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- For Information

FISHERIES & OCEANS CANADA PROGRESS REPORT ON MARINE MAMMAL RESEARCH AND MANAGEMENT IN 2016

November 9, 2017

1.0 INTRODUCTION

This report provides an overview of the research activities, management programs, and catch statistics of marine mammals for Canada’s East Coast and Arctic Archipelago in 2016. Most of the research projects in this report were conducted by the Canadian Department of Fisheries and Oceans. Many research projects involved cooperation with various universities, aboriginal organizations, and/or other research groups. Canadian universities and research groups conducted a wide variety of research on marine mammals in Canada that are not included in this report.

2.0 RESEARCH

2.1 ARCTIC

2.1.1 Community-Based Monitoring Network (S. Ferguson, B. Dunn, B. Young)

The purpose of this project is to develop community-based monitoring with several Nunavut communities to collect tissue from marine mammal subsistence hunts. The focus is on walrus, ringed seals, bearded seals, harbour seals, harp seals, and beluga whales, narwhal, and bowhead whales. Biological samples and information continue to be gathered and has resulted in a long-term data set of marine mammal tissue samples and database. The frozen tissue sample collection is currently stored in -30^{o}C; however efforts are underway to transition smaller subsamples to -80^{o}C freezers. Monitoring provides trend analysis to determine how stressors such as climate warming may affect marine mammals and the Canadian Arctic communities that depend on them. The community-based monitoring network is built on existing northern expertise, provides additional training and work opportunities for Nunavummiut, and ensures a blending of scientific and traditional methods and knowledge. These partnerships are an important element in detecting changes in the ecosystem and guiding research projects specific to the needs of the local resource users. The collection network in 2016 included the following Nunavut communities: Arviat, Sanikiluaq, Pangnirtung, Pond Inlet, Naujaat, Arctic Bay, Qikiqtarjuaq, and Kugaaruk.

2.1.2 Narwhal Habitat and Movement Behaviour (S. Ferguson)

Climate change is reducing the Arctic sea ice concentration and extent and it has been thought that narwhal will be poorly able to adjust. Here, we analyzed narwhal year-round movement, and examined winter habitat selection in relation to sea ice and bathymetry. Narwhal from Admiralty Inlet and Eclipse Sound were equipped with satellite transmitters between 2009 and 2012. Narwhal conducted multiple late-summer movement patterns with three stocks overlapping, had a delayed fall migration compared to telemetry tagging studies conducted a decade earlier, and had decreased summer site fidelity. During the winter narwhal selected 1500 to 2000m depths that likely had higher prey densities, regardless of the mobile pack ice structure. They also conducted extensive movements coinciding with a delayed growth in sea ice extent. These results indicate that narwhal may be more able to adjust to habitat changes than previously believed.

2.1.3 Arctic Killer Whales (S. Ferguson, C. Matthews)

The goal of our killer whale research, which we began in 2005, is to learn more about eastern Canadian Arctic killer whale abundance (e.g. how many are there, and are they increasing in number?), distribution (e.g. what is their seasonal distribution in Nunavut waters, where do they go during winter?) and ecological impacts (what do they eat, and how much?). We study killer whale abundance and distribution using photo identification and satellite telemetry, and we study diet using chemical analyses of biopsied skin and blubber. We also use genetic analysis to determine how killer whales in Nunavut are related to each other, and to other populations in the North Atlantic.

During spring-summer 2016, three dead killer whales showed around the Belcher Islands and with the help of the Sanikiluaq Hunters and Trappers Organization we were able to get samples from all three. No focal follows were conducted in 2016 although we continued the collection of sightings from our network of Nunavut contacts. In addition to the dead killer whales we recorded 13 live sightings of killer whales including the Belcher Islands, Quebec/Nunavik, Qikiqtarjuaq, Pangnirtung, Seal River, Eclipse Sound, Admiralty Inlet, Foxe Basin, and northern Hudson Strait. We continued our focus on analysis of samples and data collected in previous years. Killer whale skin and blubber biopsies collected since 2016 have been analysed for stable isotopes, fatty acids, and contaminants, and currently manuscripts about killer whale diet and foraging ecology are in preparation. We have also analysed tracking data of simultaneously tagged killer whales, narwhals, and bowhead whales to describe killer whale impacts on prey species behavior.

2.1.4 Ringed Seal Foraging Behaviour (S. Ferguson, B. Young, D. Yurkowski)

Almost 100 ringed seals have been tagged with satellite telemetry transmitters across the Canadian Arctic. Food habits results indicate a diet shift in the 1990s of Arctic cod to capelin and sandlance in the 2000s. Assessing seasonal feeding found a pattern of open-water pelagic feeding, followed by more benthic under-ice feeding over winter, and a diverse spring feeding prior to fasting during the molt. Spring temperature and timing of ice break-up were found to have a significant influence on ringed seal foraging ecology and population abundance, likely due to environmentally driven changes to prey availability. In 2016 we initiated an aerial survey of the Eclipse Sound area in spring to count seals using visual observers, digital photographs, and infrared imagery. Continued environmental and ecological change in Hudson Bay has been shown to have important consequences to the ringed seal energy budget and hence to their reproductive success and abundance. Research continues into reproduction to assess a recent downward trend in ovulation and pregnancy rates and pups in harvest. Plans are to survey ringed seal spring abundance in Eclipse Sound and western Hudson Bay in spring 2017 as well as capture and equip seals with satellite telemetry tags in Eclipse Sound.

2.1.5 Bowhead Whale Foraging Behaviour (S. Ferguson, S. Fortune, A. Trites)

This project has delimited summer and winter range, timing of migration, habitat use and diving behaviour of Eastern Canada-West Greenland bowhead whale population. Bowhead whales were remotely tagged with long-term and short-term transmitters to detail foraging dives and seasonal movements, respectively. Results are being analyzed to understand seasonal movement, habitat use and timing of migration. Over 100 skin/blubber biopsy samples were collected in 2016 and plans are to re-analyze data to obtain an updated estimate of bowhead abundance using capture-mark-recapture genetic analysis.

This research project also examined bowhead whale diet composition across their eastern Canadian Arctic range and bowhead whale habitat use in the context of foraging ecology within Cumberland Sound. Research conducted in 2017 with further biopsy sampling and development of a photo-id catalogue.

