



Liberty and Northstar Petroleum Development Areas Beaufort Sea, Alaska

Literature Summary

December 1999 – April 2003

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1.0 Introduction

This report, prepared for the U.S. Department of the Interior, Minerals Management Service (MMS), Anchorage, Alaska as part of the MMS program "Arctic Nearshore Impact Monitoring In the Development Area (ANIMIDA)", presents summary abstracts of recently published journal articles and gray literature reports of non-MMS studies of the coastal environment in the vicinity of the Northstar oil production unit and Liberty prospect, Beaufort Sea, Alaska (Figure 1-1). Literature associated with the North Slope Beaufort Sea shelf that is relevant to Northstar and Liberty project marine environmental concerns is included, as well as, publications from other Arctic regions that address general topics of local interest (e.g. whale behavior and migration, impacts of underwater noise).

The literature summary includes publication dates ranging from December 1999 through April 2003, and is presented as Pro-Cite 5[®] abstracts. Topics covered in the current review include the shoreline, wetlands under marine influence, and the offshore shelf environment. Coastal terrestrial subjects are not addressed in this review. Papers that include both marine and terrestrial topics are reviewed and abstracts are presented for the portion of the publication that includes marine topics.

A review of previous literature was submitted in this format to MMS (Anchorage) by Arthur D. Little, Inc. (ADL, 2000), in which publications through November 1999 were reviewed and Pro-Cite 4[®] abstracts provided. Additionally, the Final Environmental Impact Statements (EIS) for the Northstar Project (USAEDA, 1999), Liberty Development Project (MMS, 2002), and the Beaufort Sea Planning Area (MMS, 2003) provide comprehensive reviews of the human environmental issues (e.g., sociological, cultural, subsistence, aesthetic), the physical, chemical, and biological environments, site-specific conditions, development alternatives, and potential development impacts.

Pro-Cite 5[®] abstracts of reviewed literature from December 1999 through April 2003 are provided in Section 2.0. Abstracts include the references cited, author(s), a keyword index, and a summary of the reviewed literature. References cited exclusive of the literature abstracts are presented in Section 3.0.

2.0 Procite Abstracts

Agena, W.F.; Lee, L.W., and Hart, P.E. 2000. Reprocessing of Multi-channel Seismic Reflection Data Collected in the Beaufort Sea. U.S. Geological Survey Open File Report 00-460. 6 pp.

Keywords: Beaufort Sea/ Alaska/ seismic-reflection data/ SEG-Y format/ navigational data/ SEG-P1 format/ PlotSeis files

Abstract: Contained on a set of two CD-ROMs are stacked and migrated multi-channel seismic-reflection data for 65 lines recorded in the Beaufort Sea by the United States Geological Survey (USGS) in 1977. All data were reprocessed by the USGS using updated processing methods resulting in improved interpretability. Each of the two CD-ROMs contains the following files: 1) 65 files containing the digital seismic data in standard, SEG-Y format; 2) 1 file containing navigation data for the 65 lines in standard SEG-P1 format; 3) an ASCII text file with cross-reference information for relating the sequential trace numbers on each line to cdp numbers and shotpoint numbers; 4) 2 small-scale graphic images (stacked and migrated) of a segment of line 722 in Adobe Acrobat (R) PDF format; 5) a graphic image of the location map, generated from the navigation file; 6) PlotSeis, an MS-DOS application that allows PC users to interactively view the SEG-Y files; 7) a PlotSeis documentation file; and 8) an explanation of the processing used to create the final seismic sections.

Amstrup, S. C., Durner, G. M., McDonald, T. L., Mulcahy, D. M., and Garner, G. W. 2001. Comparing Movement Patterns of Satellite-Tagged Male and Female Polar Bears. Canadian Journal of Zoology. Dec; 79(12).

Keywords: *Ursus maritimus*/ polar bears/ Beaufort Sea/ black bears/ population

Abstract: Satellite radiotelemetry has provided great insights into the movements and behaviors of polar bears (*Ursus maritimus*). The diameter of the neck of adult male polar bears exceeds that of their head, however, and radio collars slip off. This has limited collection of movement information to that from radio-collared females. To overcome this difficulty and gather information about their movements, we surgically implanted satellite radio transmitters into 7 male polar bears during 1996 and 1997. We compared movements of implanted males with those of 104 adult females radio-collared between 1985 and 1995. Transmitters were implanted under the skin on the midline of the top of the neck and were equipped with percutaneous antennae. Implanted transmitters operated for up to 161 days providing 3217 satellite relocations. While transmitting, radios implanted in males provided a larger proportion of the highest quality category of position fixes than was obtained from radio-collared females. However, all implanted radios ceased transmitting before reaching their projected life-span. The abrupt termination of transmission from implanted radios suggested mechanical rather than electronic failure. Mean rates of short-term movement for males (1.18 km/h) were lower than for solitary females, females with cubs, and females with yearlings (1.70, 1.84, and 1.95 km/h, respectively). Net geographic movements from the beginning to the end of each month were comparable for males (mean = 135 km) and females (mean = 114, 152, and 168 km). Mean

azimuths of these net movements also appeared to be similar. Monthly activity-area sizes for males (mean = 8541 km²) were comparable to those for females (mean = 3698, 9397, and 10 585 km²) during the time period of comparison. In contrast to the other movement measures, males traveled longer mean distances (387 km) each month than did females (217, 289, and 302 km). Movements of males, it appears, were more directed than those of females, but males confined their travels to similar-sized areas.

Amstrup, S. C.; Durner, G. M.; Stirling, I.; Lunn, N. N., and Messier, F. 2000. Movements and Distribution of Polar Bears in the Beaufort Sea. *Canadian Journal of Zoology*. Jun; 78(6).

Keywords: Western Hudson-Bay/ home-range size/ *Ursus maritimus*/ polar bears/ independence/ patterns/ ecology/ mark/ Beaufort Sea

Abstract: We fitted 173 satellite radio collars (platform transmitter terminals) to 121 adult female polar bears in the Beaufort Sea and relocated the bears 44 736 times between 1985 and 1995. We regularly resighted many instrumented bears so that we could ascertain whether changes in movements or distribution were related to reproductive status. Mean short-term movement rates were less than 2 km/h for all classes of bears. Maximum movement rates occurred in winter and early summer. In the southern Beaufort Sea (SBS), net geographic movements from the beginning to the end of each month were smaller for females with cubs of the year than for solitary females, and larger in November than in April, May, or July. In May, June, July, and August, radio-collared bears in the SBS moved north. They moved south in October. In the northern Beaufort Sea (NBS), bears moved north in June and south in March and September. Total annual movements ranged from 1406 to 6203 km. Mean total distances moved each month ranged from 79 to 420 km. Total monthly movements by SBS bears were largest in early winter and smallest in early spring. In the NBS, movements were largest in summer and smallest in winter. In the SBS, females with cubs moved less each month than other females. Annual activity areas ranged from 7264 to 596 800 km². Monthly activity areas ranged from 88 to 9760 km². Seasonal fidelity to activity areas of bears captured in all parts of the Beaufort Sea was strongest in summer and weakest in spring.

Amstrup, S. C.; McDonald, T. L., and Stirling, I. 2001. Polar Bears in the Beaufort Sea: a 30-Year Mark-Recapture Case History. *Journal of Agricultural Biological and Environmental Statistics*. Jun; 6(2).

Keywords: capture-recapture/ covariates/ logistic modeling/ population estimation/ Alaska/ *Ursus maritimus*/ polar bears/ Beaufort Sea

Abstract: Knowledge of population size and trend is necessary to manage anthropogenic risks to polar bears (*Ursus maritimus*). Despite capturing over 1,025 females between 1967 and 1998, previously calculated estimates of the size of the southern Beaufort Sea (SBS) population have been unreliable. We improved estimates of numbers of polar bears by modeling heterogeneity in capture probability with covariates. Important covariates referred to the year of the study, age of the bear, capture effort, and geographic location. Our choice of best approximating model was

based on the inverse relationship between variance in parameter estimates and likelihood of the fit and suggested a growth from similar to 500 to over 1,000 females during this study. The mean coefficient of variation on estimates for the last decade of the study was 0.16- the smallest yet derived. A similar model selection approach is recommended for other projects where a best model is not identified by likelihood criteria alone.

Amstrup, S. C.; Weston-York, G.; McDonald, T. L.; Nielson, R., and Simac, K. 2003. Detecting denning polar bears with Forward Looking Infra-red Imagery (FLIR). Mar.

Keywords: polar bear/ *Ursus maritimus*/ Beaufort Sea/ maternal den/ forward-looking infrared/ FLIR/ Alaska

Abstract: Polar bears give birth in snow dens in mid winter, and remain in dens until early spring. Survival and development of neonates is dependent on the stable environment within the maternal den. Petroleum related activities currently span approximately 200 km of the Alaska Beaufort Sea coastal area. New and proposed developments are expected to dramatically expand the area influenced by petroleum activities. These activities are a potential threat to polar bears, especially as they might disturb denning females. In order to help manage and mitigate potential disruptions of polar bear denning, we tested whether we could detect heat, rising through the roofs of maternal dens, with forward-looking infrared (FLIR) viewing devices. We tested our ability to detect dens by flying transects, over areas where radio-collared females were known to be denning, with FLIR equipped aircraft. We recorded flight and weather conditions at each observation and tallied whether or not the den was detected. Eight previously unknown dens were discovered during searches for 15 dens of radio-collared bears. We surveyed these 23 dens on 67 occasions (1 to 7 times each). Nine dens were always detected and 10 dens visited more than once were detected on some flights but not on others. Four dens were never detected (17%), but 3 of those were visited only under marginal conditions. Models of how detection probability varied with environmental conditions revealed the odds of detecting a den increased 3 fold for every one degree (C) increase in temperature-dew-point spread. The odds of detection were 4.8X higher when airborne moisture (snow, blowing snow, fog, etc.) was absent than when it was present, and they were approximately 28X higher at night than after sunrise. Data suggested some dens never will be detectable with LFIR. Conversely, FLIR surveys conducted during conditions that maximize odds of detection could approach detection rates of 90%, and can be an important management/mitigation tool.

Angliss, R. P. and Lodge, K. L. 2002. Alaska Marine Mammal Stock Assessments, 2002. NOAA Technical Memorandum NMFS-AFSC-133. Alaska Marine Science Center. Seattle Washington.

Keywords: Beaufort Sea/ North Slope/ Alaska/ marine mammals/ pinnipeds/ cetaceans/ Marine Mammal Protection Act (MMPA)/ Public Law 103-238/ incidental take/ commercial fisheries/ native subsistence harvest/ stock assessment/ population estimate/ potential biological removal (PBR)/ beluga whale/ *Delphinapterus leucas*

Abstract: This report provides population information on stocks of seven species of pinnipeds and 15 species of cetacean marine mammal Alaska under the jurisdiction of the National Marine Fisheries Service. Stock assessment reports for polar bears, pacific walrus, and sea otters, published by the U.S Fish and Wildlife Service, are included as an appendix to the report. Public Law 103-238, enacted in April 1994, changed provisions within the Marine Mammal Protection Act, whereupon interactions between commercial fisheries and marine mammals (including incidental takes) are addressed under three new provisions requiring a regional scientific review group to advise and report on the status of marine mammals in Alaska waters. This new law replaced the interim exemption that had regulated fisheries-related incidental takes since 1988. Stock assessments are provided for the beluga whale (*Delphinapterus leucas*), the bowhead whale (*Balaena mysticetus*), and the polar bear (*Ursus maritimus*). The beluga whale occurs in both nearshore and offshore waters of the North Slope environment in the Beaufort Sea. The minimum population size estimate for the Beaufort Sea stock is 39,258 and the stock is considered to be stable or increasing. The potential biological removal (PBR) rate is estimated to be 649 animals per year. No reports of mortality incidental to commercial fisheries have been reported in recent years. The average annual take for Alaska and Canadian native subsistence harvest averaged 177 animals per year during the 5 year period from 1996-2000. The bowhead whales occur in the Western Arctic. Bowhead whales of the Western Arctic Stock migrate annually from wintering areas in the northern Bering Sea, through the Chukchi Sea in the spring, to the Beaufort Sea for the summer, and then returning to the Bering Sea in the fall. The minimum population size estimate for the Western Arctic stock is 7,738 and is considered to be increasing at approximately 3% per year. The potential biological removal (PBR) rate is estimated to be 77 animals per year. The average annual take for Alaska and Canadian native subsistence harvest averaged 52 animals per year during the 5 year period from 1996-2000. A stock of polar bears occur in the Southern Beaufort Sea with a eastern boundary south of Banks Island and east of the Baillie Islands, Canada and a western boundary near Point Hope. The minimum population size estimate for the Southern Beaufort Sea polar bear stock is 1,973 and the stock is considered to be stable with little or no growth. The potential biological removal (PBR) rate is estimated to be 88 animals per year when adjusted for to account for male harvest bias. The average annual take for Alaska and Canadian native subsistence harvest averaged 52 animals per year during the 5 year period from 1995-2000.

Arctic Research Office (NOAA). 2000. Study of Environmental Arctic Change (SEARCH). Report of the Interagency Working Group for SEARCH, *To:* Interagency Arctic Research Policy Committee. June 30. 27 pp.

Keywords: Arctic/ Arctic oscillation/ Study of Environmental Arctic Change (SEARCH)/ greenhouse gases

Abstract: A complex suite of significant atmospheric, oceanic, and terrestrial changes has occurred in the Arctic in the last decades, affecting virtually every part of the Arctic environment. Evidence indicates that many of these changes are strongly connected with the Arctic Oscillation (AO), which is apparently a natural mode of atmospheric variation that is potentially active over a broad range of time scales, including perhaps climatic time scales. There is evidence that the AO itself may be strengthened by the anthropogenic rise in greenhouse

gases. Other potential modes of large-scale human influence on the Arctic include long-range transport of contaminants and high rates of biomass removal from the marine environment. The Study of Environmental Arctic Change (SEARCH) is a broad, interdisciplinary, multi-scale program with a core aim of understanding the complex of recent and ongoing intertwined changes in the Arctic environment. SEARCH includes four major types of activities: 1) a long-term observational program to accurately track environmental changes; 2) a modeling program to test ideas about the coupling between the different environmental components, and to predict their future course; 3) studies to test hypotheses about critical feedback processes; and 4) an assessment component to understand the ultimate impact of the physical changes on the ecosystems and societies, and to distinguish between climate-related changes and other factors such as resource utilization, pollution, economic development, and population growth.

Attanasi, E. D. and Schuenemeyer, J. H. 2002. Frontier Areas and Resource Assessment: The Case of the 1002 Area of the Alaska North Slope.

Keywords: Arctic National Wildlife Refuge/ petroleum supply/ Area 1002

Abstract: The U.S. Geological Survey's 1998 assessment of the 1002 Area of the Arctic National Wildlife Refuge significantly revised previous estimates of the area's petroleum supply potential. The mean (or expected) value of technically recoverable undiscovered oil for the Study Area (Federal 1002 Area, adjacent State waters, and Native Lands) is estimated at 10.4 billion barrels of oil (BBO) and for the Federal 1002 Area the mean is 7.7 BBO. Accumulation sizes containing the oil are expected to be sufficiently large to be of economic interest. At a market price of \$21 per barrel, 6 BBO of oil in the Study area is expected to be economic. The Assessment's methodology, results, and the reasons for the significant change in assessments are reviewed. In the concluding section, policy issues raised by the assessment are discussed.

Audubon Alaska. 2001. Migratory Birds and Oil Development in the Coastal Plain of the Arctic National Wildlife Refuge. Audubon Alaska Background Analysis. National Audubon Society, Anchorage, AK. 7 pp.

Keywords: Arctic National Wildlife Refuge/ ANWR/ birds/ oil development/ oil pollution/ Long-tailed duck/ wetlands/ Common Eider/ Spectacled Eider/ Red-throated Loon/ American/ Golden Plover/ Buff-breasted Sandpiper

Abstract: Concern is expressed for potential negative impacts of North Slope oil and gas development upon the 135 species of birds that make use of the coastal habitat within the Arctic National Wildlife Refuge (ANWR). Long-tailed ducks (formerly Oldsquaw) gather in coastal lagoons and nearshore waters in mid-summer following the breeding season, at which time they molt, are flightless and are vulnerable to oil pollution impinging on coastal lagoons and nearshore waters, with the possibility of harm at the population level. Common Eiders and Red-throated Loons are also vulnerable, are experiencing regional population declines, and are on the Audubon Alaska "Watch List." The producing oils at Prudhoe Bay and associated sites are spread over an area exceeding 1,000 square miles. Habitat losses in this area have altered the

distributions of several bird species, including nesting shorebirds such as Dunlin and Stilt Sandpipers. In general, concern is greatest for species that are large (e.g., Tundra Swans and loons), declining (e.g., Dunlins), or uncommon (e.g., Spectacled Eiders, American Golden Plover, and Buff-breasted Sandpiper).

The greatest risk to birds associated with ANWR is a spill reaching coastal lagoons or nearshore waters, possibly as a result of supply barge accidents or rupture of a pipeline crossing the rivers that empties into the Beaufort Sea. At risk would be tens of thousands of Long-tailed ducks, other waterfowl, loons, and Red-necked Phalaropes. Thousands of shorebirds gathering along shorelines, in river deltas, and in coastal wetlands would also be highly vulnerable.

