

## **Overview of Arctic research and assessment activities: cetacean-relevant updates on IPY, IPCC, ACIA, PAME, AMAP, CAFF and recent publications**

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## **Background**

In 1998, the IWC/SC identified the Arctic as an area of specific concern for cetaceans due to the unknown but anticipated effects of global warming on habitat (IWC, 1999:31-32). In response, two companion papers were prepared and presented to the Standing Working Group on Environmental Concerns (SWGEC) at the 51<sup>st</sup> IWC Scientific Committee meeting: the first paper emphasized the effects of climate change on the ecology of whales (Moore *et al.*, 1999); the second emphasized the potential effects on contaminant exposure and health (O'Hara and Rowles 1999). Upon review of these papers, the SWGEC encouraged the development of a Draft Arctic Initiative (IWC, 2000:30), resulting in the preparation of a review/recommendation document for the 52<sup>nd</sup> meeting (Moore *et al.*, 2000). At that time, it became clear that a groundswell of Arctic research was already planned or underway, as evidenced by programs such as the Arctic Climate Impact Assessment (ACIA: <http://www.acia.uaf.edu>), under the direction of the Arctic Council. Thus, it was thought the best way forward for cetacean researchers would be to join forces with large-scale programs already in place or planned for the near future. To this end, a review of relevant Arctic research activities has been provided each year to the IWC.SC SWGEC (e.g. Moore and Krahn, 2006), and this contribution represents a continuation of that series with special focus on research associated with the International Polar Year (IPY), followed by a listing of ongoing programs of potential interest to cetacean researchers planning work in the Arctic.

## **1. INTERNATIONAL POLAR YEAR (IPY)**

The IPY, officially launched in Paris, France, on 1 March 2007, is envisioned as an intense internationally coordinated campaign of research that will initiate a new era in polar science (<http://www.ipy.org>). The IPY will extend through March 2009, with projects at both poles and co-sponsorship by a Joint Committee of the International Council for Science and the World Meteorological Organization. While not a comprehensive review of extant proposed research, four (at least partially funded) projects have potential links to arctic cetaceans and are briefly summarized below.

The International Polar Year Publications Database (IPYPD) is now available online (<http://www.nisc.com/ipy>) containing bibliographic records for publications about or resulting from IPY 2007-2009 and the three previous IPYs. In addition, the US National Science Foundation (NSF) Office of Polar Programs has funded the development the Arctic Research Mapping Application (ARMAP), a new interactive website (<http://www.armap.org>) to support field-based scientific research in the Arctic.

### **1.1 Canadian Flaw Lead (CFL)**

The CFL project (Project Leaders: Dave Barber and Steve Ferguson, Canada) will over-winter an icebreaker in the flaw lead in sea ice that develops along the west coast of Banks Island, extending southeastward to the Cape Bathurst polynya and Amundsen Gulf. Marine mammal investigators (CFL: Team 5) plan to monitor the use of the flaw lead by marine mammals over winter with emphasis on predator-prey interactions between polar bears, ringed seals and bearded seals. A special component of the proposed research is an investigation into the chronology of flaw lead development during spring and the primary production cascades into the life processes of migrant marine mammals (including beluga and bowhead whales) and sea birds.

## 1.2 Global Warming and Arctic Marine Mammals (GWAMM)

The GWAMM projects (Project Leader: Steve Ferguson, Canada) focus both on the health and well-being of Northern Communities, as well as climate change impacts and adaptation in marine mammals. Its goals include: (a) assessment of the present environmental status; (b) provision of a synoptic measure of polar region marine environmental processes; (c) quantification of past and present natural environmental and social changes in the Arctic; (d) improved projections of future change; and (e) advancement of knowledge on all scales regarding links and interactions between polar regions and the rest of the globe. While the initial GWAMM proposal included work in both the Canadian High Arctic and Hudson Bay, only research in the latter region will be conducted during IPY.