2.1.6 Circumpolar Biodiversity Marine Program (S. Ferguson, G. Stenson)

The Arctic Marine Biodiversity Program is a circum-Arctic, long-term, integrated biodiversity monitoring plan developed by Conservation of Arctic Flora and Fauna’s (CAFF) under the Arctic Council. The objectives of the CBMP-Marine Plan are to integrate existing circumpolar monitoring datasets and models to improve the detection and understanding of changes in Arctic marine biodiversity, as well as to inform policy and management responses to these changes. Of the five Expert Networks, the Marine Mammals Experts Network (MMEN) deals with the species of Arctic marine mammals with circumpolar or nearly circumpolar distribution. As part of the State of the Arctic Marine Biodiversity Report, the MMEN outlined a number of key stressors are affecting Arctic marine mammals, including climate change, harvesting, increased shipping, and emerging industrial activities, such as hydrocarbon and mineral exploration and production. To meet these challenges, Canada as a participating country, is represented by Fisheries and Oceans Canada (DFO) with S. Ferguson and G. Stenson as the Canadian leads of the MMEN. Current research is to coordinate monitoring and conducting analyses of marine mammals in the Canadian Arctic as part of Canada's international responsibility. The MMEN work plan includes efforts to develop and coalesce databases of relevant demographic, distribution, and condition information for all populations of marine mammals. Recently, we summarized past abundance and harvest estimates to establish historic baselines and trends as a reference for future monitoring. Existing data sets have been identified, aggregated and analyzed to establish indicator baselines on abundance of marine mammals. Future efforts will focus on summarizing Canadian Arctic marine mammal body condition, health databases, and telemetry movement/distribution.

2.1.7 Beluga whale foraging ecology and stock delineation using compound specific stable isotope analysis (C. Matthews, S. Ferguson, C. Watt)

Compound specific stable isotope analysis (CSIA) of beluga tissues from several populations in the eastern Canadian Arctic has been conducted to learn more about diet differences among individuals, diet variation over time, and to develop trophic models based on results of a captive beluga diet study. Stable isotope values in teeth that showed long-term individual diet differences have been reanalysed using CSIA, which showed long-term isotopic differences most likely reflected spatial segregation. These results may have implications for stock and population assessment. A comparison of amino acid specific stable isotope values among three different beluga tissues indicated values were similar irrespective of tissue type, and that tissue selection would not impact subsequent trophic position estimates. Samples collected during a three year controlled diet study of captive beluga whales are currently being analysed using CSIA, which will allow for calibration of amino acid-specific trophic enrichment factors between beluga tissues and their prey for application to studies of wild belugas.

2.1.8 Bowhead whale reproductive histories using hormone analysis of baleen (C. Matthews, S. Ferguson, N. Lysiak, K. Hunt)

Analysis of hormone concentrations along bowhead whale baleen has been conducted to study bowhead whale reproduction, including calving interval and mating season. Baleen grows continuously and incorporates hormones in circulating blood in its structure, so incremental measurements of hormone concentrations along its length can be used to construct reproductive histories. Analysis of samples from baleen of ten female whales showed regular peaks in progesterone that are indicative of past pregnancies over the period of baleen growth, which is about 20 years. Progesterone peaks are currently being assessed against stable isotope concentrations, which peak annually, and concurrent patterns of corticosterone, a stress hormone, to determine calving interval and elevated stress associated with pregnancy. Testosterone analysis of male baleen showed annual cycles that are offset from stable isotope cycles by several months. Since the stable isotope cycles reflect differences in summer and winter foraging/habitat use, testosterone peaks annually and likely during early spring, which is consistent with what is currently known about bowhead reproduction.

2.1.9 Diet and dive behaviour of Cumberland Sound belugas (C. Watt, J. Orr, and S. Ferguson)

Relatively little is known about the foraging behaviour of Cumberland Sound beluga whales, but there has been a change in the Arctic food web in the region, involving an increased abundance of capelin. We expected this change in the food web may impact beluga foraging behaviour. We evaluated fatty acids in blubber samples collected from subsistence-hunted belugas in Cumberland Sound from the 1980s to 2010, and analyzed satellite tag information from 7 belugas tagged in 2006 to 2008 to gain a better understanding of their foraging behaviour. There was a change in the fatty acid profile of beluga blubber from the 1980s compared to the 1990s and 2000s. Specific fatty acids indicative of capelin and Arctic cod increased and decreased over time respectively, suggesting an increased consumption of capelin with a reduction in Arctic cod in summer in more recent years. Dive behaviour suggested different foraging tactics across seasons. Shallow short dives occurred in summer, which may indicate foraging on capelin, while deeper longer dives were made in autumn and winter, possibly indicating foraging on deeper prey such as Arctic cod and Greenland halibut. How this change in summer diet may be impacting the health of the population and the population dynamics of Cumberland Sound belugas is currently unknown.

2.1.10 Narwhal foraging habitat (C. Watt, J. Orr, and S. Ferguson)

Satellite tracking of 21 narwhals from the Baffin Bay and Northern Hudson Bay populations provided information on their diving behaviour and was used to identify foraging regions. To evaluate home ranges and define areas important for benthic foraging, we conducted kernel density analysis on narwhal locations and focused on areas where deep diving occurs, as a proxy for foraging, in the winter, spring, and migratory periods. Deep-diving was used as a proxy for foraging since previous research has indicated that narwhals from these two populations consume benthic prey. Home range analyses identified important areas for foraging for narwhals tagged in Eclipse Sound and from the Baffin Bay population on the summer grounds in Eclipse Sound, and the winter grounds in Davis Strait, as well as on the migratory pathway between the two regions. Foraging areas were also identified for the Northern Hudson Bay narwhals tagged in Repulse Bay and part of the Northern Hudson Bay narwhal population. In summer, foraging areas were identified in northwestern Hudson Bay in summer, in Northern Hudson Bay and Hudson Strait on the migration, and to the east of the entrance to Hudson Strait in the winter. Overall we found narwhal use a large portion of their range for foraging activities

2.2 *ATLANTIC*

2.2.1 Indices of abundance for beluga (*Delphinapterus leucas*) in James and eastern Hudson Bay in summer 2015 (Jean-François Gosselin, Mike O. Hammill and Arnaud Mosnier)

Systematic aerial line-transect surveys were conducted in James Bay and eastern Hudson Bay from 29 July to 3 September 2015. Using an a factor of 0.478 (CV = 0.16) to account for the proportion of belugas visible at the surface and adding in a count of 167 belugas observed in the Little Whale River estuary, the corrected abundance indices were 10,615 (95% CI: 6,559 - 17,178) for James Bay and 3,819 (95% CI: 1,664 - 8,765) for eastern Hudson Bay. Two groups of 68 and 177 individuals that accounted for 67% of the belugas detected during the first survey of eastern Hudson Bay illustrate how the highly clumped distribution of belugas may influence abundance indices and population trend assessments.