Becker, P. R. 2000. Concentration of Chlorinated Hydrocarbons and Heavy Metals in Alaska Arctic Marine Mammals. *Marine Pollution Bulletin*. Oct; 40(10).

Keywords: Alaska-Arctic/ cetaceans/ marine mammals/ chlorinated hydrocarbons/ chlorinated pesticides/ heavy metals/ pinnipeds/ polychlorinated biphenyls/ whales/ *Delphinapterus leucas*/ seals/ *Callorhinus ursinus*/ Lawrence Beluga whales/ organochlorine contaminants/ environmental contaminants/ trace-metals/ harbor seals/ west-coast/ tissues/ elements

Abstract: Over the last decade, a baseline database on anthropogenic contaminants in Alaska marine mammals has been developing through the efforts of several independent investigations as well as larger research programs, although still somewhat limited in scope, the largest amount of data exists for polychlorinated biphenyls (PCBs), DDT, mercury, and cadmium in walrus, beluga whale, bowhead whale, and ringed seal. Because of their relatively large contribution to the total chlorinated hydrocarbon levels in Arctic species, chlordane and toxaphene are two pesticides that are also gaining attention. Comparison of the Alaska database with the results of studies conducted in Canada and Greenland indicates that patterns of many accumulative substances are quite similar in species that occur across the North American Arctic.

Belicka, L.; Harvey, H.R.; Yunker, M.B., and MacDonald, R.W. 2001. Molecular Biomarkers as Tracers of the Fate of Primary Production in the Western Arctic Ocean.

Keywords: Beaufort Sea/ Chukchi Sea/Arctic Ocean/biomarkers/primary production/alkanes/ alcohols/fatty acids/sterols

Abstract: The Arctic Ocean, with a great proportion of shelf area, represents a complex system with multiple inputs of organic carbon from primary production, rivers, ice, and anthropogenic activity. Organic biomarkers are useful in differentiating these sources and in understanding carbon processing in the marine realm. Biomarkers associated with primary production from the marine water column were analyzed from surface sediments of the marine-dominated Chukchi Sea and from the Beaufort Sea, which receives greater amounts of terrestrial material through rivers and ice transport. Biomarkers analyzed included alkanes, alcohols, fatty acids, and sterols. Biomarker concentrations in general were higher from the Chukchi Sea, supporting the presence

of relatively greater terrestrial inputs to the Beaufort Sea and marine production dominance in the Chukchi Sea.

Belicka, L. L.; MacDonald, R. W., and Harvey, H. R. 2002. Sources and Transport of Organic Carbon to Shelf, Slope, and Basin Surface Sediments of the Arctic Ocean. Deep-Sea Research Part I-Oceanographic Research Papers. Aug; 49(8).

Keywords: lipids/ biomarkers/ fatty acids/ sterols/ sediments/ Chukchi Sea/ Beaufort Sea/ Arctic Ocean/ Antarctic/ sea-ice/ fatty-acid/ lipid-composition/ Laptev Sea/ *Phaeocystis pouchetii*/ sequential treatments/ diatom communities/ Beaufort Shelf/ matter sources/ spring bloom

Abstract: Lipids in surface sediment transects across the Arctic Ocean were identified to define the sources of organic carbon and the transport of material in the ocean basin. Sterols representing diatoms (24-methylcholesta-5,24(28)-dien-3beta-ol, 24-methylcholesta-5,22-dien-3beta-ol) and dinoflagellates (4alpha,23,24-trimethylcholest-22-en-3beta-ol) together with algal polyunsaturated fatty acids (20:5, 22:6) demonstrated the importance of primary production to organic matter inputs on the Chukchi Shelf. The presence of terrestrial biomarkers including long-chain n-alkanes and mono- and dicarboxylic acids in shelf sediments indicated that while the fraction of terrestrial biomarkers was small compared to marine material, the transport of allochthonous material impacts carbon cycling on the shelf. Algal biomarkers were found in all surficial sediments from the central Arctic basins, demonstrating that some fraction of primary production reached bottom sediments despite ice cover and light limitation. Marine markers represented a small fraction of the total lipids in central basin sediments. This implies that the basins are less productive than shallow waters, significant degradation occurs before the organic matter reaches the sediment-water interface, and substantial amounts of vascular plant material are exported to the central Arctic. Circulation and topographical features, such as the Transpolar Drift and the Lomonosov Ridge, appear to have an important influence on the transport and focusing of terrestrial material in the Arctic Ocean basins.

Bird, K. J. and Houseknecht, D. W. 2002. U.S. Geological Survey 2002 Petroleum Resource Assessment of the National Petroleum Reserve in Alaska (NPRA).

Keywords: National Petroleum Reserve/ petroleum resources/ natural gas/ Alaska

Abstract: A new USGS assessment concludes that NPRA holds significantly greater petroleum resources than previously estimated. Technically recoverable, undiscovered oil beneath the Federal part of NPRA likely ranges between 5.9 and 13.2 billion barrels, with a mean (expected) value of 9.3 billion barrels. An estimated 1.3 to 5.6 billion barrels of those technically recoverable oil resources is economically recoverable at market prices of \$22 to \$30 per barrel. Technically recoverable, undiscovered non-associated natural gas for the same area likely ranges between 39.1 and 83.2 trillion cubic feet, with a mean (expected) value of 59.7 trillion cubic feet. The economic viability of this gas will depend on the availability of a natural-gas pipeline for transport to market.

BP Exploration (Alaska) Inc. 2000. Black Brant (*Branta bernicula nigricans*). Tech. Brief: Alaska's Northslope Oilfields. 4 pp.

Keywords: North Slope/ Alaska/ petroleum/ oilfields/ barrier islands/ Colville River Delta/ Black Brant/ *Branta bernicula nigricans*/ distribution/ abundance/ productivity/ habitat loss/ habitat alteration/ nesting success/ predation

Abstract: Several hundred to more than a thousand black brant (*Branta bernicula nigricans*) annually nest in the North Slope oilfield region of Alaska between the Colville and Saganavirktok river deltas. With development of the petroleum industry, wildlife managers have expressed concern for potential impacts upon brant from 1) loss of nesting or brood-rearing habitat through the construction of oilfield facilities and roads; 2) displacement of brant from preferred habitats in response to disturbance from human activities; 3) increased predation from elevated predator populations; and 4) potential mortality from an oil spill. Overall, habitat loss or alteration and human-generated disturbances from oilfield development on the North Slope have not had detectable impacts upon distribution, abundance, or productivity of black brant. However, increased predator populations may be having an impact upon nesting success. Although brant goslings on the North Slope have been reported to grow at significantly greater rates than those in the Yukon-Kuskokwim Delta due to a greater abundance of vegetation, nest success is chronically low in the oilfield regions.

BP Exploration (Alaska) Inc. 2001. Boulder Patch Kelp Community. Tech. Brief: Alaska's Northslope Oilfields. 4 pp.

Keywords: Alaska/ Beaufort Sea/ Steffanson Sound/ North Slope/ Endicott development/ Boulder Patch/ kelp/ *Laminaria solidungula*/ petroleum exploration/ drilling fluids/ NPDES permit/ environmental impacts/ biological community

Abstract: In the early 1970s anomalous seafloor sites were discovered in Steffanson Sound, Beaufort Sea, Alaska. Characterized by dense rock cover, ranging from pebbles to boulders comprising >25% seafloor cover, the mixed rock/sediment habitat harbors a rich biological assemblage of algae and invertebrates, dominated by the kelp species *Laminaria solidungula*. This area, designated as the "Boulder Patch," is recognized as the most diverse biological marine community in the central Alaska Beaufort Sea. The Boulder Patch is not affected by high rates of sedimentation due to its location below the depth of sea ice freezing and its protection from ice-scour by a seaward fringe of barrier islands and shoals. These requisites for kelp existence are rare along the Alaska Beaufort Sea coast, and the existing kelp population is several hundred kilometers from its nearest known population.

The Boulder Patch is located over potentially rich oil and gas reserves and Endicott, the first offshore oil and gas development in the North Slope region, is located nearby. The Endicott Environmental Impact Statement (EIS) developed by the U.S. Army Corps of Engineers suggested that significant adverse impacts upon the biological community of the Boulder Patch were unlikely. Protection of the habitat has been overseen by a task force consisting of local, state, and federal agencies and by criteria established by the U.S. Environmental Protection

Agency (EPA) for disposal of drilling fluids in its vicinity. The Endicott National Pollution Discharge Elimination (NPDES) permit allows no discharge within 1,000 m of the Patch or between individual units of the Patch that are separated by less than 5,000 m.

Endicott pre-construction monitoring, followed by six years of annual monitoring data, described the effects of Endicott development on kelp health and growth, and species diversity within the Patch. Summary reports, which have synthesized seven years of data, have documented no significant adverse impacts of petroleum development upon the Boulder Patch biological community.

Brower, C. D.; Carpenter, A.; Branigan, M. L.; Calvert, W.; Evans, T.; Fischbach, A. S.; Nagy, J. A.; Schliebe, S., and Stirling, I. 2002. The Polar Bear Management Agreement for the Southern Beaufort Sea: an Evaluation of the First Ten Years of a Unique Conservation Agreement. *Arctic. Dec*; 55(4).

Keywords: polar bears/ Beaufort Sea/ management/ agreement/ North Slope Borough/ Inuvialuit Game Council/ mark

Abstract: Polar bears (*Ursus maritimus*) of the southern Beaufort Sea population, distributed from approximately Icy Cape, west of Point Barrow, Alaska, to Pearce Point, east of Paulatuk in Canada, are harvested by hunters from both countries. In Canada, quotas to control polar bear hunting have been in place, with periodic modifications, since 1968. In Alaska, passage of the United States Marine Mammal Protection Act (MMPA) of 1972 banned polar bear hunting unless done by Alaska Natives for subsistence. However, the MMPA placed no restrictions on numbers or composition of the subsistence hunt, leaving open the potential for an over-harvest with no possible legal management response until the population was declared depleted. Recognizing that as a threat to the conservation of the shared polar bear population, the Inuvialuit Game Council from Canada and the North Slope Borough from Alaska negotiated and signed a user-to-user agreement, the Polar Bear Management Agreement for the Southern Beaufort Sea, in 1988. We reviewed the functioning of the agreement through its first 10 years and concluded that; overall, it has been successful because both the total harvest and the proportion of females in the harvest have been contained within sustainable limits. However, harvest monitoring needs to be improved in Alaska, and awareness of the need to prevent over-harvest of females needs to be increased in both countries. This agreement is a useful model for other user-to-user conservation agreements.

Burruss, R. C.; Lillis, P. G., and Collett, T. S. 2003. Geochemistry of Natural Gas, North Slope, Alaska: Implications for Gas Resources, NPRA.

Keywords: North Slope/ natural gas/ National Petroleum Reserve Alaska/ NPRA

Abstract: The North Slope of Alaska contains a significant volume of natural gas. The known amount of gas within the oil and gas fields is large and the estimated amount of undiscovered resource is even larger (Bird, 2002a). Increasing demand for gas as a relatively clean fossil fuel

is driving plans to develop this resource either through a pipeline to the lower 48 states, LNG shipments, or gas-to-liquids technologies.

To increase confidence in U. S. Geological Survey (USGS) estimates of undiscovered gas resources there is a need to understand the role of natural gas in the petroleum systems of the North Slope. Of particular interest to resource estimates in the National Petroleum Reserve in Alaska (NPRA) is whether the petroleum systems of that part of the North Slope are gas-rich. Current exploration targets are oil reservoirs, but the historic drilling experience indicates that gas is abundant in the western part of the North Slope within NPRA.

Initial drilling by the U.S. Navy in 1944 to 1953 tested gas in a number of wells and discovered small accumulations at Barrow, Meade, Square Lake, and Wolf Creek and adjacent to NPRA at Gubik as shown on the North Slope location map in Figure 1. Of the three oil accumulations discovered by the Navy, the largest, Umiat, tested gas in a deeper reservoir horizon than the oil accumulation. Later drilling by the U.S. Navy and the USGS in 1973 to 1981 discovered gas accumulations on the Barrow Peninsula at Walakpa and Sikulik, and tested gas from a number of potential reservoirs at other locations, some at depths greater than 10,000 ft.

This paper addresses several natural gas resource questions based on a summary of the geochemistry of natural gas across the North Slope of Alaska. First, is there evidence of distinct gas-rich petroleum systems? Second, is there any evidence of unique gas systems in the foothills of the Brooks Range? Third, are there any potential problems with the quality of gas (significant quantities of non-hydrocarbon gases) in undiscovered gas accumulations?

To address these questions we present evidence for the source and maturity of the known natural occurrences. In particular we will examine the effects of microbial gas generation, microbial alteration of thermogenic gas, and the role of mixing of gases of various origins in controlling the present day composition of gas. Finally, we will examine the extent to which non-hydrocarbon gases, carbon dioxide and nitrogen, affect the quality of North Slope gas. Carbon dioxide is particularly important because a large fraction (5 to 18%) of the gas cap of the Prudhoe Bay field and surrounding satellite fields is CO₂ and may amount to as much as 5 trillion cubic feet (TCF) of gas. Although this amount of CO₂ is beneficial for current practices of miscible flooding for enhanced oil recovery in Prudhoe Bay, marketable natural gas must contain 4 % or less CO₂. Therefore, gas from the Prudhoe Bay field gas cap will require processing or dilution with low CO₂ gas before it is marketable. Costs associated with gas processing or dilution may impact the economics of natural development on the North Slope.

Carmack, E. C. and MacDonald, R. W. 2002. Oceanography of the Canadian Shelf of the Beaufort Sea: a Setting for Marine Life. Arctic. 55.

Keywords: Beaufort Sea/ global warming/ upwelling/ sea ice/ nutrients/ sediments/ whale/ *Balaena mysticetus*/ Prince Albert Sound/ Arctic Ocean/ Mackenzie Shelf/ Northwest Territories/ climatic change/ *Phoca hispida*/ fresh water/ ringed seal/ inner shelf

Abstract: Conservation of marine biodiversity in the Beaufort Sea demands that we understand what individual organisms require of their physical and geochemical environments in order to survive. Specifically, how do the extraordinary spatial and seasonal variations in ice cover, temperature, light, freshwater, turbidity, and currents of the Beaufort Sea define unique places or times critical to marine life? We start with the traditional "bottom-up" approach, which is to review the strongly seasonal physical forcing of the system, and from it to infer the resultant oceanographic regimes and seasons. This approach, while valuable, remains incomplete: this is due partly to limitations of the data and partly to our limited understanding of this complex system. The oceanographic features (e.g., upwelling regions, recurrent polynyas, coastal currents, sediment types and distributions) define the backdrop that animals "know and understand" in the sense of interacting with one another and finding food and habitat. We therefore seek clues to the underlying oceanographic processes in the behavioral patterns of fish, marine mammals, and birds. This "top-down" approach also has limitations, but it offers the opportunity to seek those connections in the system where climate change is likely to have its greatest impact on biological populations.

Clark, C. W. and Ellison, W. T. 2000. Calibration and Comparison of the Acoustic Location Methods Used During the Spring Migration of the Bowhead Whale, *Balaena mysticetus*, Off Pt. Barrow, Alaska, 1984-1993. *Journal of the Acoustical Society of America*. Jun; 107(6).

Keywords: *Megaptera novaeangliae*/ quantitative analysis/ Point Barrow/ census/ bowhead whale/ *Balaena mysticetus*

Abstract: Between 1984 and 1993, visual and acoustic methods were combined to census the Bering-Chukchi-Beaufort bowhead whale, *Balaena mysticetus*, population. Passive acoustic location was based on arrival-time differences of transient bowhead sounds detected on sparse arrays of three to five hydrophones distributed over distances of 1.5-4.5 km along the ice edge. Arrival-time differences were calculated from either digital cross correlation of spectrograms (old method), or digital cross correlation of time waveforms (new method). Acoustic calibration was conducted in situ in 1985 at five sites with visual site position determined by triangulation using two theodolites. The discrepancy between visual and acoustic locations was <1%-5% of visual range and less than 0.7 degrees of visual bearing for either method. Comparison of calibration results indicates that the new method yielded slightly more precise and accurate positions than the old method. Comparison of 217 bowhead whale call locations from both acoustic methods showed that the new method was more precise, with location errors 3-4 times smaller than the old method. Overall, low-frequency bowhead transients were reliably located out to ranges of 3-4 times array size. At these ranges in shallow water, signal propagation appears to be dominated by the fundamental mode and is not corrupted by multipath.

Cooper, L. W.; Larsen, I. L.; O'Hara, T. M.; Dolvin, S.; Woshner, V., and Cota, G. F. 2000. Radionuclide Contaminant Burdens in Arctic Marine Mammals Harvested During Subsistence Hunting. *Arctic*. Jun; 53(2).