## 1.3 Pan-Arctic Tracking of Belugas (PATOB)

The PATOB project (Project Leaders: Mads Peter Heide-Jorgensen of Denmark and Rod Hobbs of USA) plans to attach satellite transmitters to roughly 40-60 belugas per year over the next three years (Odling-Smee 2007). These instruments will allow a synoptic snapshot to be obtained of the pattern and timing of beluga movements in relation to sea ice, surface temperature, primary productivity, bathymetry, as well as temperature and salinity at depth through beluga dive profiles. This baseline will provide invaluable information for comparisons through time as the Arctic undergoes climate change. Belugas will be tagged across their range in Svalbard, Russia, Alaska, Canada and Greenland. The study will take advantage of past success in satellite tagging of belugas and will train local people and young scientists in fieldwork, data analysis and educational outreach. Tissue samples, measurements and other data will be collected from each tagged beluga to aid auxiliary studies. A real-time web-based display of beluga movements is planned as a window for the public to view this research program in (near) real time.

## 1.4 Russian-American Long-term Census of the Arctic (RUSALCA)

A 2003 Memorandum of Understanding for World Ocean and Polar Regions Studies between NOAA (USA) and the Russian Academy of Sciences formed the foundation of the first RUSALCA expedition to the Bering and Chukchi Seas in 2004. Building on this effort, a second RUSALCA expedition is planned for 2008 as part of IPY and will include collaborations with Japanese, Chinese and Korean scientists. As during the 2004 cruise, RUSALCA 2008 will focus on the Chukchi and Beaufort waters that join the Western USA (Alaska) and Eastern Russian Arctic. In addition, if funded via Office of Naval Research (ONR), Dr. K. Sekiguchi will lead a cetacean sighting survey in 2007-08 as part of the oceanographic and marine biology research undertaken from the T/S *Oshoro Maru* in the Bering and Chukchi Seas.

## 1.5 Trans North Atlantic Sightings Survey (TNASS)

The multi-national TNASS has been accepted as a component of the Ecosystem Studies of Subarctic and Arctic Regions (ESSAR) project for the International Polar Year. The survey will generate summer distribution and abundance estimates of cetacean populations in the Northern North Atlantic from visual survey data collected during summer 2007. It will become part of a long-term series of international North Atlantic Sightings Surveys (NASS) that have been conducted in 1987, 1989, 1995 and 2001 (see for example IWC 1989, NAMMCO 1998, 2003). The TNASS will cover areas to the west of Greenland and the north eastern coast of Canada that have not been covered in earlier surveys, providing a full trans-Atlantic coverage for the first time. The TNASS will cover the main areas of summer distribution for the main target species – minke, fin, humpback, blue, and pilot whales and harbour porpoises. The TNASS will be using standard shipboard (visual and passive acoustic) and aerial survey techniques. Survey methods will incorporate the latest methodological developments and will be standardised among all platforms and participating countries. Participating countries in TNASS are Iceland, Faroe Islands, Canada, Russia, Greenland, and Norway. In addition surveys conducted off Western Europe (CODA) the east coast of USA and in the central North Atlantic will be co-ordinated with TNASS.

## 2.0 ONGOING PROGRAMS

### 2.1 International Panel on Climate Change (IPCC): 4<sup>th</sup> Assessment

IPCC (<http://www.ipcc.ch>) was formed in 1988 to assess the scientific, technical and socio-economic information relevant for understanding the risk of human-induced climate change. The IPCC 4th Assessment Report, issued in Paris on 1 February 2007, describes progress in understanding of human and

natural drivers of climate change, observed changes and climate processes. The 4<sup>th</sup> assessment builds upon past IPCC assessments and incorporates new findings from the past six years of research. In sum, the report states that it is highly likely (90% confidence) that humans are implicated in increasing global temperatures beyond the previous range of natural variability and that regional differences in such factors as reduction of sea ice, warmer temperatures and changes in precipitation are anticipated in the Arctic.

## 2.2 Arctic Climate Impact Assessment (ACIA)

ACIA (<http://www.acia.uaf.edu/>) was an international project of the Arctic Council<sup>1</sup> and the International Arctic Science Committee (IASC), a non-governmental organization focused on facilitation of arctic research. The ACIA synthesized information on climate variability, climate change and increased ultraviolet radiation. The loss of sea ice documented and projected in the ACIA reports have become the focus of scientific investigations regarding the potential for transition of the Arctic marine environment to a different climate state (e.g., Lindsay and Zhang 2005; Overpeck et al. 2005). While loss of sea ice habitat has immediate negative effects on ice-obligate marine mammals (i.e., polar bear, walrus and ice seals), impacts to arctic cetaceans are less certain (Laidre et al., in review; Moore and Huntington, in review). The ACIA (2004) provides a science foundation that has launched reviews on topics, such as shipping in the Arctic (see PAME), focused research questions to be addressed during the IPY and guided development within the framework of the second International Conference on Arctic Research Planning (ICARPII).