2.2.2 A management framework for Nunavik beluga (M.O. Hammill, G.B. Stenson and T. Doniol-Valcroze)

The co-management of wildlife resources transferred basic wildlife management responsibilities to co-management boards and restricted the veto powers of the responsible minister to overturn Board decisions. This has resulted in an apparent management paradox, since on one hand the Government's ability to limit harvesting has been restricted, while on the other hand, Canada has international responsibilities to ensure a management structure based on Maximum Sustainable Yield (MSY) and the Precautionary Approach (PA). The rights of hunters to harvest are often highlighted in discussions with hunters, but other aspects of the land claim agreements call for the development of management systems that also respects the principles of conservation and continued sustainability of the resource. Thus, it would appear that the development of a PA/ MSY based framework is consistent with the concepts and principles of recent land claim agreements implemented in Canada. Different management frameworks, some of which have been developed to manage marine mammal stocks in Canada were examined using the eastern Hudson Bay beluga as a study case. Other stocks were also examined for discussion. Criteria were developed that could be used to determine if a stock could be managed using a framework where the probability of reaching the management objective within a specified timeframe can be identified explicitly, or whether a more general approach referred to as the Potential Biological Removal (PBR) should be used to set Total Allowable Harvest levels.

2.2.3 Management Approaches, Abundance Indices and Total Allowable Harvest levels of Belugas in Hudson Bay (M.O. Hammill, A. Mosnier, J-F Gosselin, C.J.D. Matthews, M. Marcoux and S.H Ferguson)

A surplus production model that incorporated information on harvests and stock composition of the harvest was fitted to aerial survey data from eastern and western Hudson Bay belugas using Bayesian methods. For eastern Hudson Bay, the model produced an abundance estimate of 3400 animals and indicated that the population is stable. For eastern Hudson Bay, the sustainable yield, which maintains a stable population, was 68 belugas. Two Precautionary Approach frameworks were developed and allowed for harvests of 17-61 animals depending on the probability of achieving recovery to healthy levels within 50 years. For western Hudson Bay, the model indicated that the population could be stable or may be increasing depending on model assumptions related to environmental carrying capacity. It was concluded that the best estimate of abundance for this stock was that from the aerial survey flown in 2015 (N=54,500). The Potential Biological Removal method was used to estimate allowable removal levels from the western Hudson Bay stock. Depending on recovery factors applied, PBR estimates varied from 251 to 1,004 for recovery factors of 0.1 to 1. The most recent harvest data of Western Hudson Bay whales was 584 animals in 2015.

2.2.4 Diet of Grey Seals in the central Gulf of St Lawrence (M.O. Hammill)

Grey seal predation has been identified as a potential contributing factor to the high adult mortality observed in the southern Gulf of St. Lawrence (NAFO area 4T) Atlantic cod. Estimates of consumption indicate that significant amounts of 4T cod are being consumed by grey seals. Sampling continued in the Magdalen Islands area of the central Gulf of St Lawrence in 2016. Diets are dominated by sandlance and flatfish. Overall, cod accounts for about 10% of the diet in this region, with males consuming more cod than females.

2.2.5 Updated analysis of genetic mixing among beluga stocks in the Nunavik marine region and Belcher Islands area: information for population models and harvest allocation (Mosnier, M.O. Hammill, S. Turgeon and L. Postma)

Proportions of EHB belugas in the harvest were estimated through genetic analyses of samples obtained from Inuit hunters. A total of 1,685 samples collected between 1982 and 2015 (including 246 new samples) were used to update the previous results for the different management areas. The analyses indicate that the proportions of EHB beluga in the Hudson Strait harvest were 10.8% in spring and 26.1% in fall which were similar to previous estimates. The number of available samples for north-eastern Hudson Bay in spring and in Ungava Bay during the fall was insufficient for inference. In the Belcher Islands, the proportion of EHB beluga in the spring harvest (April 1- June 30) was estimated to be 1.5%. This proportion increased to 4.4% if spring was extended until July 14. In summer, the updated estimate was 25.6% (July 1 - September 30) and 0% in fall. Besides updating the estimated proportions of the different source populations occurring in the harvest, the additional samples contributed to a decrease in the uncertainty around the estimates.

2.2.6 Comparison of methods to estimate grey seal pup production at different colonies (Hammill, M.O., Dale, J., Stenson, G.B., den Heyer, C., Gosselin, J.-F., Leblanc, P., and Johnston, D. W.)

Aerial surveys were flown in January and February 2016 to estimate grey seal pup abundance on Sable Island, along coastal Nova Scotia and in the Gulf of St Lawrence (GSL). Owing to a combination of circumstances (absence of ice in the GSL) and opportunities, different platforms were used to obtain counts of pups on different island colonies. The methods included the use of visual counts, oblique photography from low altitude helicopter flights, photographs using an unmanned aerial vehicle (UAV) and a large format aerial photographic camera. Images from the large format camera were the easiest to count, but this option was the most expensive and presented logistic challenges in coordinating positioning of the aircraft within the four week optimum time for photography of the colonies in the different regions. Images from the UAV were easy to count; the UAV was easy to deploy and did not disturb animals, but flights were limited in some cases by high wind speeds. Images from oblique photographs were suitable for counting, but also provided challenges in ensuring coverage of a colony, particularly if the colony was flat and without obvious landmarks. If only a few pups were present, visual counts were suitable, but at large colonies visual counts underestimated abundance.

2.2.7 Pup Production at Scotian Shelf Grey Seal (*Halichoerus grypus*) Colonies in 2016 (C.E. den Heyer, S.L.C. Lang, W.D. Bowen, and M.O. Hammill)

Digital-photographic aerial surveys of breeding colonies on Sable Island and smaller islands along Atlantic coast of Nova Scotia were flown in January 2016 to estimate grey seal pup production. The estimated total pup production for Sable Island in 2016 was 83,600 with 95% confidence limits of 63,600 to 103,500. Pup production on Sable Island has continued to increase, but at a slower rate than it did in the late 1990s and early 2000s. Three digital-photographic aerial surveys were completed at Hay Island. The estimated number of pups born on Hay Island was 2,500 with 95% confidence limits of 1,700 to 3,200. This is similar to pup counts in 2007 (2,600) and 2010 (2,500), suggesting that this breeding colony may have reached carrying capacity. Pup production estimates on four small islands (Round, Mud, Noddy and Flat) in the vicinity of Seal Island, southwest Nova Scotia were 2,100 with 95% confidence limits of 1,800 to 2,400 pups. This was the first aerial photographic survey for these colonies. A helicopter survey of the coastline from Yarmouth to Cape Breton was used to obtain visual counts of pups born at other coastal Nova Scotian colonies. The total pups along the coast east of Halifax, not including Hay Island, has increased from 50 in 2010 to 78 in 2016. In total, 4,600 pups were produced by Coastal Nova Scotia breeding colonies, which accounts for 5.1% of the 88,200 pups born on the Scotian Shelf.