Keywords: Cs-137/ contamination/ marine mammals/ North Slope Borough/ radioactivity/ radionuclides/ Resolute/ Ag-108m/ subsistence hunting/ sediments/ environment/ Yenisei/ caribou/ rivers/ Pb-210/ metals/ sea/ Alaska

Abstract: We conducted gamma spectrometric analyses on more than 200 arctic marine mammal tissue samples. These samples were primarily provided by subsistence hunters from northern Alaska, with a smaller number of samples from the Resolute region in Canada. The majority of samples (>90%) had detectable levels of the anthropogenic radionuclide Cs-137, with a mean level observed in all samples of 0.67 Bq kg(-1) dry weight +/- 0.81 (SD). Converted to wet weight, the mean was 0.21 Bq kg(-1) +/- 0.19 SD. The median activity observed was 0.45 Bq kg(-1) dry weight (0.18 Bq kg(-1) wet weight) with a range from detection limits to 6.7 Bq kg(-1) dry weight (1.1 Bq kg(-1) wet weight). These findings confirm expectations that current anthropogenic gamma emitter burdens in marine mammals used in the North American Arctic as subsistence food resources are well below activities that would normally merit public health concern (similar to 1000 Bq kg(-1) wet weight). Some differences among species and tissues were observed. Beluga tissues had slightly higher mean burdens of Cs-137 overall, and epidermis and muscle tissues in bowhead and beluga whales typically had higher burdens than other tissues analyzed. Low levels of the neutron activation product Ag-108 (half-life 418 yr.), probably bioaccumulated from bomb fallout sources, were observed in 16 of 17 beluga livers analyzed, but were not found in any other tissues of beluga or in any other species sampled. A subset of 39 samples of various tissues was analyzed for the alpha and beta emitters Pu-239.240 and Sr-90. Plutonium levels were near the threshold of detectability (similar to 0.1 Bq kg(-1) dry weight) in 6 of the 39 samples; all other samples had no detectable plutonium. A detectable level of Sr-90 (10.3 +/- 1.0 Bq kg(-1) dry weight) was observed in only one of the 39 samples analyzed, a bowhead epidermis sample. Although the accumulation of Ag-108m has not been previously reported in any marine mammal livers, all of our analytical measurements indicate that only very low levels of anthropogenic radioactivity are associated with marine mammals harvested and consumed in the North American Arctic.

Dickson, D. L. and Gilchrist, H. G. 2002. Status of Marine Birds of the Southeastern Beaufort Sea. *Arctic*. 55.

Keywords: Beaufort Sea/ sea ducks/ seabirds/ Brant/ harvest/ distribution/ population status/ conservation/ red-throated loons/ *Somateria mollissima*/ common eiders/ *Uria lomvia*/ ice edges/ Alaska/ survival/ king eiders/ scoter/ behavior

Abstract: This summary and update of information on the marine birds of the southeastern Beaufort Sea is intended to support discussions on how to improve management of marine resources in the Canadian Beaufort Sea region. Perhaps the most outstanding use of the Beaufort Sea by marine birds is the staging during spring migration by hundreds of thousands of eiders and long-tailed ducks in the early open water off Cape Bathurst and Banks Island. During midsummer, tens of thousands of long-tailed ducks, scoters, scaup, and mergansers molt in the sheltered bays and behind barrier beaches and spits. Although several species of geese, ducks, loons, gulls, and terns nest on islands and in wetlands along the Beaufort Sea coast, this region has relatively few nesting seabirds compared to eastern Arctic Canada and the Bering Sea. Two

possible reasons for this are a shortage of cliffs suitable for nesting and a lack of pelagic fish. The five most common sea duck species that occur in the region, long-tailed duck, king eider, common eider, surf scoter, and white-winged scoter, have all declined in numbers since the mid-1970s. Western Arctic brant populations have also declined, although their status within the Beaufort Sea region is unclear. Brant and king eider are the only marine bird species harvested there in substantial numbers. Other threats to Beaufort Sea marine bird populations include oil spills, global warming, coastal development, and contaminants. Certain threats can be managed at a local level since they are a result of local economic development, but others, such as global warming or loss of critical wintering areas, stem from environmental problems outside the region. Solving these issues will require mutual understanding and commitment on the part of numerous countries.

Drobot, S. D. and Maslanik, J. A. 2002. A Practical Method for Long-Range Forecasting of Ice Severity in the Beaufort Sea - Art. No. 1213. *Geophysical Research Letters*. Apr 15; 29(8).

Keywords: North Pacific/ variability/ cover/ anomalies/ record/ ocean/ Beaufort Sea/ sea ice

Abstract: A linear regression model is used to forecast end of summer ice conditions in the Beaufort Sea with a few months lead-time. The model retains four sea ice and atmospheric parameters, where decreased spring total and winter multiyear ice concentrations, negative October East Atlantic phases, and positive March North Atlantic Oscillation phases are associated with lighter sea ice conditions. Monte Carlo simulations suggest that the results are not adversely affected by artificial skill, while Durbin-Watson and Variance Inflation Factor statistics imply the final model is statistically valid. Cross validation diagnostics indicate that variations in the four predictors are related to 85% of the variation in sea ice conditions, suggesting that a relatively simple ice-atmosphere statistical model can be used to forecast end of summer ice conditions in the Beaufort Sea.

Duesterloh, S.; Short, J. W., and Barron, M. G. 2002. Photoenhanced Toxicity of Weathered Alaska North Slope Crude Oil to the Calanoid Copepods *Calanus marshallae* and *Metridia okhotensis*. *Environmental Science & Technology*. Sep 15; 36(18).

Keywords: polycyclic aromatic hydrocarbons/ Prince William Sound/ Exxon Valdez Oil/ Gibba L G-3/ photoinduced toxicity/ petroleum hydrocarbons/ solar radiation/ *Daphnia pulex*/ sediments/ anthracene

Abstract: This study investigated the synergistic toxicity of aqueous polyaromatic compounds (PAC) dissolved from crude oil and ultraviolet radiation (UV) in natural sunlight to the calanoid copepods *Calanus marshallae* and *Metridia okhotensis*. These copepods were first exposed to low doses (similar to 2 mug of total PAC/Q of the water-soluble fraction of weathered Alaska North Slope crude oil for 24 h and subsequently to low or high levels of natural sunlight. Responses included mortality, impairment of swimming ability, and discoloration of lipid sacs. There was 80-100% mortality and morbidity of *C. marshallae* exposed to UV and oil as compared to less than 10% effect in oil-only or UV-only treatments. In *M. okhotensis*, 100%

mortality occurred in the UV and oil treatment, 43% mortality and 27% morbidity in the UV-only treatment, and less than 5% effect in the oil-only treatment. Bioaccumulation factors were similar to 8000 for *C. marshallae* and similar to 2000 for *M. okhotensis*. The interaction of the effect of PAC and UV radiation was highly significant ($P < 0.005$) in both experiments.

Dunton, K.H. and Schonberg, S.V. 2000. The Benthic Faunal Assemblage of the Boulder Patch Community. Chapter 18, pp. 371-397, *In: The Natural History of an Arctic Oil Field.* J. C. Truett and S. R. Johnson (Eds.). Academic Press, San Diego, CA, 422 pp.

Keywords: Alaska/ Beaufort Sea/ North Slope/ Steffanson Sound/ Prudhoe Bay/ Boulder Patch/ benthic infauna/ epilithic fauna/ algae/ biological diversity/ biomass

Abstract: The Boulder Patch, an area of cobbles and boulders that supports abundant algae and invertebrate life, was discovered in Steffanson Sound, Alaska, by marine geologists in the summers of 1971 and 1972. The Boulder Patch is located over potentially rich oil and gas reserves, and consequently has been extensively studied for potential impacts of petroleum exploration and development. Joint biological and geological investigations commencing in 1978 have revealed it to be the most diverse biological community yet discovered in the American Beaufort Sea.

Approximately 140 species of benthic infauna from 11 invertebrate phyla characterized the sedimentary habitat between and under rocks, ranging respectively from 4,134 m^{-2} to 5,525 m^{-2} in abundance and from 27 to 33 $gm\ m^{-2}$ in wet-weight biomass. The sediments consisted of sandy silts and mud. The epilithic fauna inhabiting rock substrates consisted of 158 species, with an average abundance of 18,441 organisms m^{-2} and wet-weight biomass of 238 $gm\ m^{-2}$. Dominant major invertebrate taxa on rocks were sponges, mollusks, crustaceans, cnidarians, and bryozoans, many of which are suspension- or filter-feeders that are sensitive to high levels of turbidity. Predominant species of algae included the kelp *Laminaria saccharina* (42 $gm\ m^{-2}$) and the red alga *Phycodrys rubra* (43 $gm\ m^{-2}$).

Durner, G. M.; Amstrup, S. C., and Fischbach, A. S. 2003. Habitat Characteristics of Polar Bear Terrestrial Maternal Den Sites in Northern Alaska. *Arctic.* Mar; 56(1).

Keywords: Arctic National Wildlife Refuge/ den habitat/ maternal den/ National Petroleum Reserve-Alaska/ polar bear/ *Ursus maritimus*/ Prudhoe Bay/ Beaufort Sea/ area

Abstract: Polar bears (*Ursus maritimus*) give birth to and nurture their young in dens of ice and snow. During 1999-2001, we measured the structure of 22 dens on the coastal plain of northern Alaska after polar bear families had evacuated their dens in the spring. During the summers of 2001 and 2002, we revisited the sites of 42 maternal and autumn exploratory dens and recorded characteristics of the under-snow habitat. The structure of polar bear snow dens was highly variable. Most were simple chambers with a single entrance/egress tunnel. Others had multiple chambers and additional tunnels. Thickness of snow above and below dens was highly variable, but most dens were overlain by less than 1 meter of snow. Dens were located on, or associated

with, pronounced landscape features (primarily coastal and river banks, but also a lake shore and an abandoned oil field gravel pad) that are readily distinguished from the surrounding terrain in summer and catch snow in early winter. Although easily identified, den landforms in northern Alaska were more subtle than den habitats in many other parts of the Arctic. The structure of polar bear dens in Alaska was strikingly similar to that of dens elsewhere and has remained largely unchanged in northern Alaska for more than 25 years. Knowledge of den structure and site characteristics will allow resource managers to identify habitats with the greatest probability of holding dens. This information may assist resource managers in preventing negative impacts of mineral exploration and extraction on polar bears.

Erbe, C. and Farmer, D.M. 2000a. Zones of impact around icebreakers affecting Beluga whales in the Beaufort Sea. *J. Acoustical Soc. Amer.* 108(3):1332-1340.

Keywords: Beaufort Sea/ Alaska/ marine mammals/ Beluga whale/ *Delphinapterus leucas*/ underwater noise impacts/ underwater acoustics/ icebreakers/ behavior/ disturbance

Abstract: A software model estimating zones of impact on marine mammals around man-made noise was applied to the case of icebreakers affecting beluga whales in the Beaufort Sea. Two types of noise emitted by the Canadian Coast Guard icebreaker Henry Larsen were analyzed: bubbler system noise and propeller cavitation noise. Effects on beluga whales were modeled both in a deep-water environment and a near-shore environment. The model estimated that the icebreaker was audible to beluga whales over ranges of 35 to 78 km, depending on location. The zone of behavioral disturbance is only slightly smaller. Masking of beluga communication signals is predicted within a 14 to 71 km range. Temporary hearing damage can occur if a beluga stays within 1 to 4 km of the icebreaker for at least 20 minutes. Bubbler noise impacts over the short ranges quoted; propeller cavitation noise accounts for all of the long-range effects. Serious problems may arise in heavily industrialized areas where animals are exposed to ongoing noise and cumulative anthropogenic noise sources.

Erbe, C. and Farmer, D.M. 2000b. A software model to estimate zones of impact on marine mammals around anthropogenic noise. *J. Acoust. Soc. Amer.* 108(3): 1327-1331.

Keywords: underwater acoustics/ animal behavior/ marine mammals/ anthropogenic noise impacts

Abstract: Anthropogenic noise impacts marine mammals in a variety of ways. In order to estimate the range of conditions over which these impacts occur, an understanding of the propagation of noise through the ocean away from the noise source is needed, along with an understanding of the relationship between received noise levels and impact thresholds. A software package combining both aspects is presented that includes 1) a sound propagation model based on ray theory to calculate received noise levels as a function of range, depth, and frequency, and 2) predictions of zones of impact on marine mammals around industrial sources based upon current knowledge of noise impact thresholds.

As input parameters, the software package requires the source level and spectrum of the noise of interest; physical oceanography data about the local ocean environment such as bathymetry,

bottom and surface loss data, and sound speed profiles; and bioacoustical information about the target species in the form of an audiogram, critical auditory bandwidths, spectra of typical animal vocalizations, reported sound levels of disturbance, and criteria for hearing damage. As output, the software produces data files and plots of the zones of audibility, masking, disturbance, and potential hearing damage around a noise source.

Fechelm, R.G. 1999. The effect of new breaching in a Prudhoe Bay causeway on the coastal distribution of humpback whitefish. *Arctic* 52 (4): 386-394.

Keywords: Beaufort Sea/ Alaska/ Prudhoe Bay/ West Dock Causeway/ Colville River/
Coregonus pidschian/ Humpback Whitefish

Abstract: West Dock is a solid-gravel petroleum production causeway 4.3 km long that was constructed along the Beaufort Sea coast near Prudhoe Bay, Alaska, in the late 1970s. In the winter of 1995-96, a breach 200 m wide was constructed 1 km from the base of the causeway. Fish monitoring studies conducted during the summers of 1996 and 1997 indicated that the catch of adult (>200 mm fork length) humpback whitefish (*Coregonus pidschian*) had increased significantly east of West Dock relative to levels observed in the 11 previous years. Data suggest that humpback whitefish dispersing eastward along the coast from their overwintering grounds in the Colville River had been blocked from moving east of West Dock and that construction of the breach has allowed these fish to extend their summer foraging range farther to the east.

Fechhelm, R. G.; Martin, L. R.; Gallaway, B. J.; Wilson, W. J., and Griffiths, W. B. 2001. Estimating the Hydrographic Effects of Prudhoe Bay Causeway Breaches Using the Before-After Control-Impact (BACI) Analysis. *Arctic*. Jun; 54(2).

Keywords: breaching/ causeways/ hydrography/ mitigation/ Prudhoe Bay/ water quality/
whitefish

Abstract: A Before-After Control-Impact (BACI) analysis was used to test the effects of new breaches constructed in two Prudhoe Bay causeways on hydrographic conditions during the open-water summer season. At West Dock, under east wind conditions, significant cross-causeway differentials in salinity and temperature at the surface (1 m depth or less) were observed in all eight pre-breach cases tested. In the years following construction of the breach, there were no significant cross-causeway differentials in seven of those eight cases. At Endicott Causeway, under east wind conditions, significant cross-causeway differentials in surface salinity and temperature were observed in all eight pre-breach cases tested. Significant cross-causeway differentials continued in all eight cases following construction of the new breach. Results suggest that the new breach at West Dock has successfully mitigated cross-causeway hydrographic differentials, and that the new breach at the Endicott Causeway has had no observable effect. The possible reasons for this disparity include different hydrographic dynamics in the vicinity of each causeway.

Federal Register, Department of the Interior Fish and Wildlife Service. 2000. Marine Mammals; Incidental Take During Specified Activities. Final Rule. 50 CFR Part 18.

Keywords: polar bears/ Pacific walrus/ incidental take/ Alaska/ Beaufort Sea

Abstract: These regulations authorize the incidental, unintentional take of small numbers of polar bears and Pacific walrus during year-round oil and gas industry (Industry) exploration, development, and production operations in the Beaufort Sea and adjacent northern coast of Alaska.

We made a finding that the total expected takings of polar bear and Pacific walrus during oil and gas industry exploration, development, and production activities will have a negligible impact on these species and will have no unmitigable adverse impacts on the availability of these species of subsistence use by Alaska Natives. We base this finding on results from 6 years of monitoring interactions between marine mammals and Industry and using oil trajectory models and polar bear density models to determine the likelihood of impacts to polar bears should an accidental oil release occur.

Ferguson, S. H.; Taylor, M. K.; Rosing-Asvid, A.; Born, E. W., and Messier, F. 2000. Relationships Between Denning of Polar Bears and Conditions of Sea Ice. Journal of Mammalogy. Nov; 81(4).

Keywords: annual ice/ den use/ dormancy/ seasonality/ sheltering/ *Ursus maritimus*/ Eastern Beaufort Sea/ fasting endurance/ southern ocean/ life history/ free period/ serum urea/ home-range/ seasonality/ creatinine

Abstract: We examined shelter and maternity dens used by 97 adult female polar bears (*Ursus maritimus*) in relation to conditions of sea ice. Obligate use of maternity dens for pregnancy, birth, and lactation varied little with latitude or area. In contrast, timing of facultative use of shelter dens switched from autumn in the southern area (<70 degrees N) to winter in the northern area (>75 degrees N). For the southern area, 13 of 16 female polar bears used shelter dens in autumn versus winter (median dates of entry and exit, 11 September and 2 November; total = 56 days), whereas in the northern area, 11 of 17 bears used shelter dens in winter versus autumn (median dates, 24 December and 2 March; total = 65 days). Difference in facultative use of shelter dens was associated with conditions of sea ice, southern regions had no sea ice when polar bears used shelter dens. In contrast, northern areas had more constant ice conditions that included presence of ice throughout the year. Southern regions seem to have greater primary productivity and more seals as a result of a pronounced seasonal cycle of annual ice. Polar bears in northern areas responded to the more constant ice conditions and less productive environment with use of shelter dens during the period with lowest seal accessibility.