## 2.3 Protection of the Arctic Marine Environment (PAME)

PAME (<http://www.pame/is>) is a working group of the Arctic Council, with the overarching goal of developing measures related to the protection of the arctic marine environment through coordinated action programs that complement existing international legal arrangements. The PAME working group has undertaken an Arctic Marine Shipping Assessment (AMSA) in response to **ACIA Key Finding #6: *Reduced sea ice is very likely to increase marine transport and access to resources.*** The AMSA will be conducted 2005-2008, will consider the circumpolar Arctic and is a direct follow-up to the Arctic Marine Strategic Plan (AMSP), as summarized in the Arctic Marine Transport Workshop Report (Brigham and Ellis, 2004). The AMSA follows the ACIA's projection of increased Arctic sea route access (Fig. 1). Specifically the ACIA sea ice projections for the Russian Northern Sea Route suggest an increasing length of the navigation season. Existing and future arctic shipping activity includes a broad range of vessels (e.g. tankers, bulk carriers, container ships, tug-barge combinations, fishing vessels, passenger ferries, cruise ships, research vessels, icebreakers and offshore supply vessels). Anticipated impacts to cetaceans include: (1) increased potential for collision injury or mortality and (2) elevated underwater noise levels concomitant with vessel traffic (Greene and Moore 1995; Hildebrand 2005). Further, increases in shipping and offshore development activities may disrupt subsistence hunting by arctic inhabitants either by direct interference or through displacement of wildlife.

## 2.4 Integrated Oceans Management (IOM): Project on Implementation of Integrated, Ecosystems-based Oceans Management in the Arctic

Arctic communities and settlements are largely based on the use of natural resources. Traditionally these activities focused on renewable resources, including hunting, fishing and reindeer herding. However, focus on non-renewable resources is growing in the Arctic. Specifically, both onshore and offshore petroleum developments are expanding to new areas of the Arctic. The aggregate effects of multiple uses of the oceans – hunting, fishing, transportation, petroleum development, pollution, etc. – call for an integrated approach to oceans management (IOM). The need for integrated oceans management, based on an ecosystem approach, is now widely recognized by the international community. This is reflected in calls for the implementation of the ecosystem approach by 2010 in the 2002 Johannesburg Plan of Implementation from WSSD as well as in recommendations from the UN General Assembly. In the Arctic context, the 2004 Arctic Marine Strategic Plan points to challenges and opportunities in this regard, and the working map of the 17 Arctic Large Marine Ecosystems (LMEs) presents a basis for this work.

On the basis of the mandate given at the Salekhard ministerial in 2006, Norway initiated a project on integrated oceans management (IOM). The project will be a joint effort between two working groups of the

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<sup>1</sup> The Arctic Council is a high-level intergovernmental forum, consisting of member nations: Canada, Denmark, Finland, Iceland, Norway, the Russian Federation, Sweden and the United States of America.

Arctic Council, the Sustainable Development Working Group (SDWG) and PAME. The project will build upon existing Arctic Council work, adopted strategies and programs. A planning meeting providing input to this proposal was held in Tromsø 20-21 February 2007.