2.2.8 Growth and condition in harp seals: evidence of density dependent and density-independent influences (M.O. Hammill and C. Sauve)

Life history theory predicts that resource competition increases as a population increases, leading to changes in life history traits such as growth, survival, and reproduction. The Northwest Atlantic (NWA) harp seal population has increased from a low of 1.1 million animals in 1971 to over 7 million animals in 2014. Given this 7-fold increase in abundance, we hypothesized that density-dependent regulation might be reflected by changes in body growth. Gompertz curves fitted to size at age data for harp seals collected in the Gulf of St Lawrence over a 40 year period show a decline in female asymptotic length and mass. Body mass and condition were negatively related to reproductive rates the previous year, while a quadratic relationship (‘inverse u’) was observed between body measures and the ratio of the March:April first year ice cover, a measure of ice breakup. Condition was also negatively related to January ice cover. At high densities, reproduction is likely to be relatively more expensive for Northwest Atlantic harp seals, underlining the importance of females being able to access high energy food during the winter foraging period to build-up condition prior to pupping. A complex relationship between condition and the timing of ice-breakup likely reflects the influence of the timing of ice retreat on food resources and hence female ability to rebuild energy stores prior to moulting.

2.2.9 Biological sampling of Pinnipeds (GB Stenson, A Buren, J Lawson)

Multi-disciplinary studies on Harp and Hooded Seal population dynamics, seal-fisheries interactions, and the impact of climate change continued in 2016. The ongoing programme of collections involving sealers and DFO personnel from Newfoundland, Labrador and the Gulf of St. Lawrence continues to provide annual biological samples of seals (Harp, Hood, Ringed, Bearded, and Grey) in the region. These data facilitate the long-term monitoring of reproductive status, diets, and the growth and condition of seals during a period of significant ecological change.

2.2.10 Density dependent and density independent factors influencing harp seal reproduction (GB Stenson, A Buren)

A study on the impact of changing abundance and prey availability associated with climate change was published. While climate change has been shown to affect harp seals directly through increased mortality of young, it may also impact indirectly through changes in prey and subsequent reproductive rates. Over the past four decades, harp seals have also undergone a large change in abundance, increasing from approximately 1.5 million seals in the early 1970s to ~7.4 million seals today and, since 1987, late-term abortions have been observed. To determine the importance of biological and environmental factors influencing reproduction, pregnancy and abortion rates of harp seals were estimated from samples collected between 1954 and 2014 off Newfoundland, Canada. Since the early 1980s, late-term pregnancy rates among mature females have declined while interannual variability increased, ranging from 0.2 to 0.86. Analyses indicated that while the general decline in pregnancy was associated with increased population size, including the rate of late-term abortions captured much of the interannual variability. Changes in abortion rates were described by a model that incorporated capelin biomass and mid-winter ice cover (likely a proxy for ecosystem changes in overall prey abundance). Harp seals appear to respond to relatively small variations in environmental conditions when they are at high population levels. If the observed changes in climate continue, negative impacts on the Northwest Atlantic harp seal population will likely increase due to the predicted warming trend and associated reduction in ice cover.

2.2.11 Environmental influences on attendance and nursing patterns of harp seals (GB Stenson, A Buren)

Attendance and nursing patterns of harp seals were examined under varying environmental conditions to determine whether and how these patterns respond to changing weather conditions. The behaviour of females and pups off north- eastern Newfoundland was recorded during daylight hours. Air and water temperature, and wind speed were recorded at the beginning of each observation session. GAMM models were constructed to examine the importance of these variables in predicting attendance and nursing patterns. The best model for predicting attendance included time of day, air temperature, wind speed, and the interaction between wind and air temperature. The best model for predicting nursing included wind speed, air temperature and time of day. Females were more likely to attend their pups during the afternoon when solar radiation appeared to be high, but reduced attendance during high winds and/or low temperatures. The likelihood of attending females nursing during these poor weather conditions was greater than when conditions were better. Thus, females were less likely to be present when weather conditions were poor but when present, they were more likely to be provisioning their pups. This strategy may help these females defray the thermoregulatory demands on their limited resources while ensuring that their young attain weights that are likely to increase post-weaning survival and hence maternal fitness. It is likely that nursing and attendance patterns will change as global changes in the weather increase the frequency and severity of storms.

2.2.12 Reported harvests of harp and hooded seals (GB Stenson)

Reported Canadian commercial catches of harp and hooded seals		
Year	**Harp**	**Hood**
2003	289,512	151
2004	365,971	389
2005	329,829	28
2006	354,867	40
2007	224,745	17
2008	217,850	5
2009	76,668	10
2010	69,101	0
2011	40,393	2
2012	69,189	1
2013	90,703	0
2014	54,830	7
2015	35,304	1
2016	66,805	13

2.2.13 Abundance of cetaceans in Canadian waters (J Lawson)

In the late summer and fall of 2016, DFO undertook a large-scale aerial survey of Canadian waters from the northern tip of Labrador in the north to the U.S. border in the south. This North Atlantic International Sightings Survey (NAISS), like DFO's 2007 TNASS survey, employed three fixed-wing aircraft flying at slow speed and 183 m altitude on transect lines from the coast to beyond the shelf break. Despite being hampered by poor weather during much of the survey period, most planned transects were flown. From data gathered during the NAISS survey, DFO will produce abundance estimates and distribution maps for species including cetaceans, sea turtles, and large fish species such as basking sharks and sunfish sighted. Target species included multiple Species at Risk including the blue whale, north Atlantic right whale, fin whale, St Lawrence Estuary beluga whale, Scotian Shelf northern bottlenose whale, Sowerby's beaked whale, leatherback and loggerhead sea turtles, and basking sharks. The number of sightings were greater than during the 2007 survey. White-beaked dolphins were the most commonly-sighted cetacean species in 2016, accounting for half of the sightings and almost 80% of the total number of animals around Newfoundland and Labrador. Many cetaceans were sighted on the Grand Banks and NAFO Regulatory areas, including at the edge of the shelf breaks. Sighting density data will be compared with physical and biological features such as bathymetry, sea surface temperature, and marine productivity to determine if there are relationships that could be used later in habitat assessments (such as to support critical habitat designation), or to refine future survey designs (see below). This survey was conducted in a way that will facilitate data integration with the 2016 U.S. and European marine surveys, and provide a cross-Atlantic context to interpret results; an international workshop was held at the biennial marine mammal conference in Halifax in 2017 to discuss means of data integration.