Ferrero, R.C.; DeMaster, D.P.; Hill, P.S.; Muto, M.M., and Lopez, A.L. 2000. Alaska Marine Mammal Stock Assessments. NOAA Technical Memorandum NMFS-AFSC-119. Alaska Marine Fisheries Service, Alaska Fisheries Science Center. Seattle, Washington.

Keywords: Beaufort Sea/ North Slope/ Alaska/ marine mammals/ pinnipeds/ cetaceans/ Marine Mammal Protection Act (MMPA)/ Public Law 103-238/ incidental take/ commercial fisheries/ native subsistence harvest/ stock assessment/ population estimate/ potential biological removal (PBR)/ BelugaWhale/ *Delphinapterus leucas*

Abstract: This report provides population information on stocks of seven species of pinnipeds and 15 species of cetacean marine mammal Alaska under the jurisdiction of the National Marine Fisheries Service. Public Law 103-238, enacted in April 1994, changed provisions within the Marine Mammal Protection Act, whereupon interactions between commercial fisheries and marine mammals (including incidental takes) are addressed under three new provisions requiring a regional scientific review group to advise and report on the status of marine mammals in Alaska waters. This new law replaced the interim exemption that had regulated fisheries-related incidental takes since 1988. Stock assessment is provided for the beluga whale (*Delphinapterus leucas*), which occurs in both nearshore and offshore waters of the North Slope environment in the Beaufort Sea. Population size estimate for the Beaufort Sea population is 39,258 and the stock is considered to be stable or increasing. A productivity rate is not available. The potential biological removal (PBR) rate is estimated to be 649 animals per year. No reports of mortality incidental to commercial fisheries have been reported in recent years. The average annual take for Alaska native subsistence harvest averaged 61 animals for the years 1993 to 1997.

Garbarino, J. R.; Snyder-Conn, E.; Leiker, T. J., and Hoffman, G. L. 2002. Contaminants in Arctic Snow Collected Over Northwest Alaskan Sea Ice. *Water Air and Soil Pollution*. Sep; 139(1-4).

Keywords: Alaska/ anions/ Arctic/ atmospheric/ Beaufort/ cations/ chlorpyrifos/ Chukchi/ contaminants/ mercury/ metals/ organochlorine/ snow/ aerosol chemical components/ plasma mass spectrometry/ atmospheric mercury/ trace-elements/ seasonal variations/ heavy metals/ polychlorinated biphenyls/ toxicological assessment/ peregrine falcons/ pollution aerosol

Abstract: Snow cores were collected over sea ice from four northwest Alaskan Arctic estuaries that represented the annual snowfall from the 1995-1996 season. Dissolved trace metals, major cations and anions, total mercury, and organochlorine compounds were determined and compared to concentrations in previous arctic studies. Traces (<4 nanograms per liter, ng L⁻¹) of cis- and trans-chlordane, dimethyl 2,3,5,6-tetrachloroterephthalate, dieldrin, endosulfan II, and PCBs were detected in some samples, with endosulfan I consistently present. High chlorpyrifos concentrations (70-80 ng L⁻¹) also were estimated at three sites. The snow was highly enriched in sulfates (69-394 mg L⁻¹), with high proportions of non-sea salt sulfates at three of five sites (9 of 15 samples), thus indicating possible contamination through long-distance transport and deposition of sulfate-rich atmospheric aerosols. Mercury, cadmium, chromium, molybdenum, and uranium were typically higher in the marine snow (n = 15) in relation to snow from arctic terrestrial studies, whereas cations associated with terrigenous sources, such as aluminum, frequently were lower over the sea ice. One Kasegaluk Lagoon site (Chukchi Sea) had especially high concentrations of total mercury (mean = 214 ng L⁻¹, standard deviation = 5 ng L⁻¹), but no methyl mercury was detected above the method detection limit (0.036 ng L⁻¹) at any

of the sites. Elevated concentrations of sulfate, mercury, and certain heavy metals might indicate mechanisms of contaminant loss from the arctic atmosphere over marine water not previously reported over land areas. Scavenging by snow, fog, or riming processes and the high content of deposited halides might facilitate the loss of such contaminants from the atmosphere. Both the mercury and chlorpyrifos concentrations merit further investigation in view of their toxicity to aquatic organisms at low concentrations.

Gibson, J. A. E.; Vincent, W. F.; Nieke, B., and Pienitz, R. 2000. Control of Biological Exposure to UV Radiation in the Arctic Ocean: Comparison of the Roles of Ozone and Riverine Dissolved Organic Matter. *Arctic*. Dec; 53(4).

Keywords: Arctic/ CDOM/ DNA/ global change/ ozone depletion/ phytoplankton/ Siberia/ transparency/ ultraviolet radiation/ fresh water balance/ natural waters/ Laptev Sea/ Lena River/ carbon/ phytoplankton/ inhibition/ absorption/ depletion

Abstract: Reports of severe stratospheric ozone depletion over the Arctic have heightened concern about the potential impact of rising ultraviolet-B (UV-B) radiation on north polar aquatic ecosystems. Our optical measurements and modeling results indicate that the ozone-related UV-B influence on food web processes in the Arctic Ocean is likely to be small relative to the effects caused by variation in the concentrations of natural UV-absorbing compounds, known as chromophoric dissolved organic matter (CDOM), that enter the Arctic basin via its large river inflows. The aim of our present study was to develop and apply a simple bio-optical index that takes into account the combined effects of attenuation by atmospheric ozone and water column CDOM, and photobiological weighting for high-latitude environments such as the Arctic Ocean. To this end, we computed values for a biologically effective UV dose rate parameter ("weighted transparency" or T^*) based on underwater UV measurements in high-latitude lakes and rivers that discharge into the Arctic Ocean; measured incident UV radiation at Barrow, Alaska; and published biological weighting curves for UV-induced DNA damage and UV photoinhibition of photosynthesis. The results underscore how strongly the Arctic Ocean is influenced by riverine inputs: shifts in CDOM loading (e.g., through climate change, land-use practices, or changes in ocean circulation) can cause variations in biological UV exposure of much greater magnitude than ozone-related effects.

Harris, R. E.; Miller, G. W., and Richardson, W. J. 2001. Seal Responses to Airgun Sounds during Summer Seismic Surveys in the Alaskan Beaufort Sea. *Marine Mammal Science*. Oct; 17(4).

Keywords: ringed seal/ *Phoca hispida*/ Beaufort Sea/ Alaska/ Arctic/ seismic disturbance/ airgun array/ underwater noise/ behavior/ harassment/ underwater

Abstract: Numbers, sighting distances, and behavior of seals were studied during a nearshore seismic program off northern Alaska in July–September 1996. We observed from the seismic vessel for 885.6 h, including all periods (day and night) when airguns operated and many periods without airguns. Of 422 seals seen, 421 were seen in daylight; 91.8% were ringed seals, 7.3%

were bearded seals, and 0.9% were spotted seals. About 79% were first seen within 250 m of the seismic boat, and sighting rate declined rapidly at lateral distances >50 m. During daylight, seals were seen at nearly identical rates (0.60–0.63/h) during periods with no airguns firing, one airgun, and a “full-array” of 8–11 120-in³ airguns. However, seals tended to be farther away ($P < 0.0001$) during full-array seismic. There was partial avoidance of the zone <150 m from the boat during full-array seismic, but seals apparently did not move much beyond 250 m. “Swimming away” was more common during full-array than no-airgun periods, but relative frequencies of five behaviors did not differ significantly among distance categories. Airgun operations were interrupted 112 times when seals were sighted within safety radii (150–250 m). The National Marine Fisheries Service specified these radii in the Incidental Harassment Authorization issued for the project; they are based on a 190 dB re 1 μ Pa (rms) criterion for broadband received level. Methods for estimating numbers of seals potentially affected by the seismic program are described, and effectiveness of monitoring and mitigation is discussed. There is an urgent need for more data on effects of strong seismic pulses on seals.

Headley, J. V.; Marsh, P.; Akre, C. J.; Peru, K. M., and Lesack, L. 2002. Origin of Polycyclic Aromatic Hydrocarbons in Lake Sediments of the Mackenzie Delta. *Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering.* 37(7).

Keywords: PAHs/ Mackenzie River/ alkylated PAHs/ sediment/ mass spectrometry/ Beaufort Sea/ river/ Canada/ shelf

Abstract: The concentrations and distribution of polycyclic aromatic hydrocarbons (PAHs) were assessed in sediment cores from among 14 lakes from three regions comprising a transect across the central Mackenzie Delta. PAHs were consistently found in the lake sediments, with parent concentrations in the 20–200 ng/g range. Concentrations were generally independent of depth in the sediment cores and this pattern was similar among the 3 regions of the delta. Concentrations increased in a westerly direction among the regions. For some lakes, the concentration of PAHs decreased with decreasing flooding frequency, and decreasing sedimentation rates. For the latter, maximum concentrations occurred at shallower depths within the sediment cores as flooding frequency among the lakes decreased. The distributions of C-0-C-4 alkylated 2- and 3-ring PAHs were consistent with a petrogenic origin, while the corresponding distribution of 4-ring PAHs appears to be more consistent with a biogenic or pyrogenic origin. Based on relative contributions to the overall PAH budget, a petrogenic source appears to be dominant. However, the pyrene/fluoranthene ratio is more consistent with a source derived from peat. The alkylated PAH profiles are inconsistent with those in the Athabasca River system, and support a previously published hypothesis that the contribution of PAHs from the Athabasca oil sands to the lower Mackenzie River is minimal. A double ratio plot of chrysene vs. dibenzothiophene, diagnostic of weathering, suggests most weathering occurred before the sediments were deposited in the lakes, while a double ratio plot of dibenzothiophene vs. phenanthrene suggests a common source of PAHs across the delta, despite differing water sources from east to west across the delta. PAH inputs to the delta appear to mirror sediment inputs documented in previous work, where high sediment input from the Mackenzie mainstem during high floods dominates the delta sediment influx and masks any influence of the Peel River.

Hequette, A.; Desrosiers, M.; Hill, P. R., and Forbes, D. L. 2001. The Influence of Coastal Morphology on Shoreface Sediment Transport under Storm-Combined Flows, Canadian Beaufort Sea. *Journal of Coastal Research*. Summer; 17(3).

Keywords: shoreface sediment transport/ combined flows/ storm surges/ Beaufort Sea/ Canada/ Continental Shelf/ Atlantic Bight/ currents/ model/ beach/ spit

Abstract: Wind, wave and current measurements were carried in the nearshore zone of the Canadian Beaufort Sea at two coastal sites having distinct morphologies. The first site is a sandy beach backed by a low bluff, while the second site consists of low-lying barriers. Computation of potential sediment transport using a numerical model for combined flow conditions (Li and Amos, 1993) suggests that coastal morphology may play a significant role on circulation and sediment transport on the shoreface during storm events. Downwelling near-bottom currents and offshore sediment transport were observed at all sites during storm surges, but with some variations in the shoreface current patterns and sediment transport. According to the numerical model used in this study, offshore sediment transport is more significant where the beach is backed by a bluff acting as a natural barrier. Such condition appears to be favorable to the development of strong seaward-directed horizontal pressure gradients that drive offshore bottom currents. Along low barriers that are easily submerged and overwashed, sediment transport is mainly directed obliquely offshore due to more limited set-up of sea level at the coast during storm surges. These results suggest that coastal morphology may be responsible for variable offshore sediment dispersal on the shoreface during storms. Our results show that sediment may be transported offshore to depths from which fairweather waves may not be capable of returning the material onshore. Consequently, a loss of material to the offshore may be greater where overwashing is restricted due to the presence of a coastal feature that acts as a boundary for onshore-driven surface waters.

Hoekstra, P. F.; Dehn, L. A.; George, J. C.; Solomon, K. R.; Muir, D. C. G., and O'Hara, T. M. 2002. Trophic Ecology of Bowhead Whales (*Balaena mysticetus*) Compared with that of Other Arctic Marine Biota as Interpreted from Carbon-, Nitrogen-, and Sulfur-Isotope Signatures. *Canadian Journal of Zoology*. Feb; 80(2).

Keywords: stable isotopes/ tissues/ fractionation/ delta-C-13/ zooplankton/ delta-N-15/ migration/ turnover/ growth/ diet

Abstract: In this study, stable carbon ($\delta^{13}\text{C}$), nitrogen ($\delta^{15}\text{N}$), and sulfur ($\delta^{34}\text{S}$) isotope ratios were measured in muscle tissue from the Bering-Chukchi-Beaufort Sea population of bowhead whales (*Balaena mysticetus*; $n = 84$) and various marine biota between 1997 and 2000. In previous investigations, stable carbon and nitrogen isotope ratios in baleen from this population have been used to elucidate age, migratory behavior, and feeding ecology. However, information on $\delta^{13}\text{C}$, $\delta^{15}\text{N}$, and $\delta^{34}\text{S}$ isotope patterns in bowhead whale muscle tissue and variability within the Bering Sea population is limited. Stable sulfur isotope values did not vary with $\delta^{13}\text{C}$ enrichment for three consecutive seasons ($n = 53$) and this suggests

that habitat selection by bowhead whales was consistent over the sampling period. We found that in contrast to other studies, seasonal differences (spring versus fall) in $\delta(13)C$ values were not associated with seasonal changes in $\delta(15)N$ values, suggesting either that bowhead whales maintain a consistently lower trophic position relative to other marine mammals or that stable carbon and nitrogen isotope fractionation is tissue-dependent and (or) isotope-dependent within this species. Seasonal fluctuation in $\delta(13)C$ values was consistent for all age classes of bowhead whales and suggests that the Bering and Beaufort seas are both important regions for feeding.

Hoekstra, P. F.; O'Hara, T. M.; Pallant, S. J.; Solomon, K. R., and Muir, D. C. G. 2002. Bioaccumulation of Organochlorine Contaminants in Bowhead Whales (*Balaena mysticetus*) from Barrow, Alaska. Archives of Environmental Contamination and Toxicology. May; 42(4).

Keywords: technical toxaphene/ Atlantic right whale/ marine food web/ Northwater Polynya/ persistent organochlorines/ *Balaenoptera acutorostrata*/ polychlorinated biphenyls/ *Eubalaena glacialis*/ aquatic biota/ bowhead whale/ *Balaena mysticetus*/ Alaska/ DDT/ chlordanes/ chlorobenzene/ hexachlorocyclohexane/ DDE/ biomagnification/ bioaccumulation

Abstract: Bowhead whale (*Balaena mysticetus*) blubber (n = 72) and liver (n = 23) samples were collected during seven consecutive subsistence harvests (1997-2000) at Barrow, Alaska, to investigate the bioaccumulation of organochlorine contaminants (OCs) by this long-lived mysticete. The rank order of OC group concentrations (geometric mean, wet weight) in bowhead blubber samples were toxaphene (TOX; 455 ng/g) > polychlorinated biphenyls (SigmaPCBs 410 ng/g) > dichlorodiphenyltrichloroethane-related compounds (SigmaDDT; 331 ng/g) greater than or equal to hexachlorocyclohexane isomers (SigmaHCHs; 203 ng/g) greater than or equal to chlordanes and related isomers (SigmaCHLOR; 183 ng/g) > chlorobenzenes (SigmaClBz, 106 ng/g). In liver, SigmaHCH (9.5 ng/g; wet weight) was the most abundant SigmaOC group, followed by SigmaPCBs (9.1 ng/g) greater than or equal to TOX (8.8 ng/g) greater than or equal to SigmaCHLOR (5.5 ng/g) > SigmaClBz (4.2 ng/g) greater than or equal to SigmaDDT (3.7 ng/g). The dominant analyte in blubber and liver was p,p'-DDE and alpha-HCH, respectively. Total TOX, SigmaPCBs, SigmaDDT, and SigmaCHLOR concentrations in blubber generally increased with age of male whales (as interpreted by body length), but this relationship was not significant for adult female whales. Biomagnification factor (BMF) values (0.1-45.5) for OCs from zooplankton (*Calanus* sp.) to bowhead whale were consistent with findings for other mysticetes. Tissue-specific differences in OC patterns in blubber and liver may be attributed to variation of tissue composition and the relatively low capacity of this species to biotransform various OCs. Principal component analysis of contaminants levels in bowhead blubber samples suggest that proportions of OCs, such as beta-HCH, fluctuate with seasonal migration of this species between the Bering, Chukchi, and Beaufort Seas.

Hoekstra, P. F.; Wong, C. S.; O'Hara, T. M.; Solomon, K. R.; Mabury, S. A., and Muir, D. C. G. 2002. Enantiomer-Specific Accumulation of PCB Atropisomers in the Bowhead Whale (*Balaena mysticetus*). Environmental Science & Technology. Apr 1; 36(7).