## **2.5 Arctic Monitoring and Assessment Program (AMAP)**

The AMAP (<http://www.amap.no/>) is another working group of the Arctic Council with current objectives of providing information on threats to the arctic environment and of supporting arctic governments in taking remedial and preventive actions relating to contaminants. The AMAP persistent organic pollutant (POPs) Expert Group met in Burlington, Ontario, Canada in March 2006 to plan future work that would contribute effectively to assessments of POPs in the Arctic and would also support the needs of global agreements (e.g., the Stockholm Convention) for information from the Arctic region. The Expert Group decided to focus its work over the next few years on evaluating data and writing review articles about emerging contaminants-of-concern (e.g., brominated flame retardants and perfluorinated chemicals used as stain-resistant coatings) that have been rapidly increasing in arctic biota, including cetaceans. Further increases to the already high POPs burden in many arctic cetacean species may have adverse health implications. In addition, AMAP issued a report late in 2006 '*AMAP assessment 2006: acidifying pollutants, Arctic haze and acidification in the Arctic*' wherein emission of sulfur dioxide (SO<sub>2</sub>) was reported to have dropped about 21% between 1992 and 2003, but that emissions of nitrogen oxides (NO<sub>x</sub>) are increasing. Most airborne pollution in the Arctic comes from lower latitude industrial sources in Europe, North America and Southeast Asia and from smelters on Russia's Kola Peninsula and in Siberia.

## **2.6 Program for the Conservation of Arctic Flora and Fauna (CAFF)**

CAFF was established to address the special needs of arctic species and their habitats in the rapidly developing Arctic region (<http://www.caff.is>). The CAFF's main goals are (1) to conserve arctic flora and fauna, their diversity and their habitats; (2) to protect the arctic ecosystem from threats; (3) to seek to develop improved conservation management, laws, regulations and practices for the Arctic; (4) to collaborate for more effective research, sustainable utilization and conservation; and (5) to integrate arctic interests into global conservation fora. The CAFF is currently spearheading the Circumpolar Biodiversity Monitoring Project, which is meant to coordinate existing and new arctic biodiversity monitoring programs.

## **2.7 Arctic Oceans Science Board (AOSB)**

AOSB (<http://www.aosb.org>) is a non-governmental body established in May 1984 to coordinate the priorities and programs of countries and institutions engaged in research in the Arctic Ocean and adjacent seas. The long-term mission of the AOSB is to facilitate Arctic Ocean research by support of multi-national and multidisciplinary natural science and engineering programs. Members are from research and government institutions in Canada, China, Denmark, Finland, France, Germany, Iceland, Japan, Korea, the Netherlands, Norway, Poland, Russia, Sweden, Switzerland, the United Kingdom and the United States of America.

## **2.8 National Snow and Ice Data Center (NSIDC)**

Established by NOAA as a national information and referral center in support of polar and cryospheric research, the NSIDC (<http://www.nsidc.colorado.edu>) is part of the University of Colorado Cooperative Institute for Research in Environmental Sciences and is affiliated with NOAA's National Geophysical Data Center through a cooperative agreement. NSIDC serves as one of eight Distributed Active Archive Centers funded by the National Aeronautics and Space Administration (NASA) to archive and distribute data from NASA's past and current satellites and field measurement programs. NSIDC also supports the NSF through the Arctic System Science Data Coordination Center and the Antarctic Glaciological Data Center.

## **2.9 Alaska Ocean Observing System (AOOS)**

AOOS (<http://www.aos.org>) provides a centralized location for information products from sources such as NOAA weather buoys, processed satellite imagery (sea surface temperature and ocean color), high frequency radar (geographically comprehensive surface current data) and data about fish, birds and marine mammals and the environmental effects of human activities and natural ocean variability.

## **2.10 North Slope Borough (NSB), Department of Wildlife Management**

NSB (<http://www.north-slope.org>) encompasses 89,000 square miles of Arctic territory in Alaska, bordered by the foothills of the Brooks Range to the south and the Arctic Ocean to the north. The Department of Wildlife Management is responsible for helping to assure participation by borough residents in the management of wildlife resources, to keep these resources at healthy population levels and to assure that residents can continue their subsistence harvest of wildlife resources.

### 2.11 Cooperative Institute for Arctic Research (CIFAR)

CIFAR (<http://www.cifar.uaf.edu>) was established to foster collaboration between NOAA, the University of Alaska and others doing research in the Western Arctic (Alaska and the Bering, Chukchi and Beaufort Seas). CIFAR's major goals are to: (1) facilitate the establishment of joint research projects between NOAA and the University of Alaska; and (2) encourage, facilitate and promote research among all organizations and programs active in the Western Arctic. CIFAR was instrumental in proposal review and research organization for the RUSALCA/IPY project.