2.2.14 The impact of noise on marine mammals (J Lawson)

The study examining the noise environment and marine mammal assemblages for candidate Valued Marine Ecosystems (VMEs) on the Grand Banks and NAFO Regulatory areas has continued, and now includes deployments on the southern Labrador Shelf. In cooperation with research partners in St. Pierre and Miquelon (France), DFO deployed AURAL autonomous acoustic recorders in multiple locations to 1) characterize the acoustic environment of several VME and/or LOMA sites, and 2) use these data to characterize ambient noise levels and identify which marine mammal species are associated with identified VMEs/LOMAs, some of which are listed under SARA. Analysis of the recordings is underway, and DFO researchers in Newfoundland and Labrador have been working with colleagues in other Atlantic Canadian DFO labs, U.S. government researchers, and a private firm (JASCO Ltd.) to coordinate acoustic collections and automate analyses. Further, an international effort with Canadian and American government, academic, and NGO researchers in underway to coordinate large-scale acoustic deployments in the western offshore and nearshore Atlantic in the next several years. There are seasonal and inter-annual variations in the species that have been detected; unusual results include detection of calling humpback whales off the coast of Labrador in the winter period, and species at risk such as blue and right whales off the southern Grand Banks of Newfoundland.

A review on the behavioural responses of wild marine mammals to noise was published in 2016. Noise has individual and population effects on marine mammals. The current North American regulation of human activities identifies received levels of sound at which individuals are predicted to display significant behavioural responses. Behavioural responses by cetaceans are bet explained by the type of sound source (i.e., continuous, sonar, or seismic/explosion), and functional hearing group (proxy for hearing capabilities, i.e., high-, mid-, and low-frequency cetaceans). The severity of the behavioural responses exhibited was not related to sound levels received by cetaceans. This indicates that monitoring and regulation of acoustic effects from anthropogenic activities on cetacean behaviour should not exclusively rely upon received level thresholds.

2.2.15 Habitat suitability modelling for cetaceans (J Lawson)

Using long-term sightings and environmental data from government, NGO, and industry sources, Species Distribution Models (SDM) were developed to predict suitable habitat for many of the cetacean species found in Atlantic Canadian waters and the NAFO Regulatory Area. For example, the most suitable habitat for blue whales was located primarily on the Scotian Shelf and along the southern Grand Banks. Highly-suitable habitat for northern bottlenose whales was identified in areas along the edge of the Scotian, and Newfoundland and Labrador Shelves, submarine canyons, and deep basins. We interpreted suitable habitat as regions where cetacean monitoring efforts should be prioritized to determine if they are important areas for these species. The SDM results and tools as presented in this study are a timely component in the process of identifying human activities that may be contributing to the lack of recovery of these whales at risk in Canadian and international waters. This approach has been extended to all marine mammal species, with the addition of seasonal analyses. In addition, the Department will generate General Additive Models using the same data as a means to assess the reliability of the MaxEnt SDM.

2.2.16 Risk Assessment Framework (J Lawson)

The abundance and distribution of marine mammal and sea turtle populations is influenced by a variety of factors, including resource availability, reproductive status, predator distribution, ice presence and structure, or more generally, mortality risks. Recently, anthropogenically-related, non-harvest removals are being considered for managed marine mammal populations worldwide; a high-profile recent example is the role of climate change as a population-level factor that might reduce carrying capacity and/or increase mortality. More "proximal" negative consequences could arise from industrial activities and associated noise, vessel strikes, or introduction of new predators or other invasive species. There is currently no internationally-accepted approach as to how impacts of marine development projects should be evaluated. DFO is continuing to develop a general assessment framework that could be used to quantify and cumulate risks of impacts on marine mammal and sea turtle populations associated with anthropogenic activities, while taking into account population conservation status and vulnerability, cumulative impacts from other stressors (such as climate change), and those associated with similar projects, expected susceptibility to stressors, and the expected efficacy of mitigation measures. This framework could be extended to encompass other types of marine species, anthropogenic activities, or stressors. DFO convened two international workshops to solicit expert assessment and garner the scientific support for the rationale behind the framework and integral thresholds, and the applicability of the framework in the legal and applied context that are typical of environmental impact assessments by developers and governmental agencies worldwide. This project has been augmented with two additional projects in which the Department is gathering and integrating information with associated spatial and temporal, such as physical, biological, and functional aspects of the Atlantic marine ecosystem. One of the projects will see these data used in a large-scale modelling process in an effort to create three-dimensional risk maps.

2.2.17 Ocean Productivity (A Buren)

A project aimed at characterizing spatial and temporal variability, long-term trends, and the influence of environmental conditions (e.g., ice cover, SST, etc.) on energy content of key forage species in the northwest Atlantic was initiated. In collaboration with University partners we are determining energy contents of important prey species through bomb calorimetry and proximal compositional analyses. This project is ongoing and will continue until March 2019.

3.0 CATCH DATA

a. Pinnipeds

	Atlantic Canada (including Quebec)	Eastern Canadian Arctic
Harp Seal	66,871	no data
Hooded Seal	13	no data
Bearded Seal	62	no data
Grey Seal	1612	no data
Harbour Seal	0	no data
Walrus	29*	368**
Ringed Seal	353	no data

b. Cetaceans

	Western Canadian Arctic	Eastern Canadian Arctic	Quebec Region
Beluga	48	384***	225
Bowhead	0	2	0
Narwhal	0	585	0

* This number does not include all of the walrus harvested in the Nunavik Marine Region
** some communities have yet to report catches
*** some communities have yet to report catches

4.0 BYCATCH DATA

There is no systematic reporting of bycatch of marine mammals for most species in Canada. Currently, there is a dedicated analysis of certain marine mammals in Newfoundland and Labrador Region.

5.0 SCIENCE ADVICE PROVIDED

Canadian Science Advisory Secretariat Reports (advice provided in 2016):