Keywords: polychlorinated biphenyl congeners/ *Narwhal monodon monoceros*/ *Delphinapterus leucas*/ organochlorine contaminants/ *Balaenoptera acutorostrata*/ marine environment/ Mediterranean Sea/ cytochromes P450/ food chain/ metabolism/ bowhead whale/ *balaena mysticetus*

Abstract: Blubber ($n = 40$) and liver ($n = 20$) samples from the bowhead whale (*Balaena mysticetus*) were collected during the 1997-1998 Native (Inuit) subsistence harvests in Barrow, AK. Bowhead tissues and zooplankton were analyzed for polychlorinated biphenyl (PCB) concentrations and the enantiomeric fractions (EFs) of eight chiral PCB congeners (PCB 91, 95, 135, 136, 149, 174, 176, and 183) to quantify the enantiomer-specific accumulation of PCBs in this cetacean. PCB concentrations in bowhead blubber were low (mean \pm 1 SE: 610 \pm 54 ng g⁻¹ lipid) relative to other cetaceans. The accumulation of several chiral PCBs (PCB 91, 135, 149, 174, 176, and 183) in bowhead blubber was enantiomer-specific relative to bowhead liver and zooplankton, suggesting that biotransformation processes within the bowhead whale are enantioselective. The EFs for PCB 95 and 149 were significantly correlated with body length in male and female whales, while EFs for PCB 91 correlated with length in males only. Despite evidence for enantioselective biotransformation, all three congeners bioaccumulated in the bowhead relative to PCB 153. Results suggest that enantioselective accumulation of PCB 91, 95, and 149 is influenced by PCB concentrations, age, and/or the modification of an uncharacterized stereoselective process (or processes) during sexual maturity.

Hudak, D. R. and Young, J. M. C. 2002. Storm Climatology of the Southern Beaufort Sea. Atmosphere-Ocean. Jun; 40(2).

Keywords: ice cover/ El-Nino/ Tuktoyaktuk/ hemisphere/ features/ Canada/ trends/ cycles/ water/ warm/ Beaufort Sea

Abstract: Building on the expertise from the Beaufort Weather Office, an objective method of identifying storm periods in the southern Beaufort Sea area based on surface wind speed criteria was developed. Algorithms that used hourly observations from Tuktoyaktuk and Sachs Harbour were trained to identify storm periods over the southern Beaufort Sea. The Master List produced by Eid and Cardone (1992) was used as a training set to tune the algorithms. A check with independent observations taken by a drilling platform verified the soundness of the approach. The National Centers for Environmental Prediction (NCEP) reanalysis dataset was used to characterize storm type. In doing so, upper air data were introduced to the classification process. The important variables were 50-kPa wind speed and direction, and the 85-kPa temperature. The former variable is a reflection of the steering current of the storm systems while the latter is related to airmass characteristics within the storm system. The algorithms were applied to the 1970 to 1995 time period for the months of June to November inclusive. On the average, there were 14 storms per storm season, with a standard deviation of 5. The years 1976 to 1982 were the most stormy with an average of 19 storms per storm season. There was no discernable trend in the storm frequency over the 25-year period. By month, October had the highest storm frequency, July the lowest. The average 50-kPa wind direction during storm periods was used to classify the storms as Arctic, Pacific or Irregular. The three storm types were further subdivided based on the average 50-kPa wind speed and the 85-kPa temperature change. Overall, 58% of

the storms were Arctic, 27% Pacific and 15% Irregular. There was an indication that Pacific storms have become less frequent in recent years. This decrease was the result of an absence of Pacific storms associated with relatively small net 85-kPa temperature changes. The data were then stratified by El Nino episodes. There were more storms during El Nino years because of an increase in Arctic storms. However, despite this overall increase, there was a decrease in the percentage of Arctic storms associated with strong cold air outbreaks. This storm information was used to aid in the interpretation of two studies related to conditions in 1994. The first was the Beaufort and Arctic Storms Experiment and the second the 1994/95 water year of the Mackenzie River basin.

Krembs, C.; Eicken, H.; Junge, K., and Deming, J. W. 2002. High Concentrations of Exopolymeric Substances in Arctic Winter Sea Ice: Implications for the Polar Ocean Carbon Cycle and Cryoprotection of Diatoms. Deep-Sea Research Part I-Oceanographic Research Papers. Dec; 49(12).

Keywords: Arctic/ sea ice/ polysaccharides/ exopolymers/ diatom/ carbon/ dissolved organic-matter/ nutrient concentrations/ microbial biofilms/ particles tep/ Weddell Sea/ pack ice/ water/ growth/ brine/ temperatures

Abstract: Exopolymeric substances (EPS) produced by microorganisms play important roles in various aquatic, porous, and extreme environments. Only recently has their occurrence in sea ice been considered. We used macroscopic and microscopic approaches to study the content and possible ecological role of EPS in wintertime fast ice near Barrow, Alaska (71 degrees 20' N, 156 degrees 40' W). Using Alcian blue staining of melted ice samples, we observed high concentrations of EPS in all samples examined, ranging from 0.79 to 7.71 mg xanthan gum equivalents (XGEQV)1(-1). Areal conversions to carbon equivalents yielded 1.5-1.9gCm(-2) ice in March and 3.3-4.0gCm(-2) in May (when the ice was thicker). Although EPS did not correlate with macronutrient or pigment data, the latter analyses indicated ongoing or recent biological activity in the ice within temperature horizons of -11degreesC to -9degreesC and warmer. EPS correlated positively with bacterial abundance (although no functional relationship could be deduced) and with dissolved organic carbon (DOC) concentrations. Ratios of EPS/DOC decreased at colder temperatures within the core, arguing against physical conversion of DOC to EPS during freezing. When sea-ice segments were maintained at representative winter temperatures (-5 degrees C, -15 degrees C and -25 degrees C) for 3-14 months, the total EPS content increased significantly at rates of 5-47 mug XGEQV1(-1)d(-1), similar to published rates of EPS production by diatoms. Microscopic images of ice-core sections at these very cold temperatures, using a recently developed non-invasive method, revealed diatoms sequestered in spacious brine pockets, intact autofluorescent chloroplasts in 47% of the (pennate) diatoms observed, and indications of mucus in diatom-containing pores. The high concentrations of EPS detected in these winter ice cores represent a previously unrecognized form of organic matter that may contribute significantly to polar ocean carbon cycles, not only within the ice but after springtime release into the water column. The EPS present in very high concentrations in the brine of these microhabitats appear to play important buffering and cryoprotectant roles for microorganisms, especially diatoms, against harsh winter conditions of high salinity and potential ice-crystal damage.

Krutzikowski, G.K. and Mate, B.R. 2000. Dive and surfacing characteristics of bowhead whales (*Balaena mysticetus*) in the Beaufort and Chukchi Seas. *Can. J. Zool.* 78: 1182-1198.

Keywords: Beaufort Sea/ Chukchi Sea/ bowhead whale/ *Balaena mysticetus*/ ice cover/ whale diving depth/ whale diving duration

Abstract: We received data from eight bowhead whales instrumented with satellite-monitored radio tags for 3 to 33 days. Of 42,306 dives made by eight whales during 1,695 h, 9,573 were sounding dives (>1 min). Mean duration of sounding dives for individuals varied from 6.9 to 14.1 min ($= 10.4 \pm 2.4$ min, $n = 8$). Five whales recorded dives ≥ 61 min; longest dives for the other three were 56, 45, and 32 min. Five tags measured maximum depths of 29,499 dives during 1220 h and time-at-depth during 1228 h. All five whales dived >100 m; the deepest dive was 352 m. Whales spent most of their time at depths ≤ 16 m, but three whales spent most of their time >48 m during some sampling periods. Mean surfacing rates ranged from 18.2 to 47.0 surfacings/h ($= 26.2 \pm 9.0$, $n = 8$). Tags were exposed to air 4.0 to 7.3% of the time ($= 5.5 \pm 0.95$, $n = 8$), and whales were potentially visible from aircraft 8.5 to 16.4% of the time ($= 11.1 \pm 2.4$, $n = 8$). Three whales made longer sounding dives and had lower surfacing rates when in ice cover >90%. No consistent diet patterns were found.

Kucklick, J. R.; Struntz, W. D. J.; Becker, P. R.; York, G. W.; O'Hara, T. M., and Bohonowych, J. E. 2002. Persistent Organochlorine Pollutants in Ringed Seals and Polar Bears Collected From Northern Alaska. *Science of the Total Environment.* Mar 15; 287(1-2).

Keywords: ringed seal/ polar bear/ Alaska/ Arctic/ persistent organochlorine pollutants/ organochlorines/ bioaccumulation/ polychlorinated biphenyl congeners/ marine food chains/ *Phoca hispida*/ *Ursus maritimus*/ Northwest Territories/ contaminant levels/ temporal trends/ bowhead whales/ pesticides/ blubber

Abstract: Blubber samples from ringed seal (*Phoca hispida*; $n = 8$) and polar bear subcutaneous fat (*Ursus maritimus*; $n = 5$) were collected near Barrow, Alaska in 1996 as part of the Alaska Marine Mammal Tissue Archival Project (AMMTAP) and retained in the National Biomonitoring Specimen Bank at the National Institute of Standards and Technology in Gaithersburg, Maryland (USA). The samples were analyzed for a variety of persistent organochlorine pollutants (POPs) including polychlorinated biphenyls (PCBs), hexachlorocyclohexanes (HCHs), chlordane and metabolites, hexachlorobenzene (HCB) and DDTs and metabolites. The geometric mean, on a wet mass basis, of SigmaPCBs (sum of 29 congeners and congener groups) were 732 ± 282 ng/g (1 SD) in seals and 3395 ± 1442 ng/g in polar bears. The geometric mean of SigmaDDTs, SigmaHCHs (alpha-, beta- and gamma- HCH) and HCB concentrations (wet mass basis) in seals and bears were 562 ± 261 ng/g vs. 74.8 ± 39 ng/g, 380 ± 213 ng/g vs. 515 ng/g, and 17.4 ± 10.1 ng/g vs. 183 ± 153 ng/g, respectively. The geometric mean sum of chlordane (Sigma chlordane, sum of cis- and trans-chlordane, cis- and trans-nonachlor, oxychlordane and heptachlor epoxide) and dieldrin concentrations in ringed seals and polar bears were 753 ± 617 ng/g vs. 720 ± 315 ng/g and 38.6 ± 22.8 ng/g vs. 130

+/- 65 ng/g, respectively. Apparent bioaccumulation factors (polar bear/ringed seal POP concentrations) were lower in the animals sampled near Barrow, Alaska than in those from locations in the Canadian Arctic. This suggests that polar bears are also preying on marine mammals from lower trophic levels than the ringed seals with correspondingly lower organochlorine levels, such as bowhead whale carcasses. PCB congener patterns in the samples demonstrated the metabolism of certain PCB congeners in the polar bear relative to the ringed seal in agreement with previous studies. Regional comparisons of animals collected in Alaska and Arctic Canada are presented.

Kumar, K. S.; Kannan, K.; Corsolini, S.; Evans, T.; Giesy, J. P.; Nakanishi, J., and Masunaga, S. 2002. Polychlorinated Dibenzo-P-Dioxins, Dibenzofurans and Polychlorinated Biphenyls in Polar Bear, Penguin and South Polar Skua. *Environmental Pollution*. 119(2).

Keywords: Antarctic/ Arctic/ PCBs/ PCDD/ DF/ polar bear/ penguin/ South Polar Skua/ isomer-specific analysis/ Mediterranean Sea/ breeding season/ risk assessment/ marine mammals/ PCBs/ Antarctica/ pollution/ seabirds

Abstract: Concentrations of 2378-substituted polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (DFs) and non- and mono-ortho-substituted polychlorinated biphenyls (dioxin-like PCBs) were measured in livers of polar bears from the Alaskan Arctic and in eggs of Adelie penguin and south polar skua and weddell seal liver, fish and krill from Antarctica. This is one of the first reports to document the concentrations of PCDDs/DFs in polar bear livers from Alaska, and in penguin and skua eggs from Antarctica. Concentrations of total PCDD/DFs in livers of polar bears ranged from 8 to 66 (mean: 26) pg/g, on a lipid weight basis. Concentrations of total PCDD/DFs in Antarctic samples were in the increasing order on a lipid weight basis; weddell seal liver (8.9 pg/g) < fish (11-17 pg/g) < krill (27 pg/g) < penguin eggs (mean: 23 pg/g) < south polar skua eggs (mean: 181 pg/g). Concentrations of dioxin-like PCBs (including two di-ortho congeners) in polar bear livers were in the range of 1080-3930 ng/g, lipid wt. Concentrations of dioxin-like PCBs in Antarctic samples were in the following order on a lipid weight basis; south polar skua eggs (mean: 1440 ng/g) >> penguin eggs (30 ng/g) > seal liver (57 ng/g) > fishes (6.2 ng/g) > krill (0.9 ng/g). Concentrations of 2378-tetrachlorodibenzo-p-dioxin equivalents (TEQs) calculated based on the WHO TEFs were higher in the eggs of polar skua (mean: 344; range: 220-650 pg/g, lipid wt.) from Antarctica than in polar bear livers from Alaska (mean: 120; range: 69-192 pg/g). In general, concentrations of PCDFs were greater than those of PCDDs in polar organisms. 23478-PeCDF is one of the dominant congener found in several samples. Concentrations of TEQs in polar bear livers and skua eggs were close to those that may cause adverse health effects. Dioxin-like PCBs, particularly, non-ortho coplanar PCBs were the major contributors to TEQ concentrations in penguin and skua eggs whereas mono-ortho PCBs accounted for a major portion of TEQs in polar bear livers.

Kumar, N.; Bird, K. J.; Nelson, P. H; Grow, J. A., and Evans, K. R. 2002. A Digital Atlas of Hydrocarbon Accumulations within and Adjacent to the National Petroleum Reserve Alaska (NPRA).

Keywords: National Petroleum Reserve Alaska/ NPRA/ Alpine Field/ petroleum reserves

Introduction: The United States Geological Survey (USGS) has initiated a project to reassess the hydrocarbon potential of the NPRA. Although exploration for hydrocarbons in the NPRA was initiated in 1944, it has taken fifty years for the first commercial discovery to be made. That discovery, the Alpine field (projected recoverable reserves of 430 million barrels), was made in 1994 along the eastern boundary of the NPRA. This field produces from a formation heretofore considered to be mostly a source rock. The Alpine discovery made such a reassessment necessary. As part of this assessment, we have compiled stratigraphic, structural, petrophysical, and seismic data related to nineteen accumulations within and nearby the NPRA. The goal is to provide basic documentation and a set of analog accumulations for the new assessment.

The first two displays of this atlas consist of a location map and a stratigraphic column showing the stratigraphic settings for the primary reservoir and source rocks for these accumulations. The third display is a table listing each accumulation and providing the hydrocarbon fluid type, reservoir, operator, status, and discovery well and date for each. Compilation of basic information for each individual accumulation follows these displays. A typical compilation includes a structure contour map on or near the reservoir horizon, a log display of the discovery well with reservoir characteristics along with figures for recoverable volumes, and one or two seismic lines across or near the accumulation.

Marquette, W. M. 2002. Annotated bibliography of the bowhead whale, *Balaena mysticetus*, 1767-1983.

Keywords: bowhead whale/ *Balaena mysticetus*/ Alaskan Eskimos/ whaling/ bibliography

Abstract: The bowhead whale, *Balaena mysticetus*, is now an endangered species following an intensive commercial fishery for this cetacean for about 300 years, first in the North Atlantic Arctic from 1610 to 1910, then in the North Pacific Arctic from 1848 to 1910. The intensive annual hunt by hundreds of whaling vessels reduced the estimated residual bowhead population in the North Atlantic Ocean to a few hundred animals and that in the North Pacific Ocean to one or two thousand. Because of the precarious status of the bowhead, beginning in 1972 the Scientific Committee of the International Whaling Commission (IWC) expressed concern about the lack of information on the status of the western Arctic bowhead, especially because of the continuing annual harvest by Alaskan Eskimos for subsistence and cultural purposes. The IWC was specifically concerned by the lack of information on population abundance, on the size of and trends in the subsistence harvest, and on the number of whales which were struck and lost during the hunt. As part of a research program begun in 1973 by the National Marine Mammal Laboratory, an extensive search of the literature was conducted to obtain information needed by scientists studying the natural history and historical record of the shore-based whaling effort and catch for this endangered species. References on commercial whaling also were collected. The results of the literature search are presented here as an annotated bibliography of selected references on the bowhead whale covering the period of 1767 to 1983.

Masterson, W.D. 2000. Petroleum generation, migration, and filling history models for the Prudhoe Bay, Kuparuk, and West Sak fields, North Slope, Alaska. Amer. Assoc. Petrol Geol. Annual Meeting, New Orleans, Louisiana, April 16-19.