### 2.12 Arctic Research Consortium of the United States (ARCUS)

ARCUS (<http://www.arcus.org>) helps identify and coordinate the distributed human and facilities resources of the arctic research community. ARCUS is a non-profit corporation consisting of institutions organized and operated for educational, professional or scientific purposes. ARCUS objectives are to: (1) serve as a forum for planning, facilitating, coordinating and implementing disciplinary and interdisciplinary studies of the Arctic; (2) synthesize and disseminate scientific information relevant to state, national and international programs of arctic research; and (3) encourage and facilitate the education of scientists and the public in the needs and opportunities of research in the Arctic. This web site offers a calendar of events and meetings, a comprehensive list of arctic researchers and links to educational programs investigating arctic cultures and science.

## 3. RECENT PUBLICATIONS

The papers listed in this section represent a sampling of recent publications pertaining to cetacean habitat and health. The lists are not comprehensive, but represent recent papers known to the e-mail group.

### 3.1 Environment and Sea Ice

Belikov, S.E. 2006. Territorial protection of marine mammals and the polar bear (*Ursus maritimus*) in the Russian Arctic. pp. 60-64 in Belkovich (ed.) Marine Mammals of the Holarctic, Collection of Scientific papers, from the Fourth International Conference, 10-14 September 2006, Saint Petersburg, Russia.

Comiso, J.C. 2006. Abrupt decline in the Arctic winter sea ice cover. *Geophysical Research Letters* 33, L18504: 5 pages.

Grebmeier, J.M., J.E. Overland, S.E. Moore, E.V. Farley, E.C. Carmack, L.W. Cooper, K.E. Frey, J.H. Helle, F.A. McLoughlin and S.L. McNutt. 2006. A major ecosystem shift in the northern Bering Sea. *Science* 311: 1461-1464.

Leaper, R., Cooke, J., Trathan, P., Reid, K., Rowntree, V. and Payne, R. 2006. Global climate drives southern right whale (*Eubalaena australis*) population dynamics. *Biology Letters* 2(2):289-92.

Huntington, H.P. and S.E. Moore. In press. Assessing the impacts of climate change on Arctic marine mammals: Introduction to the **Special Issue of Ecological Applications**.

Laidre, K.L., I. Stirling, L.F. Lowry, O.Wiig, M.P. Heide-Jorgensen and S.H. Ferguson. In press. Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change. *Ecological Applications*: xx-xx.

Moore, S.E. and H.P. Huntington. In press. Arctic marine mammals and climate change: impacts and resilience. *Ecological Applications*: xx-xx

Moore, S.E. and K.L. Laidre. 2006. Trends in sea ice cover within habitats used by bowhead whales in the western Arctic. *Ecological Applications* 16(4): 932-944.

Odling-Smee, L. 2007. Polar research: polar year projects. *Nature* 446: 127-131.

Stoll, H.M. 2006. The Arctic tells its story. *Nature* 441: 579-581.