- INFORMATION IN SUPPORT OF THE IDENTIFICATION OF CRITICAL HABITAT FOR FIN WHALES (BALAENOPTERA PHYSALUS) IN CANADIAN PACIFIC WATERS
- INFORMATION IN SUPPORT OF THE IDENTIFICATION OF ADDITIONAL CRITICAL HABITAT FOR RESIDENT KILLER WHALES (ORCINUS ORCA) OFF THE WEST COAST OF CANADA
- INFORMATION RELEVANT TO THE ASSESSMENT OF BLUE WHALE CRITICAL HABITAT IN THE NORTHWEST ATLANTIC
- ASSESSING THE RISK OF LETHAL SHIP STRIKES TO HUMPBACK (MEGAPTERA NOVAEANGLIAE) AND FIN (BALAENOPTERA PHYSALUS) WHALES OFF THE WEST COAST OF VANCOUVER ISLAND, CANADA
- POPULATION ASSESSMENT PACIFIC HARBOUR SEAL (PHOCA VITULINA RICHARDSI) IN THE STRAIT OF GEORGIA
- IMPACT OF THE 2015 NARWHAL (MONODON MONOCEROS) ENTRAPMENT ON THE ECLIPSE SOUND STOCK
- POPULATION MODELLING FOR SHARED NARWHAL (MONODON MONOCEROS) STOCKS
- ESTIMATES OF ABUNDANCE AND TOTAL ALLOWABLE REMOVALS FOR ATLANTIC WALRUS (Odobenus rosmarus rosmarus) IN THE CANADIAN ARCTIC
- HARVEST ADVICE FOR EASTERN AND WESTERN HUDSON BAY BELUGA (DELPHINAPTERUS LEUCAS)
- STOCK ASSESSMENT OF CANADIAN NORTHWEST ATLANTIC GREY SEALS (HALICHOERUS GRYPUS)

6.0 PUBLICATIONS AND DOCUMENTS

Aulanier, F., Simard, Y., Roy N., Gervaise, C., and Bandet, M. 2016. Ground-truthed probabilistic shipping noise modeling and mapping: Application to blue whale habitat in the Gulf of St. Lawrence. In: Proceedings of Meeting on Acoustics 27, 07006. pp. 1-14. Fourth International Conference on the Effects of Noise on Aquatic Life, Dublin, Ireland. 10-15 July. http://dx.doi.org/10.1121/2.0000258

Aulanier, F., Simard, Y., Roy N., Gervaise, C., and Bandet, M. 2016. Spatial-temporal exposure of blue whale habitats to shipping noise in St. Lawrence system. DFO Can. Sc. Adv. Sec. Res. Doc. 2016/090. vi + 26 p. http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2016/2016_090-eng.pdf

Aulanier, F., Simard, Y., Bandet, M., Roy N., and Gervaise, C. In press. Effects of shipping on marine acoustic habitats in Canadian Arctic estimated via probabilistic modelling and mapping. Marine Pollution Bulletin

Bowen, D. 2016. *Halichoerus grypus*. The IUCN Red List of Threatened Species 2016: e.T9660A45226042. http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T9660A45226042.en

Bowen, D. 2016. *Phoca vitulina ssp. vitulina*. The IUCN Red List of Threatened Species 2016: e.T17020A66991409. http://dx.doi.org/10.2305/IUCN.UK.2016-1.RLTS.T17020A66991409.en

Breton-Honeyman, Kaitlin, C. M. Furgal and M. O. Hammill. 2016. Systematic Review and Critique of the Contributions of Traditional Ecological Knowledge of Beluga Whales in the Marine Mammal Literature. Arctic. 69:37-46

Breton-Honeyman, K., M. Hammill, C. Furgal, and B. Hickie. 2016. Inuit knowledge of beluga whale (*Delphinaterus leucas*) foraging ecology in Nunavik (Arctic Quebec), Canada. Canadian Journal of Zoology 94:713-726

Brewster, J.D, Giraldo, C., Swanson, H., Reist, J.D., Stern, G.A., Loseto, L.L. 2016. Ecological niche of coastal Beaufort Sea fishes defined by biotracers: Recommendations for a marine protected area monitoring program. Marine Ecology Progress Series, 559:159-173

Brown, TM, DCG Muir, SH Ferguson, BG Young, AT Fisk, KJ Reimer, X Wang. 2016. Mercury and cadmium in ringed seals in the Canadian Arctic: influence of location and diet. Science of the Total Environment 545–546: 503–511

Burns, L. D., S.D. Petersen and S.H. Ferguson, 2016. Exploring the use of citizen science to process aerial photographs: challenges and next steps. Can. Tech. Rep. Fish. Aquat. Sci. 3165: vi + 11 p.

Choy, E.S., Roth, J.D., Loseto, L.L. 2016. Lipid removal and acidification affect nitrogen and carbon stable isotope ratios of beluga whales and their potential prey species in the Beaufort Sea ecosystem. Marine Biology. 163: 220. doi:10.1007/s00227-016-2992-x

Doniol-Valcroze, T, MO Hammill, S Turgeon & LD Postma. 2016. Updated analysis of genetic mixing among Nunavik beluga summer stocks to inform population models and harvest allocation. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/008. iv + 13 p.

Doniol-Valcroze, T, A Mosnier & MO Hammill. 2016. Testing estimators of walrus abundance: insights from simulations of haul-out behavior. DFO Can. Sci. Advis. Sec.Res. Doc. 2016/40. v +18 p.

Galicia, M.P., Thiemann, G.W., Dyck, M.G., Ferguson, S.H. and Higdon, J.W., 2016. Dietary habits of polar bears in Foxe Basin, Canada: possible evidence of a trophic regime shift mediated by a new top predator. Ecology and Evolution, 6(16), pp.6005-6018

Gomez, C., J.W. Lawson, A.J. Wright, A.D. Buren, D. Tollit, V. Lesage. 2016. A systematic review on the behavioural responses of wild marine mammals to noise: the disparity between science and policy. Canadian Journal of Zoology, 2016, 94(12): 801-819, https://doi.org/10.1139/cjz-2016-0098

Hammill, M.O., Stenson, G.B. and Mosnier, A. 2016. Science Advice on Theoretical Harvest Reduction Scenarios and Sustainable Catches of NWA harp seals? DFO Can. Sci. Advis. Sec. Res. Doc. 2016/055. v + 32 p.

Hammill, M.O., P. Blanchfield, J.W. Higdon, D.B. Stewart, S.H Ferguson. 2016. Estimating abundance and total allowable removals for walrus in Foxe Basin. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/014. iv + 20 p.

Hammill M.O., J. Dale, G.B. Stenson, C.E. den Heyer, J-F Gosselin, and D. Johnston. 2016. Comparison of methods to estimate grey seal pup production at different colonies DFO Can. Sci. Advis. Sec. Res Doc. 2017/041. iv + 19 p.

Hammill, MO, T Doniol-Valcroze, A Mosnier & J-F Gosselin. 2016. Modelling walrus population dynamics: A direction for future assessments. DFO Can. Sci. Advis. Sec.Res. Doc. 2016/50. v +47 p

Hammill, M.O.,den Heyer, C.E., and Bowen, W.D. 2016. Grey Seal Population Trends in Canadian Waters, 1960-2016 and Harvest Advice. DFO Can. Sci. Advis. Sec. Res. Doc. 2017/052. vi + 30 p.

