ivory Gulls (Canadian Arctic Archipelago), Auklets (West Coast of Vancouver Island), cormorants (Strait of Georgia), and terns (Gulf of Maine and Scotian Shelf). It is suspected that seabirds are declining on the Newfoundland and Labrador Shelves, but specific species have not yet been identified.

Linkages to Terrestrial Ecozones

Human-Ecosystem Interactions

Terrestrial protected areas have increased, both in total area and representativeness since the 1960s, and the rate of creation of terrestrial protected areas has accelerated since the 1990s. However, the creation of marine protected areas (MPA) is still in its infancy with less than 1% of Canadian oceans afforded protection.

Land use patterns in the terrestrial environment, particularly from linear development associated with resource use, are fragmenting the landscape and interfering with ecosystem processes in terrestrial, coastal, and freshwater systems. Similarly, patterns of exploitation in the marine environment have altered bottom habitat and impacted ecosystems.

Invasive alien species are a significant stressor to ecosystem function, processes, and structure in terrestrial, freshwater, and marine systems – particularly those in estuarine or coastal zones.

The concentration of legacy contaminants present in wildlife in terrestrial, freshwater, and marine systems has largely improved over the past 30 years. However, the concentration of many emerging chemicals in wildlife and marine sediments is increasing.

Changes in most climatic variables over the past 50 years have had both direct and indirect impacts on biodiversity in terrestrial, freshwater, and marine systems. In some places, although the climate has changed, impacts on biodiversity have not yet been observed.

Nutrients in some freshwater and marine systems are increasing. Nutrients coupled with other factors, such as increases in water temperature and alien invasive species, are leading to depleted oxygen levels, algal blooms, and in some cases “dead zones”.

Soil erosion in terrestrial and coastal marine systems remains a serious threat to biodiversity. On average, soil loss from the combined effects of wind, water, and tillage decreased between 1981 and 2006 in agricultural systems. Trends in erosion from other land use practices, such as forestry, are not as well documented.

Ecosystem services address the benefits of ecosystem processes to humans. Evidence of deterioration in ecosystem services has been found. For example, less favourable timing and quantity of river flow is affecting aquatic species as well as humans, the availability of important country foods (e.g. fish and caribou) is declining, and decreasing salmon populations have compromised our ability to provide an adequate Pacific Aboriginal salmon fishery.

Habitat and Wildlife

Large tracts of relatively intact natural landscapes and waterscapes, where ecosystem processes are either known or presumed to be functioning, are found in many places, particularly in the north. However, there are significant areas where the fragmentation and conversion of land cover has altered the landscape and waterscapes, resulting in compromised ecosystem processes.

Many Canadian species in terrestrial, freshwater, and marine systems are migratory (i.e. spend part of their life cycle outside of Canada). The impact of habitat changes along migratory pathways is often unknown and can be an important factor in observed population changes in Canada. Globally significant migration corridors are found in many areas, crossing ecological boundaries. Some terrestrial, freshwater, and marine migration corridors may be unobstructed while others have obstructions that inhibit movement (e.g. dams, shipping lanes, areas of intensive fishing, etc.).

Many species of special economic or cultural interest are in decline or have contracting ranges. However, some species have increased to levels that exceed the carrying capacity of the environment to support them (e.g. migratory birds, salmonids, all ecotypes of caribou, some sub-populations of polar bear, certain populations of seals, and many marine fish).

Ecosystem Processes

Primary productivity (i.e. the foundation of the food chain) has increased on approximately 22% of the land area of Canada over the past 20 years. It has also increased in freshwater systems such as Lake Winnipeg and the Great Lakes, and in some marine systems.

Ecosystem processes have developed under predictable natural disturbance patterns for terrestrial and marine systems (e.g. the extent and frequency of fire, insect outbreaks, and storms) and these patterns have been changing over the past 30 years.

The amount and timing of low, high, and average annual river flows is changing across Canada, affecting the availability of water for aquatic species and the input of freshwater into marine systems.

Fundamental changes in ecological processes involving the relationship among species have been observed in many places, including changes in trophic structure, predator-prey dynamics, and population cycles. These changes have been observed in terrestrial, marine, and freshwater systems.

Science-Policy Interface

The lack of consistent biodiversity monitoring, analytical tools, information systems, and reporting makes it difficult to deliver a national-scale ecosystem assessment. While there is a wealth of descriptive information, trend information is lacking - particularly that which is appropriate to detect early-warning signals.

Surprises, non-linear responses, unexpected impacts and interactions, and an emerging understanding of ecological thresholds and tipping points, especially as they relate to climate change, have resulted in the need to develop new policy responses that address multiple factors and complex interactions.

With the notable exception of a few studies, there have been few measurements and valuation that assess trends in Ecosystem Goods and Services and their effects on human well-being.

CONCLUSIONS

The status and trends of Canadian marine ecozones are changing, and these changes are related to a wide variety of contributing factors. Climate variability and oceanographic changes are notable in most ecozones, and there are a variety of changes occurring with respect to species and/or ecosystem status, community structure, and trophodynamics. The consequences of the identified changes are often poorly understood, however change is not unexpected as these systems are rarely static.

Although information is available for many elements of the marine system, it was often minimal and not always appropriate for the determination of the status and trends of the ecosystems reviewed. Long-term studies and monitoring programmes are imperative to the success of this exercise and to similar exercises in the future.

Notwithstanding the enormity of the task of describing the biodiversity in Canada's three oceans, there are recurring and important omissions in this ecosystem status and trends report for Canadian marine ecozones. While every effort has been made to be comprehensive, relevant available information likely exists that was not included in the technical reports and consequently not considered in this science advice. For example, very little information was provided for review with respect to the diversity of the different communities and the number and types of organisms in different habitats. There is also information lacking on the greater proportion of benthic invertebrate biomass which, although of little economic importance, is likely of considerable ecological importance. Lastly, there is a near absence of information on coastal communities, especially benthic ones.

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