### 3.2 Cetacean Health and Body Condition

- Andersen, M., Gwynn, J.P., Dowdall, M., Kovacs, K.M. and Lydersen, C. 2006. Radiocaesium ((CS)-C-137) in marine mammals from Svalbard, the Barents Sea and the North Greenland sea. *Sci. Total Environ.* 363(1-3):87-94.
- Andersen, G., Foreld, S., Skaare, J.U., Jenssen, B.M., Lydersen, C. and Kovacs, K.M. 2006. Levels of toxaphene congeners in white whales (*Delphinapterus leucas*) from Svalbard, Norway. *Sci. Total Environ.* 357(1-3):128-37.
- Beineke, A., Siebert, U., Muller, G. and Baumgartner, W. 2007. Increased blood interleukin-10 mRNA levels in diseased free-ranging harbor porpoises (*Phocoena phocoena*). *Vet. Immunol. Immunopathol.* 115(1-2):100-6.
- Bradley, M.J., S.J. Kutz, E. Jenkin, T.M. O'Hara. 2005. The Potential Impact of Climate Change on Infectious Diseases of Arctic Fauna. *Int J Circumpolar Health* 2005; 64(5): 468-478
- Braune, B.M., Outridge, P.M., Fisk, A.T., Muir, D.C.G., Helm, P.A., Hobbs, K., Hoekstra, P.F., Kuzyk, Z.A., Kwan, M., Letcher, R.J., Lockhart, W.L., Norstrom, R.J., Stern, G.A. and Stirling, I. 2005. Persistent organic pollutants and mercury in marine biota of the Canadian Arctic: An overview of spatial and temporal trends. *Sci. Total Environ.* 351:4-56.
- Dehn, L.-A., Follmann, E.H., Rosa, C., Duffy, L.K., Thomas, D.L., Bratton, G.R., Taylor, R.J. and O'Hara, T.M. 2006. Stable isotope and trace element status of subsistence-hunted bowhead and beluga whales in Alaska and gray whales in Chukotka. *Mar. Pollut. Bull.* 52(3):301-19.
- Dehn, L.A., Follmann, E.H., Thomas, D.L., Sheffield, G.G., Rosa, C., Duffy, L.K. and O'Hara, T.M. 2006. Trophic relationships in an Arctic food web and implications for trace metal transfer. *Sci. Total Environ.* 362(1-3):103-23.
- Deutch, B., Pedersen, H.S., Asmund, G. and Hansen, J.C. 2007. Contaminants, diet, plasma fatty acids and smoking in Greenland 1999-2005. *Sci. Total Environ.* 372(2-3):486-96.
- de Wit, C.A., Alae, M. and Muir, D.C.G. 2006. Levels and trends of brominated flame retardants in the Arctic. *Chemosphere*: in press.
- Herman, D.P., Burrows, D.G., Wade, P.R., Durban, J.W., LeDuc, R.G., Matkin, C.O. and Krahn, M.M. 2005. Feeding ecology of eastern North Pacific killer whales from fatty acid, stable isotope, and organochlorine analyses of blubber biopsies. *Mar. Ecol. Prog. Ser.* 302:275-91.
- Hoekstra, P.F., O'Hara, T.M., Backus, S.M., Hanns, C. and Muir, D.C.G. 2005. Concentrations of persistent organochlorine contaminants in bowhead whale tissues and other biota from northern Alaska: Implications for human exposure from a subsistence diet. *Environmental Research* 98(3):329-40.
- Hughes-Hanks, J. M., L. G. Rickard, C. Panuska, J. R. Saucier, T. M. O'Hara, L. Dehn, and R. M. Rolland. 2005. Prevalence of *Cryptosporidium* spp. and *Giardia* spp. in Five Marine Mammal Species. *J. of Parasitology*: 1225-1228
- Krahn, M.M., Herman, D.P., Matkin, C.O., Durban, J.W., Barrett-Lennard, L., Burrows, D.G., Dahlheim, M.E., Black, N., LeDuc, R.G. and Wade, P.R. 2007. Use of chemical tracers in assessing the diet and foraging regions of eastern North Pacific killer whales. *Mar. Environ. Res.* 63:91-114.
- McKinney, M.A., de Guise, S., Martineau, D., Beland, P., Arukwe, A. and Letcher, R.J. 2006. Biotransformation of polybrominated diphenyl ethers and polychlorinated biphenyls in beluga whale (*Delphinapterus leucas*) and rat mammalian model using an in vitro hepatic microsomal assay. *Aquatic Toxicology* 77(1):87-97.
- McKinney, M.A., De Guise, S., Martineau, D., Beland, P., Lebeuf, M. and Letcher, R.J. 2006. Organohalogen contaminants and metabolites in beluga whale (*Delphinapterus leucas*) liver from two Canadian populations. *Environ. Toxicol. Chem.* 25(5):1246-57.