Keywords: North Slope/ Alaska/ Prudhoe Bay/ Kuparuk/ West Sak/ petroleum generation/ Shublik formation/ Kingak shale

Abstract: The petroleum generation and migration history of the central Alaskan North Slope coast between the Canning and Colville Rivers was reconstructed with map-based burial history models. Regional structure maps of 6 horizons were combined with source rock oil generation kinetics for Triassic marine carbonate (Shublik Formation), Cretaceous marine shale (HRZ Formation), and Jurassic marine shale (Kingak Formation) to model the filling history of the Prudhoe Bay, Kuparuk, and West Sak fields. Maximum burial of source rocks in the central Alaskan North Slope occurred between Middle Eocene and Late Oligocene time (~ 45 to 23 myBP). Shublik source rock is buried less than 500 feet deeper than the Kingak Shale source interval, but generated hydrocarbons much earlier because Shublik kerogen is sulfur-rich and transforms to hydrocarbons at lower temperatures than the marine shales of the Kingak Formation.

Prudhoe Bay field oil in the Triassic Ivishak sandstone reservoir was generated primarily from Shublik and HRZ source rocks to the south and east. Oils in Jurassic Sag River sandstone reservoirs on the northwestern side of the Prudhoe Bay field are mixtures co-sourced from Shublik carbonate and Kingak shale. Kuparuk field oils migrated vertically through faults that connect their predominant Shublik source with the Lower Cretaceous Kuparuk River Formation. West Sak field oil is a moderately biodegraded oil mixture that spilled from the Prudhoe Bay field into Upper Cretaceous West Sak sandstone reservoirs, and a lightly biodegraded secondary gas/condensate charge that leaked up faults from the underlying Kuparuk field.

Masterson, W. D.; Dzou, L. I. P.; Holba, A. G.; Fincannon, A. L., and Ellis, L. 2001. Evidence for Biodegradation and Evaporative Fractionation in West Sak, Kuparuk and Prudhoe Bay Field Areas, North Slope, Alaska. *Organic Geochemistry*. 32(3).

Keywords: evaporative fractionation/ biodegradation/ isotopes/ Alaska/ Kuparuk/ West Sak/ Prudhoe Bay/ petroleum migration/ biomarkers/ GC/ IRMS/ light hydrocarbons/ natural gas/ geochemical characterization/ isotopic fractionation/ compositional changes/ crude oils/ petroleum/ carbon/ degradation/ reservoir

Abstract: Oils from the West Sak, Kuparuk, and Prudhoe Bay fields on the North Slope of Alaska display geochemical evidence for a complex petroleum filling history that includes multiple sources and alteration by evaporative fractionation and biodegradation. Source-specific biomarkers in West Sak oils indicate generation from the same source rocks in approximately the same proportions as Prudhoe Bay field oil, consistent with the hypothesis that oil spilled from the deeper Prudhoe accumulation and remigrated about 10 miles laterally and 5000 feet vertically into the West Sak Field. West Sak oils are moderately biodegraded but exhibit anomalously high concentrations of gasoline-range saturate and aromatic compounds interpreted as a secondary

gas/condensate charge that arrived after biodegradation of the spilled Prudhoe oil. The shallowest West Sak oils have less secondary gas/condensate charge, lower API gravities, and reduced concentrations of methylcyclopentane, benzene, cyclohexane, 3-methylhexane, heptane, methylcyclohexane, and toluene relative to the deepest West Sak Zone A oils. The carbon isotopic compositions of these C-6 and C-7 compounds in the shallowest West Sak reservoirs are heavier than those of the deepest West Sak oil reservoirs by up to 3 parts per thousand and the isotopic compositions of saturate compounds are altered more than those of aromatic compounds. The heavier isotopic compositions of C-6 and C-7 compounds in the shallow West Sak reservoirs are interpreted to result from a kinetic isotope shift caused by light biodegradation of the secondary gas/condensate charge. West Sak field solution gas is also interpreted as biodegraded, based upon its dryness (>98% methane), relatively high isobutane/n-butane ratio, the presence of isotopically heavy carbon dioxide acid isotopically light methane, and propane that is isotopically heavier than either ethane or butane. The isotopic compositions of methane and carbon dioxide in West Sak gas suggest that biogenic methane was generated during CO₂ reduction under anaerobic conditions. The isotopic compositions of C-6 and C-7 compounds in the deepest, least biodegraded West Sak oils are nearly identical to those of the underlying oils from the Kuparuk Field but differ from the Prudhoe Bay Field oils. The Kuparuk Field is therefore postulated as the source of the secondary gas/condensate charge observed in oils from the West Sak Field. Ratios of toluene/heptane and heptane/methylcyclohexane in Kuparuk oils provide independent evidence for loss of gas and condensate from the Kuparuk reservoir by the process of evaporative fractionation, and the oils subjected to the most evaporative fractionation are isotopically heavier in the C-6-C-7 range. The isotopic compositions of West Sak zone A C₆ and C₇ hydrocarbons suggest that a slight (similar to 0.8 parts per thousand) isotopic fractionation resulted from evaporative fractionation of the gas/condensate charge from the Kuparuk Field oil accumulation. North/northeast-striking faults that connect the Kuparuk and West Sak reservoirs provide a potential migration pathway for the secondary gas/condensate charge through 3000 feet of intervening shale. This model of West Sak oil biodegradation, subsequent secondary gas/condensate charge, and further biodegradation has implications for development of North Slope West Sak oil reserves, because heavily biodegraded West Sak oils that lack a secondary gas/condensate charge may be too viscous to develop by conventional waterflooding methods.

Mate, B. R.; Krutzikowsky, G. K., and Winsor, M. H. 2000. Satellite-monitored movements of radio-tagged bowhead whales in the Beaufort and Chukchi Seas during the late-summer feeding season and fall migration. *Can. J. Zool.* 78: 1168-1181.

Keywords: Beaufort Sea/ Mackenzie River Delta/ Chukchi Sea/ bowhead whale/ *Balaena mysticetus*/ satellite monitoring/ migration

Abstract: From 30 August to 6 September 1992, 12 juvenile bowhead whales were tagged with Argos satellite-monitored radio tags in the Canadian Beaufort Sea off the Mackenzie River Delta. Eight tags documented 9,820 km of movements between 392 locations during 111 whale-tracking days. The whales did not move in unison. Individual movements and average speeds (1.1 to 5.8 km/h) varied widely. One whale stayed in Mackenzie Bay for 23.5 d while the rest stayed an average of only 2.4 d. The majority of locations for all whales were in shallow water:

65% in <50 m and 87% in <100 m. Seven whales went into water >100 m and four were in water >500 m. The whale with the longest record traveled „3886 km to Siberia in 32.5 d, averaging 5.0 km/h. Its westerly route through the Beaufort and Chukchi Seas was between 70 to 72°N and primarily in heavy ice (ca. 90% coverage), which was continuous west of 151°W. This whale's speed was not significantly slower in heavy ice than in more open water. This is the first documentation of the detailed route and speed for a bowhead whale during its fall migration from Canadian to Russian waters.

Matthiessen, J.; Kunz-Pirrung, M., and Mudie, P. J. 2000. Freshwater Chlorophycean Algae in Recent Marine Sediments of the Beaufort, Laptev and Kara Seas (Arctic Ocean) as Indicators of River Runoff. *International Journal of Earth Sciences*. Dec; 89(3).

Keywords: Arctic Ocean/ Beaufort Sea/ Laptev Sea/ Kara Sea/ recent sediments/ chlorophyte distribution/ freshwater discharge/ St-Erth Beds/ Southwestern England/ Western Kara/ ice/ water/ shelf/ assemblages/ entrainment/ microalgae/ quaternary

Abstract: Freshwater chlorophycean algae are characteristic organic-walled microfossils in recent coastal and shelf sediments from the Beaufort, Laptev and Kara seas (Arctic Ocean). The persistent occurrence of the chlorophycean algae *Pediastrum spp.* and *Botryococcus cf. braunii* in marine palynomorph assemblages is related to the discharge of freshwater and suspended matter from the large Siberian and North American rivers into the Arctic shelf seas. The distribution patterns of these algae in the marine environments reflect the predominant deposition of riverine sediments and organic matter along the salinity gradient from the outer estuaries and prodeltas to the shelf break. Sedimentary processes overprint the primary distribution of these algae. Resuspension of sediments by waves and bottom currents may transport sediments in the bottom nepheloid layer along the submarine channels to the shelf break. Bottom sediments and microfossils may be incorporated into sea ice during freeze-up in autumn and winter leading to an export from the shelves into the deep sea. The presence of these freshwater algae in sea ice and bottom sediments in the central Arctic Ocean confirm that transport in sea ice is an important process which leads to a redistribution of shallow water microfossils.

Moore, S. E. 2000. Variability of Cetacean Distribution and Habitat Selection in the Alaskan Arctic, Autumn 1982-91. *Arctic*. Dec; 53(4).

Keywords: Alaska/ Arctic/ Beaufort Sea/ bowhead whale/ Chukchi Sea/ gray whale/ habitat selection/ white whale/ Cod/ *Boreogadus Saida*/ interannual variability/ Bering Strait/ Chukchi Sea/ climatic change/ aerial surveys/ ice extent/ waters/ ocean

Abstract: Ten years (1982-91) of autumn sighting data from aerial surveys offshore northern Alaska were analyzed to investigate variability in cetacean distribution and habitat selection. Habitat selection indices were calculated for bowhead, white, and gray whales in heavy, moderate, and light ice conditions; and for high, moderate, and low transport (inflow) conditions at Bering Strait. Bowhead whales selected shallow inner-shelf waters during moderate and light ice, and deeper slope habitat in heavy ice conditions (chi (2), $p < 0.05 - 0.001$). White whales

selected slope habitat (chi (2), $p < 0.001$), and gray whales selected coastal/shoal and shelf/trough habitat (chi (2), $p < 0.025 - 0.001$), in all ice conditions. In the Alaskan Beaufort Sea, bowheads selected shelf waters and white whales chose slope waters, without regard to transport conditions (chi(2), $P < 0.01 - 0.001$). In the northern Chukchi Sea, gray whales selected coastal/shoal habitat in high transport conditions (chi(2), $p < 0.005$), and shelf/trough habitat (chi(2), $p < 0.001$) during moderate and low transport conditions. Variability in distribution and habitat selection among these species is likely linked to prey availability at dissimilar trophic levels, although this hypothesis has yet to be rigorously tested.

Moore, S.E.; DeMaster, D.P.; and Dayton, P.K. 2000. Cetacean Habitat Selection in the Alaskan Arctic during Summer and Autumn. *Arctic* 53(4): 432-447.

Keywords: Alaska/ Arctic/ Beaufort Sea/ Chukchi Sea/ bowhead whale/ *Balaena mysticetus*/ white whale/ *Delphinapterus leucas*/ gray whale/ *Eschrichtius robustus*/ habitat selection

Abstract: Ten years (1982 to 1991) of sighting data from aerial surveys offshore of northern Alaska were analyzed to investigate seasonal variability in cetacean habitat selection. Distinct habitats were described for bowhead whales (*Balaena mysticetus*), white whales (*Delphinapterus leucas*), and gray whales (*Eschrichtius robustus*) on the basis of habitat selection ratios calculated for bathymetric and ice-cover regimes. In summer, bowheads selected continental slope waters and moderate ice conditions; white whales selected slope and basin waters and moderate to heavy ice conditions; and gray whales selected coastal/shoal waters and open water. In autumn, bowheads selected inner-shelf waters and light ice conditions; white whales selected outer-shelf and slope waters and moderate to heavy ice; and gray whales selected coastal and shoal/trough habitats in light ice and open water. Habitat differences among species were significant in both seasons (ANOVA $F > 28$, $p < 0.00001$). Interseasonal depth and ice-cover habitats were significantly different for bowhead whales ($p < 0.00002$), but not for gray whales ($p > 0.35$). White whale depth habitat was significantly different between seasons ($p < 0.00002$), but ice cover was not ($p < 0.08$).

Moran, S. B. and Smith, J. N. 2000. Th-234 as a Tracer of Scavenging and Particle Export in the Beaufort Sea. *Continental Shelf Research*. Jan; 20(2).

Keywords: thorium/ scavenging/ particles/ Beaufort Sea/ particulate organic carbon/ Western Arctic Ocean/ disequilibria/ seawater/ nitrogen/ profiles/ water/ flux

Abstract: Water column measurements of Th-234 were made at three stations in the shelf-slope regime and one offshore station in the Beaufort Sea, August-September 1995, to quantify rates of scavenging and particle export. Large-volume water samples (200-600l) were collected in situ and dissolved and particulate Th-234 activities determined at-sea. Th-234/U-238 disequilibrium was evident at all locations. The distribution of the total Th-234/U-238 activity ratio reveals a transition, centered at the shelf break, from low values (0.4-0.6) over the shelf to elevated values approaching secular equilibrium offshore. These results further constrain the extent to which shelf scavenging and lateral transport contribute to Th-234/U-238 disequilibrium in the Arctic

interior. Residence times of dissolved Th-234 range from similar to 25-50 disequilibrium in the shelf and slope waters to similar to 150 d offshore, compared to similar to 12-18 d for particulate ²³⁴Th. Estimates of POC export from the upper 50 m derived from Th-234 range from similar to 4-7 mmol C m⁻² d⁻¹ over the shelf to similar to 1-2 mmol C m⁻² d⁻¹ in the slope waters and central Beaufort.

Moulton, V. D.; Richardson, W. J.; McDonald, T. L.; Elliott, R. E., and Williams, M. T. 2002. Factors Influencing Local Abundance and Haulout Behaviour of Ringed Seals (*Phoca hispida*) on Landfast Ice of the Alaskan Beaufort Sea. *Canadian Journal of Zoology*. Nov; 80(11).

Keywords: breeding habitat/ Northwest Territories/ Barrow Strait/ out patterns/ harp seals/ predation/ Vitulina/ Groenlandica/ Svalbard/ females/ Beaufort Sea/ ringed seals/ *Phoca hispida*

Abstract: This study investigates how the local abundance of ringed seals (*Phoca hispida*) on landfast ice of the central Alaskan Beaufort Sea is related to habitat factors and how the haulout behaviour of seals is influenced by temporal and weather factors. An understanding of these relationships is required before the potential impacts of industrial activity on ringed seals can be assessed. Intensive and replicated aerial surveys employing strip transect methodology were conducted during the springs of 1997-1999. Data were examined with chi(2) tests and Poisson regression. The overall observed densities of ringed seals over water depths >3 m was 0.43, 0.39, and 0.63 seals/km(2) in 1997-1999, respectively. Significantly more seals occurred over intermediate water depths, especially 10-20 m. In all years, seals were widely distributed on the landfast ice, but during breakup, higher numbers of seals occurred near the ice edge. Densities were significantly lower in areas with high ice deformation and extensive melt water. There was no consistent relationship between seal sightings and time of day within the 10:00-18:00 period with surveys. The peak period of haulout occurred around 1 and 2 June. Significantly more ringed seals were observed on warm, cloudy days. There was no indication that limited winter industrial activity, including ice roads and Vibroseis, occurring within the study area in 1997-1999 significantly affected ringed seal density in spring.

Naidu, A. S.; Cooper, L. W.; Finney, B. P.; MacDonald, R. W.; Alexander, C., and Semiletov, I. P. 2000. Organic Carbon Isotope Ratios (delta C-13) of Arctic Amerasian Continental Shelf Sediments. *International Journal of Earth Sciences*. Dec; 89(3).

Keywords: Arctic Amerasian Shelf/ sediment carbon and nitrogen isotopes/ Chukchi Seas/ trophic relationships/ delta-N-15 analysis/ surface sediments/ coastal sediments/ margin sediments/ Mackenzie River/ food webs/ matter/ ocean

Abstract: Organic matter origins are inferred from carbon isotope ratios (delta C-13) in recent continental shelf sediments and major rivers from 465 locations from the north Bering-Chukchi-East Siberian-Beaufort Sea, Arctic Amerasia. Generally, there is a cross-shelf increase in delta C-13, which is due to progressive increased contribution seaward of marine-derived organic carbon to surface sediments. This conclusion is supported by the correlations between sediment

delta C-13, OC/N, and delta N-15. The sources of total organic carbon (TOC) to the Amerasian margin sediments are primarily from marine water-column phytoplankton and terrigenous C-3 plants constituted of tundra taiga and angiosperms. In contrast to more temperate regions, the source of TOC from terrigenous C-4 and CAM plants to the study area is probably insignificant because these plants do not exist in the northern high latitudes. The input of carbon to the northern Alaskan shelf sediments from nearshore kelp community (*Laminaria solidungula*) is generally insignificant as indicated by the absence of high sediment delta C-13 values (-16.5 to -13.6 parts per thousand) which are typical of the macrophytes. Our study suggests that the isotopic composition of sediment TOC has potential application in reconstructing temporal changes in delivery and accumulation of organic matter resulting from glacial-interglacial changes in sea level and environments. Furthermore, recycling and advection of the extensive deposits of terrestrially derived organic matter from land, or the wide Amerasian margin, could be a mechanism for elevating total CO₂ and pCO₂ in the Arctic Basin halocline.

National Marine Mammal Laboratory (NOAA). 2000. Summary Report. Workshop on the design of studies needed for the evaluation of cumulative impacts of oil and gas exploration and production on fall migrating bowhead whales and the fall bowhead whale subsistence hunt. *In:* Workshop Proceedings, Cumulative Effects of North Slope Oil and Gas Activities, Deadhorse, Alaska, July 9-14, 2001. U.S. National Academy of Sciences, Division on Earth and Life Studies. 19 pp.