Hammill, M.O., Young, R.A. and Mosnier, A and 2016. Evaluating impacts of flexible quota system on walrus harvesting. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/112

Hammill, MO, A Mosnier , J-F Gosselin, JW Higdon, DB Stewart, T Doniol-Valcroze, SH Ferguson & JB Dunn. 2016. Estimating abundance and total allowable removals for walrus in the Hudson Bay-Davis Strait and south and east Hudson Bay stocks. DFO Can. Sci. Advis. Sec.Res. Doc.2016/036. v + 37p.

Hays, G. C., L. C. Ferreira, et al. 2016. Key Questions in Marine Megafauna Movement Ecology. Trends in Ecology & Evolution 31(6): 463-475, doi:10.1016/j.tree.2016.02.015

Hoover, C., Ostertag, S., Hornby, C., Parker, C., Hansen-Craik, K., Loseto, L.L, Pearce, T. 2016. The Continued Importance of the Hunting for Inuit Food Security. Solutions, 7 (4): 40-51

Hornby, C., Iacozza, J., Hoover, C., Barber, D., Loseto, L.L. 2016. Spring habitat use of beluga whales (*Delphinapterus leucas*) during arrival to the Mackenzie River Estuary. Polar Biology. DOI 10.1007/s00300-16-1899-9

Ford, John K. B., James F. Pilkington, Brian Gisborne, Timothy R. Frasier, Robin M. Abernethy and Graeme M. Ellis. 2016. Recent observations of critically endangered North Pacific right whales (*Eubalaena japonica*) off the west coast of Canada. Marine Biodiversity Records 9:50

Lavoie, D., Chassé, J., Simard, Y., Lambert, N., Galbraith, P.S., Roy, N., Brickman, D. 2016. Large-scale atmospheric and oceanic control on krill transport into the St. Lawrence estuary evidenced with 3D numerical modelling. Atmosphere-Ocean 54: 299-325. http://dx.doi.org/10.1080/07055900.2015.1082965

Lawson, J.W., and Lesage, V. 2016. Modelling ship strike risks for marine mammals and sea turtles. Department of Fisheries and Oceans. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/in press

LeBot, O., Simard, Y., Roy, N., Mars, J.I., and Gervaise, C. 2016. Whistle source levels of free-ranging beluga whales in Saguenay-St. Lawrence marine park. Journal of the Acoustical Society of America 140: EL89-EL93

Lesage, V., Gavrilchuk, K., Andrews, R.D., and Sears, R. 2016. Wintering areas, fall movements and foraging sites of blue whales satellite-tracked in the Western North Atlantic. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/078. v + 38 p.

Lesage, V., Gosselin, J.-F., Lawson, J.W., McQuinn, I., Moors-Murphy, H., Plourde, S., Sears, R., Simard, Y. 2016. Information relevant to the assessment of the critical habitat of blue whales (*Balaenoptera musculus*) in the Northwest Atlantic. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/nnn. vi + xx p.

Marcoux, M., Ferguson, S.H., Roy, N., Bédard, J., and Simard, Y. 2016. Seasonal marine mammal occurrence detected from passive acoustics in Scott Inlet, Nunavut. Polar Biology 1-12. (on line 2016-10-19) DOI 10.1007/s00300-016-2040-9

Marcoux, M., and Hammill, M.O. 2016. Model estimates of Cumberland Sound beluga (*Delphinapterus leucas*) population size and total allowable removals. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/077. iv + 35 p.

Marcoux, M., Young, B., Asselin, N.C., Watt, C.A., Dunn, J.B., and Ferguson, S.H. (2016) Estimate of Cumberland Sound beluga (*Delphinapterus leucas*) population size from the 2014 visual and photographic aerial survey. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/037. iv + 19 p.

Martinez-Levasseur, L.M., C.M. Furgal, M.O. Hammill and G. Burness. 2016. Towards a Better Understanding of the Effects of UV on Atlantic Walruses, *Odobenus rosmarus*

rosmarus: a Study Combining Histological Data with Local Ecological Knowledge. PLoS ONE 11(4): e0152122. doi:10.1371/ journal.pone.0152122

Matthews, C.J., Longstaffe, F.J. and Ferguson, S.H., 2016. Dentine oxygen isotopes (δ18O) as a proxy for odontocete distributions and movements. Ecology and Evolution, 6(14), pp.4643-4653

McQuinn, I.H., Gosselin, J.-F., Bourassa, M.-N., Mosnier, A., St-Pierre, J.-F., Plourde, S., Lesage, V., Raymond, A. 2016. The spatial association of blue whales (*Balaenoptera musculus*) with krill patches (*Thysanoessa spp*. and *Meganyctiphanes norvegica*) in the estuary and northwestern Gulf of St. Lawrence. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/104. iv + 19 p.

Moors-Murphy, H.B., Lawson, J.W., Gomez, C., Rubin, B., Marotte, E., and Renaud, G. 2016. Occurrence of blue whales (*Balaenoptera musculus*) off Nova Scotia, Newfoundland, and Labrador. DFO Canadian Science Advisory Secretariat Research Document. 2016/in press.

Mosnier, A., Larocque, R., Lebeuf, M., Gosselin, J.-F., Dubé, S., Lapointe, V., Lesage, V., Lefaivre, D., Senneville, S., Chion, C. 2016. Définition et caractérisation de l'habitat du béluga (*Delphinapterus leucas*) de l'estuaire du Saint-Laurent selon une approche écosystémique. Secr. can. de consult. sci. du MPO. Doc. de rech. 2016/052. vi + 93 p.

Nichol, L.M., Ford, J.K.B. 2016. Information in Support of the Identification of Critical Habitat for Fin Whales (*Balaenoptera physalus*) in Canadian Pacific Waters. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/nnn. vii + 35 p.

O-Corry-Crowe, G., Mahoney, A. Suydam, R. Quakenbush, L., Whiting, A., Lowry, L., Ferreira, L., Tazruk, J., Saccheus, C., Harwood, L. 2016. Genetic profiling links changing sea ice to shifting beluga whale migration patterns. Biology Letters 12: 20160404. http://rsbl.royalsocietypublishing.org

Perry, E., G.B. Stenson & A.D. Buren. 2016. Attendance and nursing patterns of harp seals in the harsh environment of the northwest Atlantic. Polar Biology. DOI: 10.1007/s00300-016-1938-6

Pleskach, K., Hoang, W., Chu, M., Haldorson, T., Loseto, L.L., Ferguson, S., Tomy G. 2016. Use of mass spectrometry to measure aspartic acid racemization for ageing beluga whales. Marine Mammal Science 32: 1370–1380

Plourde, S., Lehoux, C., McQuinn, I.H., and Lesage, V. 2016. Describing krill distribution in the western North Atlantic using statistical habitat models. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/111. v + 34 p.