O'Hara, T. M., C. Hanns, V. M. Woshner, J. Zeh, G. Bratton and in press. Essential and non-essential elements of the subsistence hunted bowhead whale: Epidermis-based predictions of blubber, kidney, liver and muscle tissue concentrations. *J. of Cetacean Research and Management*

Reynolds, J., D. Wetzel, and T. O'Hara. 2006. "Human health implications of omega-3 and omega-6 fatty acids in bowhead whale (*Balaena mysticetus*) blubber." *Arctic* Vol. 59, No. 2: 155-164

Rosa, C., T.M. O'Hara, P. Hoekstra, K. Refsal J.E. Blake. 2007. Serum thyroid hormone concentrations and thyroid histomorphology as biomarkers in bowhead whales (*Balaena mysticetus*). *Canadian Journal of Zoology* (accepted)

Tryland, M., Thoresen, S.I., Kovacs, K.M. and Lydersen, C. 2006. Serum chemistry of free-ranging white whales (*Delphinapterus leucas*) in Svalbard. *Veterinary Clinical Pathology* 35(2):199-203.

Wilson, J.Y., Cooke, S.R., Moore, M.J., Martineau, D., Mikaelian, I., Metner, D.A., Lockhart, W.L. and Stegeman, J.J. 2005. Systemic effects of arctic pollutants in beluga whales indicated by CYP1A1 expression. *Environ. Health Perspect.* 113(11):1594-9.

#### 4.0 LITERATURE CITED

ACIA. 2004. Impacts of a warming arctic: Arctic Climate Impact Assessment, Cambridge University Press, Cambridge UK.

Brigham, L. and B. Ellis (eds.). 2004. Arctic marine transport workshop. Report of the workshop held at Scott Polar Research Institute, 28-30 September 2004.

Greene, C.R. and S.E. Moore. 1995. Man-made noise. pp. 101-158 in *Marine Mammals and Noise*, W.J. Richardson, C.R. Greene, Jr., C.I. Malme and D.H. Thomson (eds). Academic Press, San Diego, CA.

Hildebrand, J.A. 2005. Impacts of anthropogenic sound. pp. 101-124 in *Marine Mammal Research: Conservation beyond Crisis*, J.E. Reynolds III, W.F. Perrin, R.R. Reeves, S. Montgomery and T.J. Ragen (eds.). The Johns Hopkins University Press, Baltimore MD.

International Whaling Commission [IWC] 1989. North Atlantic Sightings Survey 1987. A compilation of publications in *Rep. Int. Whal. Commn* 39: 395-455.

International Whaling Commission. 1999. Annual Report of the International Whaling Commission, 1998. 94pp.

International Whaling Commission. 2000. Annual Report of the International Whaling Commission, 1999. 103pp

Laidre, K.L., I. Stirling, L.F. Lowry, O. Wiig, M.P. Heide-Jorgensen and S.H. Ferguson. In press. Quantifying the sensitivity of arctic marine mammals to climate-induced habitat change. *Ecological Applications*, Special Volume on Marine Mammals and Climate Change.

Moore, S.E. and M. M. Krahn. 2006. Overview of Arctic research and assessment of activities: cetacean-relevant updates on ACIA, PAME, AMAP, IPY, ICARPII and recent publications. SC/58/E7, 7 pp.

Moore, S.E., D.P. DeMaster and C.T. Tynan. 1999. Effects of global climate change on the ecology of whales in the Arctic. SC/51/E9, 12 pp.

Moore, S.E., T. Rowles, S. Belikov, D. DeMaster, T. O'Hara, L. Rojas-Bracho, J. Urban, H. Perez-Cortes, C. Tynan and E. Born. 2000. Arctic Initiative: Potential effects of climate change on Arctic cetaceans. SC/52/E2, 8 pp.

NAMMCO [North Atlantic Marine Mammal Commission] 1998. Report of the NAMMCO Scientific Committee Working Group on abundance estimates. *NAMMCO Annual Report 1997*: 173-202.

NAMMCO [North Atlantic Marine Mammal Commission] 2003. Report of the NAMMCO Scientific Committee Working Group on abundance estimates. *NAMMCO Annual Report 2002*: 227-258.

O'Hara, T. and T. Rowles 1999. A proposed initiative for assessment of Arctic cetacean contamination for the International Whaling Commission (IWC) Standing Working Group on Environmental Concerns (SWGEC). SC/51/E10, 13pp.

Overpeck J. [18 co-authors]. 2005. Arctic system on trajectory to new, seasonally ice-free state. *EOS Transactions American Geophysical Union* 86 (309): 312-313.



**Figure 1. Projections of sea ice reductions and associated shipping routes (from ACIA, 2004).**