Keywords: Beaufort Sea/ oil & gas exploration/ bowhead whale/ *Balaena mysticetus*/ cumulative impacts/ subsistence harvest/ behavior/ acoustic integration model/ industrial noise

Abstract: Workshop objectives are summarized for development of an approach to evaluate cumulative oil and gas exploration impacts in the Beaufort Sea upon bowhead whales for 1) the fall whale migration; 2) the fall subsistence harvest; 3) individual whale behavior (e.g., changes in breathing rates, swimming rates, and vocalizations); 4) use of feeding areas; and 5) whale contaminant loads. The workshop group determined relative study priorities, concluding that a multiyear study of noise impacts was the first priority with impacts related to air/water quality and visual disturbance being of lower priority. Cumulative impacts were defined as occurring from a single source over many years or from many sources within a single year. An acoustic integration model was presented to examine and predict changes in swimming behavior in response to noise sources. Types of data that are available and that are needed for an integrated model were discussed, with a recommendation that any model results be confirmed by follow-up monitoring. The workshop concluded that no survey methods currently exist which detect small-scale changes in bowhead migration paths (e.g., 1 to 2 km). An approach to designing a multi-year study to assess impacts on the whale subsistence hunt was discussed, including impacts to the hunt as it takes place on the water, as well as socio-cultural impacts from alteration of hunting patterns and potential loss of resources. Recommendations were presented for means of studying changes in individual whale behavior in response to industrial noise.

Noel, L. E.; Johnson, S. R., and O'Doherty, G. M. 2002. Aerial surveys of molting long-tailed ducks and other waterfowl in the barrier island-lagoon systems between Spy Island and

Brownlow Point, Alaska, 2001. Report for BP Exploration (Alaska) Inc. by LGL Alaska Research Associates, Inc., Anchorage, Alaska, USA. 122 p.

Keywords: central Alaska Beaufort Sea/ *Clangula hyemalis*/ eider/ glaucous gull/ *Larus hyperboreus*/ long-tailed duck/ marine waterbirds/ *Melanitta perspicillata*/ coter/ *Somateria mollissima v-nigrum*

Abstract: There is concern about declines in sea duck populations in western North America and Alaska. We collected aerial survey data for molting sea ducks and other waterfowl in central Alaskan Beaufort Sea barrier island-lagoon systems collected during July-August 2001. These data add to the 15 years of long-term monitoring data collected on the same survey transects over the 25-year period since 1977. Our study objectives were to determine current distribution and abundance of molting sea ducks and other waterfowl, and to compare current and historical numbers and distributions of long-tailed ducks (*Clangula hyemalis*) in the barrier island-lagoon system between Spy Island and Brownlow Point, Alaska. Three low-level aerial strip-transect surveys were conducted between 23 July-11 August 2001, covering 1986 linear km and 790 km². Long-tailed ducks comprised 78% of the avian fauna in July-August 2001. This is slightly lower than results since 1977 (80-98%) across this same survey area. Eiders, primarily common eiders (*Somateria mollissima v-nigrum*), were more abundant in the eastern lagoon system (west of the Arctic National Wildlife Refuge; mean density \pm standard error; 5.0 ± 2.13 eiders/km²); while scoters, primarily surf scoter (*Melanitta perspicillata*), were more abundant in the western lagoon system (west of Prudhoe Bay; 1.8 ± 0.43 scoters/km²). Geese and swans were most abundant along the mainland shoreline in the western lagoon (6.0 ± 2.04 geese/km²) and on tundra transects south of the eastern lagoon (4.1 ± 2.28 geese/km²). Gulls, primarily glaucous gulls (*Larus hyperboreus*), were more abundant in the western lagoon system (1.5 ± 0.78 gulls/km²), compared to the eastern lagoon system (0.8 ± 0.61 gulls/km²). During July-August 2001, density of long-tailed ducks was highest in the eastern lagoon system (18.5 ± 15.26 ducks/km²), followed by Stefansson Sound (9.5 ± 6.93 ducks/km²), the western lagoon system (8.1 ± 7.75 ducks/km²), and tundra (0.1 ± 0.10 ducks/km²). Throughout the survey area the total number of long-tailed ducks increased from 23 July ($n = 8,973$) to 8 August ($n = 14,736$) and then decreased on 11 August 2001 ($n = 3,169$). Mean density of long-tailed ducks within the entire survey area (combined western and eastern lagoons) during July and August declined from 1978-2001 ($P = 0.018$). Mean areal density declined for 9 of 16 western lagoon transects, 1 offshore, 4 barrier island, 2 lagoon, and 2 mainland, through the 3 summary time periods (1978-1984, 1989-1991, 1998-2001) between 1978 and 2001. In the eastern lagoon, mean long-tailed duck density decreased on 3 barrier island transects and 1 lagoon transect from 1989-1991 to 1998-200, while density on 2 mainland shoreline transects increased.

Noel, L. E.; Johnson, S. R.; O'Doherty, G. M., and Helmericks, J. W. 2002. The status of snow geese in the Sagavanirktok River delta area, Alaska: 2001 monitoring program. Report for BP Exploration (Alaska) Inc. by LGL Alaska Research Associates, Inc., Anchorage, Alaska, USA. 40 p.

Keywords: *Alopex lagopus*/ arctic fox/ *Chen caerulescens caerulescens*/ grizzly bear/ Howe Island/ lesser snow goose/ nesting colony/ *Ursus arctos*/ Sagavanirktok River

Abstract: The Sagavanirktok River delta population of lesser snow geese (*Chen caerulescens caerulescens*) was the only established nesting colony of this species in Alaska and the United States and the only nesting colony in proximity to an active oilfield for many years. A monitoring project was established in 1980 to investigate potential effects of the Endicott Development Project on the Sagavanirktok River delta snow goose population and has continued through 2001. The purpose of this long-term monitoring project is to census the nesting colony on Howe Island, assess productivity and disturbance effects, and document the distribution and movements of snow geese during molting and brood-rearing. We conducted an aerial photo survey of nesting lesser snow geese on Howe Island, Duck Island and other East Channel islands in the Sagavanirktok River delta on 17 and 22 June 2001, and ground-based nest searches on 9 July 2001. There were 428 and 474 snow geese observed in the 17 and 22 June 2001 photo surveys of Howe Island, Duck Island, and islands in the east channel of the Sagavanirktok River, respectively. Based on the ground nest search and aerial photo survey, we estimate 146 active snow goose nests were present in the Sagavanirktok River delta: 124 nests on Howe Island, 6 nests on Duck Island, and 16 nests on the east channel islands. Snow goose nesting effort in 2001 is lower than nesting efforts in the mid-1990's. Most snow geese failed to produce goslings in the Sagavanirktok River delta in 2001 as a result of nest predation by grizzly bears (*Ursus arctos*), arctic foxes (*Alopex lagopus*), glaucous gulls (*Larus hyperboreus*), and raven (*Corvus corax*). Grizzly bear predation on snow goose eggs during the June nesting period has been implicated in the total production failures on Howe Island in 1992, 1994, 1998, 2000, and 2001, and partial failure in 1999. Prior to 1989, there was little evidence of predation on Howe Island. Multiple nesting failures of the Howe Island colony, displacement of nesting activities to other islands in the Sagavanirktok River delta, and new oil and gas developments near traditionally used coastal brood-rearing areas have raised concerns about the status of the snow geese in the Sagavanirktok River delta.

Noel, L. E.; Rodrigues, R. J., and Johnson, S. R. 2002. Nesting status of the common eider in the central Alaskan Beaufort Sea, summer 2001. Report for BP Exploration (Alaska) Inc., by LGL Alaska Research Associates, Inc., Anchorage, Alaska. 66 p.

Keywords: arctic tern/ *Sterna paradisaea*/ driftwood habitat/ egg depredation/ glaucous gull/ *Larus hyperboreus*/ *Somateria mollissima v-nigrum*/ common eider/ Beaufort Sea

Abstract: Global sea duck populations appear to be in decline, including the Pacific race of the common eider (*Somateria mollissima v-nigrum*). Whether or not this decline is expressed in nest numbers found in the vicinity of Alaska's North Slope oilfields is not known. To assess the nesting status of common eiders in this region, common eider, glaucous gull (*Larus hyperboreus*), and arctic tern (*Sterna paradisaea*) nests were located on 9 barrier islands along the central Alaskan Beaufort Sea coast from Thetis Island to the Stockton Islands during 12-16 July 2001. Common eider nest were most numerous accounting for 82% (110 of 134) of all active nests within the approximately 308.1-ha area searched. Glaucous gull and arctic tern nests represented approximately 16% (21 of 134) and 2% (3 of 134), respectively, of all active nests. Mean and 95% confidence intervals of clutch size for common eider nests were 2.7 ± 0.43 eggs per nest ($n = 43$) and for glaucous gulls 2.4 ± 0.39 eggs per nest ($n = 16$). Active common eider

nests were not distributed evenly across islands and island groups searched during 2001 either in proportion to island surface area ($P < 0.001$), or in proportion to the available island area with driftwood habitat ($P < 0.001$). In both cases, there were more active nests on the McClure Island and Lion Point than expected, and fewer active nests on the Stockton Islands than expected. Of the islands searched during 2001, Narwhal Island supported the most active common eider nests (27%, 30 of 110) although nest density was highest on Duck Island #1&2 and on Lion Point. Duck Island #1&2 also supported the highest number and density of glaucous gull nests. Of the 620 active and failed common eider nest sites with habitat data, 3 nest sites (<1%) were within buildings, 23 nest sites (4%) had no driftwood, 307 nest sites (49%) were located in low-density driftwood, 218 (35%) were in medium-density driftwood, and 69 (11%) were in high-density driftwood. More active nests, than depredated nests, were found in high-density driftwood, and fewer were in low-density driftwood on islands searched during 2001 ($P < 0.001$). Active and depredated nests were distributed similarly within medium-density and no driftwood habitats. Predation by arctic fox and glaucous gulls at the islands searched in 2001 had a marked impact on nesting success of common eiders (82% of 620 nests were depredated). Because common eiders are long-lived and exhibit remarkable fidelity to nest sites, it seems reasonable to concentrate nest searches on those islands which consistently support large numbers of nesting eiders. The most productive nesting islands from 1970-2001 have included Cross Island (mean = 116.8 nests/year), Pole Island (mean = 59.1 nests/year), Stump Island (mean = 48.9 nests/year), Egg Island (W) (mean = 45.8 nests/year), Lion Point (mean = 48.0 nests/year), and Thetis Island (mean = 39.4 nests/year). During the period 1970-1991, many islands had 14 or more years of data. During the period 1998-2001 most islands had 3 years of data. The mean annual number of nests for 25 islands was lower during 1970-1991 (485 nests/year) than during 1998-2001 (589 nests/year). Variation for individual islands was high and the paired difference for 1970-1991 (19 ± 11.6 [95% confidence limit] nests/islands) and 1998-2001 (24 ± 13.3 [95% confidence limit] nests/island) by individual island was not significant ($P = 0.236$). Variation in timing of nest searches across years may influence the number of active nests counted because of missed late-initiated nests, early failed nests, or not recognizing some empty nests as hatched.

Outridge, P. M.; Hobson, K. A.; McNeely, R., and Dyke, A. 2002. A Comparison of Modern and Preindustrial Levels of Mercury in the Teeth of Beluga in the Mackenzie Delta, Northwest Territories, and Walrus at Igloodik, Nunavut, Canada. *Arctic*. Jun; 55(2).

Keywords: mercury/ beluga/ *Delphinapterus leucas*/ walrus/ temporal trends/ teeth/ *Odobenus rosmarus rosmarus*/ dated sediment cores/ lake sediments/ heavy metals/ *Delphinapterus leucas*/ Arctic lakes/ trace metals/ contaminants/ sea/ accumulation

Abstract: Mercury (Hg) concentrations were compared in modern and pre-industrial teeth of belugas (*Delphinapterus leucas*) and walrus (*Odobenus rosmarus rosmarus*) at sites in the Canadian Arctic so that the relative amounts of natural and anthropogenic Hg in modern animals could be estimated. Mercury levels in the teeth of Beaufort Sea belugas captured in the Mackenzie Delta, Northwest Territories, in 1993 were significantly ($p = 0.0001$) higher than those in archeological samples dated A.D. 1450-1650. In terms of geometric means, the Hg levels in modern animals were approximately four times as high as pre-industrial levels in 10-

year-old belugas, rising with age to 17 times as high in 30-year-olds. Because Hg levels in modern teeth were highly correlated with those in soft tissues, including muscle and muktuk, which are part of traditional human diets, it is likely that soft-tissue Hg has increased to a similar degree over the past few centuries. The increase was not due to dietary differences over time, as shown by analysis of stable-C and -N isotopes in the teeth, and was unlikely to be due to sex differences or to chemical diagenesis of historical samples. Industrially related Hg inputs to the Arctic Ocean and Canadian Arctic Archipelago may be the most likely explanation for the increase. If so, then 80-95% of the total Hg in modern Beaufort Sea belugas more than 10 years old may be attributed to anthropogenic activities. In contrast, tooth Hg concentrations in walrus at Igloodik, Nunavut, were no higher in the 1980s and 1990s than in the period A.D. 1200-1500, indicating an absence of industrial Hg in the species at this location.

Overland, J. E.; Wang, M. Y., and Bond, N. A. 2002. Recent Temperature Changes in the Western Arctic During Spring. *Journal of Climate*. Jul; 15(13).

Keywords: North Atlantic oscillation/ winter/ trends/ reanalysis

Abstract: The lower troposphere of the western Arctic (eastern Siberia to northern Canada) was relatively warm during spring in the 1990s. Based on the NCEP-NCAR reanalysis, supplemented by the Television Infrared Observational Satellite (TIROS) Operational Vertical Sounder (TOVS) Polar Pathfinder dataset, this warmth is a result of a recent increase in the frequency of warm months, compared to the previous four decades. The primary difference between four notably warm springs in the 1990s and four cold springs in the 1980s was the sense of the horizontal advection term in a lower-tropospheric heat budget for northern Alaska/southern Beaufort Sea. While the horizontal advection of heat was highly episodic, it was related to changes in the mean circulation at low levels, in particular a shift from anomalous northeasterly flow in the 1980s to anomalous southwesterly flow in the 1990s during March and April. This change in the low-level winds in the western Arctic coincided with a systematic shift in the Arctic Oscillation (AO) near the end of the 1980s, and reflects the equivalent barotropic nature of the AO. The stratospheric temperature anomalies associated with the AO were greatest in March; the low-level wind anomalies brought about near-surface temperature anomalies in northern Alaska that peaked in April. In addition to substantial decadal differences, there was considerable month-to-month and year-to-year variability within the last two decades.

Patenaude, N. J.; Richardson, W. J.; Smultea, M. A.; Koski, W. R.; Miller, G. W.; Wursig, B., and Greene, C. R. 2002. Aircraft Sound and Disturbance to Bowhead and Beluga Whales During Spring Migration in the Alaskan Beaufort Sea. *Marine Mammal Science*. Apr; 18(2).

Keywords: bowhead whale/ *Balaena mysticetus*/ beluga whale/ *Delphinapterus leucas*/ Beaufort Sea/ Alaska/ Arctic/ aircraft disturbance/ aircraft sound/ underwater noise/ helicopter/ behavior/ hearing thresholds

Abstract: Short-term behavioral responses of bowhead whales (*Balaena mysticetus*) and beluga whales (*Delphinapterus leucas*) to a Bell 212 helicopter and Twin Otter fixed-wing aircraft were

observed opportunistically during four spring seasons (1989-1991 and 1994). Behaviors classified as reactions consisted of short surfacings, immediate dives or turns, changes in behavior state, vigorous swimming, and breaching. The helicopter elicited fewer detectable responses by bowheads (14% of 63 groups) than by belugas (38% of 40). Most observed reactions by bowheads (63%) and belugas (86%) occurred when the helicopter was at altitudes less than or equal to 150 m and lateral distances less than or equal to 250 m. Belugas reacted significantly more frequently during overflights at lateral distances less than or equal to 250 m than at longer lateral distances ($P = 0.004$). When the helicopter was on the ice with engines running, 7 of 14 groups of belugas reacted, up to 320 m away, sometimes with small-scale (less than or equal to 100 m) diversion; only 1 of 8 groups of bowheads reacted.

For the fixed-wing aircraft, few bowheads (2.2%) or belugas (3.2%) were observed to react to overflights at altitudes 60-460 m. Most observed reactions by bowheads (73%) and belugas (70%) occurred when the fixed-wing aircraft was at altitudes less than or equal to 182 m and lateral distances less than or equal to 250 m. However, the proportions reacting, especially to low-altitude flights (e.g., less than or equal to 182 m), were underestimated for both species because observation opportunities were brief. Even so, reactions were more common when the aircraft was low (less than or equal to 182 m): $P = 0.009$ for belugas, $P = 0.06$ for bowheads. There was little if any reaction by bowheads when the aircraft circled at altitude 460 m and radius 1 km.