Puryear, Wendy B., M. Keogh, N. Hill, J. Moxley, E. Josephson, K.R. Davis, C. Bandoro, D. Lidgard, A. Bogomolni, M. Levin, Lang S.,Hammill, M.,Bowen,W.D., Johnston, D.W., Romano, T., Waring, G. , and Runstadler. 2016. Prevalence of influenza A virus in live-captured North Atlantic gray seals: a possible wild reservoir. Emerging Microbes and Infections 5. e81; doi:10.1038/emi.2016.77

Salewski, V., and Watt, C.A. (2016) Bergmann's rule – a biophysiological rule examined in birds. Oikos. Doi: 10.1111/oik.03698

Simard, Y., Bandet, M., Gervaise, C., Roy N., and Aulanier, F. 2016. Soundscape cube: A holistic approach to explore and compare acoustic environments. In: Proceedings of Meeting on Acoustics 27(1):070012. pp. 1-8. Fourth International Conference on the Effects of Noise on Aquatic Life, Dublin, Ireland. 10-15 July. http://dx.doi.org/10.1121/2.0000319

Simard, Y., Roy N., Aulanier, F., and Giard, S. 2016. Blue whale continuous frequentation of the St. Lawrence system from multi-year PAM time series. DFO Can. Sc. Adv. Sec. Res. Doc. 2016/091. v + 14 p. http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2016/2016_091-eng.pdf

Simard, Y., Roy, N., Gervaise, C., Giard, S. 2016. A seaway acoustic observatory in action: The St. Lawrence Seaway. Chapter 128. In: Popper, A. N. and Hawkins, A. eds. The effects of noise on aquatic life II. Springer Science+Business Media, LLC, New York. Series: Advances in Experimental Medicine and Biology, Vol. 875. Chapter 128. pp. 1031-1040. (Proc. Third International Conference on The Effects of Noise on Aquatic Life, August 11-16, 2013, Budapest, Hungary.) DOI 10.1007/978-1-4939-2981-8

Simard, Y., Roy, N., Gervaise, C., Giard, S. 2016. Analysis and modeling of 255 ship source levels from an acoustic observatory along St. Lawrence Seaway. Journal of the Acoustical Society of America 140(3):2002-2018. http://dx.doi.org/10.1121/1.4962557

Stanistreet, J.E., Nowacek, D.P., Read, A.J., Baumann-Pickering, S., Moors-Murphy, H.B. and Van Parijs, S.M. 2016. Effects of duty-cycled passive acoustic recordings on detecting the presence of beaked whales in the Northwest Atlantic. Journal of Acoustical Society of America. 140: EL31, 7 pp.

Stenson, G.B., A.D. Buren and M. Koen-Alonso. 2016. The impact of changing climate and abundance on reproduction in an ice-dependent species, the Northwest Atlantic harp seal, *Pagophilus groenlandicus*. ICES. Journal of Marine Science 73:250-262

Stocki, T.J., Gamberg, M., Loseto, L., Pellerin, E., Bergman, L., Mercier, J., Genovesi, L., Cooke, M., Todd, B., Whyte, J., Wang, X. 2016. Measurements of cesium in Arctic beluga and caribou before and after the Fukushima accident of 2011. Journal of Environmental Radioactivity 2016: 162-163: 379-387

Stredulinsky EH (2016) Determinants of group splitting: an examination of environmental, demographic, genealogical and state-dependent factors of matrilineal fission in a threatened population of fish-eating killer whales (*Orcinus orca*). MSc thesis, University of Victoria.

Themelis, D., Harris, L., and Hayman, T. 2016. Preliminary analysis of human-induced injury and mortality to cetaceans in Atlantic Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2016/085. v + 15 p.

Trana, M.R., Roth, J.D., Tomy, G.T., Anderson, W.G. and Ferguson, S.H., 2016. Increased blubber cortisol in ice-entrapped beluga whales (*Delphinapterus leucas*). Polar Biology, 39(9), pp.1563-1569

Trzcinski, M. K. and W. D. Bowen 2016. The recovery of Atlantic halibut: a large, long-lived, and exploited marine predator. ICES Journal of Marine Science 73(4): 1104-1114

Ure, D.L., W.D. Bowen, and C.E. den Heyer. 2016. Grey seal population status and trends, Sable Island National Park Reserve, in State of Park Assessment Technical Report

Watt, C.A., Orr, J.R., and Ferguson, S.H. (2016) A shift in foraging behaviour of beluga whales *Delphinapterus leucas* from the threatened Cumberland Sound population may reflect a changing Arctic food web. Endangered Species Research. 31: 259-270

Westdal KH, Davies J, MacPherson A, Orr J, Ferguson SH. 2016. Behavioural changes in belugas (*Delphinapterus leucas*) during a killer whale (*Orcinus orca*) attack in southwest Hudson Bay. Canadian Field-Naturalist 130(4): 315-319

Westdal, K.H., Higdon, J.W. and Ferguson, S.H., Review of killer whale (*Orcinus orca*) ice entrapments and ice-related mortality events in the Northern Hemisphere. Polar Biology pp.1-7.

Wright BM, Stredulinsky EH, Ellis GM, and Ford JKB. 2016. Kin-directed prey sharing promotes lifetime natal philopatry of both sexes in a population of fish-eating killer whales, *Orcinus orca*. Animal Behaviour 115:81-95

Young, B.G. and Ferguson, S.H. 2016. Comparison of photographic and visual surveys of ringed seals in western Hudson Bay. Can. Tech. Rep. Fish. Aquat. Sci. 3153: iii + 11 p.

Yurkowski, D.J., Ferguson, S., Choy, E.S., Loseto, L.L., Brown, T.M., Muir, D.C., Semeniuk, C.A. and Fisk, A.T., 2016. Latitudinal variation in ecological opportunity and intraspecific competition indicates differences in niche variability and diet specialization of Arctic marine predators. Ecology and Evolution 6(6), pp.1666-1678

Yurkowski DJ, SH Ferguson, CAD Semeniuk, TM Brown, DCG Muir, AT Fisk. 2016. Spatial and temporal variation of an ice-adapted predator's feeding ecology in a changing Arctic marine ecosystem. Oecologia 180: 631–644. DOI 10.1007/s00442-015-3384-5

Yurkowski, D.J., Semeniuk, C. A. D., Harwood, LA., Asvid-Rosing, A., Dietz, R., Brown, T. M., Clackett, S. Grgicak-Mannion, A. G., Fisk, A., and Ferguson, S. H. 2016. The influence of sea ice phenology on the movement ecology of ringed seals across their latitudinal range. Marine Ecology Progress Series 562: 237-250. doi: 10.3354/meps11950