Aircraft sounds measured underwater at depths 3 m and 18 m showed that a Bell 212 helicopter was 7-17.5 dB noisier than a Twin Otter (10-500 Hz band). Bell 212 sound consisted mainly of main rotor tones ahead of the helicopter and tail rotor tones behind it. Twin Otter sound contained fewer prominent tones. Peak sound level as received underwater was inversely related to aircraft altitude, and received levels at 3 m depth averaged 2.5 dB higher than at 18 m depth. The dominant low-frequency components of aircraft sound are presumed to be readily audible to bowheads. For belugas, these components may be inaudible, or at most only weakly audible. Mid-frequency sound components, visual cues, or both, are probably important in eliciting beluga reactions to aircraft.

Petersen, M. R. and Flint, P. L. 2002. Population Structure of Pacific Common Eiders Breeding in Alaska. *Condor*. Nov; 104(4).

Keywords: Alaska/ Pacific common eider/ population structure/ *Somateria mollissima v-nigrum*/ winter/ spectacled eiders/ *Somateria mollissima*/ harlequin ducks/ at-sea/ *Anatidae*/ patterns/ birds/ Beaufort Sea/ Yukon-Kuskokwim Delta

Abstract: We used satellite telemetry to study the migration routes and wintering areas of two allopatric breeding populations of Pacific Common Eiders (*Somateria mollissima v-nigrum*) in Alaska: the Yukon-Kuskokwim Delta, and the western Beaufort Sea coast. Only 6% (2 of 36) of females wintered within the wintering area of the other breeding population. Both breeding populations wintered in the closest available ice-free habitat, perhaps to minimize migratory distance. Two Beaufort Sea females wintered in areas used by Yukon-Kuskokwim Delta females, implying potential gene flow among breeding areas. Yet, we conclude that these two

populations are largely geographically isolated throughout the annual cycle and the environmental factors influencing survival and reproduction likely differ between these groups of birds. Thus, regardless of the potential gene flow among breeding populations, we suggest that birds from these two breeding areas should be managed as separate populations.

Poltermann, M. 2001. Arctic Sea Ice as Feeding Ground for Amphipods - Food Sources and Strategies. *Polar Biology*. Feb; 24(2).

Keywords: cod /*Boreogadus saida*/ sympagic macro-fauna/ Barents Sea/ trophic relationships/ covered waters/ Frobisher Bay/ Beaufort Sea/ *Crustacea*/ behavior/ mechanisms

Abstract: The amphipod species *Gammarus wilkitzkii*, *Apherusa glacialis*, *Onisimus nanseni* and *O. glacialis* live permanently associated with the Arctic sea ice. Qualitative and semi-quantitative investigations of gut contents and faeces showed that all four species use detritus as the main food source. Detrital lumps from the underside of sea ice had the same item composition as amphipod gut contents and faeces. Crustacean remains and ice algae were additional food items, but overall they were quantitatively less important. All species are omnivorous; however, differences in gut contents, behavioural observations and functional-morphological studies of the mandibles suggest a differentiation within this feeding strategy. *G. wilkitzkii* is a detritivorous-carnivorous-necrophagous-suspension-feeding species and shows the most complex feeding strategy. *O. nanseni* and *O. glacialis* are predominantly detritivorous-necrophagous, whereas *A. glacialis* is characterised as a more herbivorous-detritivorous species. By using a variety of the available food sources under Arctic sea ice, the amphipods are well adapted to the under-ice habitat and are less influenced by temporal and spatial variations. Furthermore, the wide food spectrum of all four species reduces the intra- and interspecific competition in a habitat where certain food sources are limited or only seasonally available.

Proshutinsky, A.; Pavlov, V., and Bourke, R. H. 2001. Sea Level Rise in the Arctic Ocean. *Geophysical Research Letters*. Jun 1; 28(11).

Keywords: sea level/ Arctic Ocean/ sea ice

Abstract: About 60 tide-gauge stations in the Kara, Laptev, East-Siberian and Chukchi Seas have recorded the sea level change from the 1950s through 1990s. Over this 40-year period, most of these stations show a significant sea level rise (SLR). In light of global change, this SLR could be a manifestation of warming in the Arctic coupled with a decrease of sea ice extent, warming of Atlantic waters, changes in the Arctic Ocean circulation, and an increase in coastal erosion and thawing of permafrost. We have analyzed monthly mean sea level data and assessed the role that different factors may play in influencing the process of sea level change in the Arctic Ocean. Analysis of the observational data and model results shows that changes in the patterns of wind-driven and thermohaline circulation may account for most of the increase of sea level in the Arctic Ocean and their cumulative action can explain more than 80% of the sea level variability during 1950-1990.

Proshutinsky, A. Y. and Johnson, M. 2001. Two Regimes of the Arctic's Circulation from Ocean Models with Ice and Contaminants. *Marine Pollution Bulletin*. Jan-Jun 30; 43(1-6).

Keywords: variability/ sea level/ Pacific Ocean/ Arctic Ocean/ ice drift

Abstract: A two-dimensional barotropic, coupled, ocean-ice model with a space resolution of 55.5 km and driven by atmospheric forces, river run-off, and sea-level slope between the Pacific and the Arctic Oceans, has been used to simulate the vertically averaged currents and ice drift in the Arctic Ocean. Results from 43 years of numerical simulations of water and ice motions demonstrate that two wind-driven circulation regimes are possible in the Arctic, a cyclonic and an anti-cyclonic circulation. These two regimes appear to alternate at 5-7 year intervals with the 10-15 year period. It is important to pollution studies to understand which circulation regime prevails at any time. It is anticipated that 1995 is a year with a cyclonic regime, and during this cyclonic phase and possibly during past cyclonic regimes as well, pollutants may reach the Alaskan shelf. The regime shifts demonstrated in this paper are fundamentally important to understanding the Arctic's general circulation and particularly important for estimating pollution transport.

Proshutinsky, A. Y.; Johnson, M. A., and Proshutinsky, T. O. 2001. Understanding Climatic Controls on Sea Ice Transport Pathways in the Arctic Ocean. 33.

Keywords: sea ice/ ocean/ Atlantic/ circulation/ temperatures/ models/ Arctic Ocean

Abstract: The primary goal of this paper is to demonstrate the dependence of Arctic Ocean sea-ice transport pathways on climate variations. We build our analysis on the results of Proshutinsky and Johnson (1997), Johnson and others (1999), Polyakov and others (1999) and Proshutinsky and others (1999), where we have shown that wind-driven ice motion and upper ocean circulation alternate between anticyclonic and cyclonic states. Shifts between regimes occur at 5-7 year intervals, resulting in a 10-15 year period. The anticyclonic circulation regime has been observed in our model results for 1946-52, 1958-62, 1972-79, 1984-88, and 1998-present. The cyclonic circulation regime prevailed during 1953-57, 1963-71, 1980-83, and 1989-97. The regime shifts are fundamentally important to understanding the Arctic's general circulation and particularly useful for estimating pollution transport by sea ice and surface waters. It is important to pollution studies to understand which circulation regime prevails. Initially, we simulate trajectories of a non-reactive, conservative soluble tracer. Results from this research demonstrate realistic potential flow pathlines and we describe how those pathlines change in response to climate forcing. These results can be used to aid current and future scenario risk assessments and may provide management agencies with the tools to determine where risks from contaminants might exist.

Rachold, V.; Grigoriev, M. N.; Are, F. E.; Solomon, S.; Reimnitz, E.; Kassens, H., and Antonow, M. 2000. Coastal Erosion vs Riverine Sediment Discharge in the Arctic Shelf Seas.

Keywords: Laptev Sea/ Beaufort Sea/ coastal erosion/ fluvial sediment discharge/ sediment budget/ Canadian Beaufort Sea/ Laptev Sea/ ice/ ocean/ circulation/ permafrost/ topography/ evolution/ nutrients/ transport

Abstract: This article presents a comparison of sediment input by rivers and by coastal erosion into both the Laptev Sea and the Canadian Beaufort Sea (CBS). New data on coastal erosion in the Laptev Sea, which are based on field measurements and remote sensing information, and existing data on coastal erosion in the CBS as well as riverine sediment discharge into both the Laptev Sea and the CBS are included. Strong regional differences in the percentages of coastal erosion and riverine sediment supply are observed. The CBS is dominated by the riverine sediment discharge ($64.45 \times 10^6 \text{ t a}^{-1}$) mainly of the Mackenzie River, which is the largest single source of sediments in the Arctic. Riverine sediment discharge into the Laptev Sea amounts to $24.10 \times 10^6 \text{ t a}^{-1}$, more than 70% of which are related to the Lena River. In comparison with the CBS, the Laptev Sea coast on average delivers approximately twice as much sediment mass per kilometer, a result of higher erosion rates due to higher cliffs and seasonal ice melting. In the Laptev Sea sediment input by coastal erosion ($58.4 \times 10^6 \text{ t a}^{-1}$) is therefore more important than in the CBS and the ratio between riverine and coastal sediment input amounts to 0.4. Coastal erosion supplying $5.6 \times 10^6 \text{ t a}^{-1}$ is less significant for the sediment budget of the CBS where riverine sediment discharge exceeds coastal sediment input by a factor of ca. 10.

Richard, P. R.; Martin, A. R., and Orr, J. R. 2001. Summer and Autumn Movements of Belugas of the Eastern Beaufort Sea Stock. *Arctic*. Sep; 54(3).

Keywords: Beluga/ *Delphinapterus leucas*/ Beaufort Sea/ Chukchi Sea/ satellite-linked tracking/ autumn migration/ survey biases/ white whales/ abundance

Abstract: Beluga whales of the eastern Beaufort Sea stock were tagged with satellite-linked time-depth recorders and tracked during summer and autumn in 1993, 1995, and 1997. Whales occupied the Mackenzie estuary intermittently and for only a few days at a time. They spent much of their time offshore, near or beyond the shelf break and in the polar pack ice of the estuary, or in Amundsen Gulf, M'Clure Strait, and Viscount Melville Sound. The movements of tagged belugas into the polar pack and into passages of the Canadian Arctic Archipelago suggest that aerial surveys conducted in the southeastern Beaufort Sea and Amundsen Gulf may have substantially underestimated the size of the eastern Beaufort Sea stock. Ranges of male and female belugas were somewhat segregated in two of the three years of study. In late July of 1993 and 1995, most males were located in Viscount Melville Sound, while females were primarily in Amundsen Gulf. Movement patterns of males tagged in late July in 1997 were different from those of males tagged in early July in 1993 and 1995. In September, belugas migrated westward along the continental shelf and farther offshore in the Alaskan Beaufort Sea. The tracks from 1997 show that the western Chukchi Sea is an autumn migratory destination and that at least some belugas continued their migration south towards the Bering Strait in November. Some conclusions from this study about beluga ecology challenge conventional

wisdom, in that estuarine occupation appears to be short-lived, belugas travel long distances in summer to areas hundreds of kilometers from the Mackenzie Delta, and they do not avoid dense pack ice in summer and autumn.

Richardson, W. J. 2001. Offshore Oil and Gas Industry Noise and Marine Mammal Behavior. *From:* Workshop Proceedings, Cumulative Effects of North Slope Oil and Gas Activities, Deadhorse, Alaska, July 9-14, 2001. U.S. National Academy of Sciences, Division on Earth and Life Studies. 28 pp.

Keywords: Arctic/ Alaska/ North Slope/ Prudhoe Bay/ underwater acoustics/ petroleum exploration / seismic surveys/ biological impacts/ ringed seal /*Phoca hispida*/ bowhead whale/ *Balaena mysticetus*

Abstract: Underwater sounds generated by petroleum industry seismic survey airgun arrays and from offshore production facilities are reviewed with respect to potential impacts upon behavior and distribution of bowhead whale (*Balaena mysticetus*) and ringed seal (*Phoca hispida*) living in nearshore marine waters of Alaska's North Slope environment in the Beaufort Sea. Studies were conducted in years 1996 through 2001.

Acoustic effects of seismic surveys on whales and seals were examined during the open-water season. Effects of offshore production facilities on seals were examined during the ice-covered season, and upon whales during the open-water season.

Airgun arrays generate low-frequency sound pulses with most energy generated in the range of 10 to 150 Hz. While airgun arrays are designed to direct sound downward, considerable sound propagates horizontally and pulses may be detectable 50 to 100 km away and are usually strong (e.g., >160 dB re 1 μ Pa rms) within several km. Received levels and properties at long horizontal ranges vary widely depending on propagation conditions, with attenuation usually more rapid in shallow water.

The National Marine Fisheries Service has established that whales and seals should not be exposed to pulsed sounds with received levels of 1,800 and 190 dB re 1 μ Pa (rms), respectively, ruling that hearing damage may occur above these levels. However, no specific data exist regarding how much exposure to airgun pulses any marine mammal can tolerate before temporary or permanent hearing impairment occurs.

Bowhead whales avoided areas within 20 km of small-moderate airgun arrays, with some evidence of avoidance up to 30 km. Almost all bowheads stayed well beyond "safety radius" levels of 180 dB (re 1 μ Pa rms), while whales were observed approaching the 20 km radius, receiving pulse levels of approximately 115 to 135 dB re 1 μ Pa rms (and other weaker pulses). These are well below levels of pulsed seismic sounds previously known to elicit avoidance by baleen whales. Bowheads tended to re-occupy areas within 12 to 24 hours after termination of airgun operations.

Seal results from 1996 to 1999 monitoring in the Beaufort Sea indicated that seals regularly remained inside a 190 dB re 1 μ Pa rms radius from noise airgun arrays. Average sighting distances were only slightly greater when airguns were operating and avoidance reactions were limited. It cannot be assumed that seals will stay outside of a "safety radius" of 180 dB. Underwater sounds during construction of the offshore Northstar oil and gas development project near Prudhoe Bay were detectable under the ice out to a few kilometers. There was no indication of reduced densities of ringed seals near the facility in late spring 2000 after intense winter construction. Spring 2001 data await analysis. A slight displacement of the southern edge of the bowhead corridor is expected from Northstar operations. Further analysis is required for testing of this hypothesis.

Schick, R. S. and Urban, D.L. 2000. Spatial components of Bowhead whale (*Balaena mysticetus*) distribution in the Alaskan Beaufort Sea. Canadian Journal of Fisheries and Aquatic Sciences 57:2193-2200

Keywords: Beaufort Sea/ Alaska/ petroleum exploration/ bowhead whale/ *Balaena mysticetus*/ spatial analysis/ correlation/ Mantel Test/ habitat loss

Abstract: Bowhead whales (*Balaena mysticetus*) on their fall migration are exposed to oil exploration activities in the Alaskan Beaufort Sea. To account for the presence of spatially autocorrelated and intercorrelated data, a suite of spatial analysis techniques (random resampling, Mantel Tests) were utilized to assess the distribution of bowhead whales around active drilling rigs in 1993. Results from the resampling tests indicated whales were distributed farther from the drilling rig than they would be under a random scenario. Results from the Mantel Tests indicated that in 1993, the spatial pattern of bowhead whale distribution was highly correlated with distance from the drilling rig, indicating that the presence of the drilling rig resulted in a significant temporary loss in available habitat.

Solomon, S.; Mudie, P.J.; Cranston, R.; Hamilton, T.; Thibaudeau, S.A., and Collins, E.S. 2000. Characterization of marine and lacustrine sediments in a drowned thermokarst embayment, Richards Island, Beaufort Sea, Canada. International Journal of Earth Sciences 89(3): 503-521.

Keywords: Beaufort Sea/ Mackenzie River Delta/ thermokarst/ Kittigazuit sand/ microfossils/ geochemistry/ sedimentation rate/ radiocarbon dating

Abstract: A multidisciplinary study was made of lakes and lagoons in a thermokarst embayment on Richards Island, Canadian Beaufort Sea, in order to investigate the response of the Mackenzie Delta shoreline to changing hydrological influences. Seismo-acoustic profiles made from an amphibious vehicle, combined with sediment core data, show that the deepest lakes contain up to 10 m of transparent or stratified silty mud overlying the Kittigazuit sand basement. Palynological and microfossil data from 21 surface samples allow delineation of freshwater, saltmarsh, tidal flat and subtidal assemblages. These modern reference data allow distinction of freshwater and marine facies in the cores and subsequent interpretation of geochemical content (carbon,

ammonia, and sulphate). Radiocarbon dates and ^{137}Cs show that sedimentation rates have increased by an order of magnitude since drowning of the embayment during the past millennium, and that most of this sediment is from the Mackenzie River plume.

Stirling, I. 2002. Polar Bears and Seals in the Eastern Beaufort Sea and Amundsen Gulf: a Synthesis of Population Trends and Ecological Relationships Over Three Decades. *Arctic*. 55.

Keywords: polar bear/ ringed seal/ Beaufort Sea/ harvest/ climatic fluctuation/ *Ursus maritimus* populations/ growth layer groups/ Western Hudson Bay/ *Phoca hispida*/ Northwest Territories/ Arctic Ocean/ movements/ abundance/ mark

Abstract: In the eastern Beaufort Sea and Amundsen Gulf, research on polar bear populations and their ecological interrelationships with seals and sea ice conditions began in the fall of 1970. Analysis of movement data from mark-recapture studies and tracking of adult female bears with satellite radio collars indicated that there are two populations of polar bears in the area, one that inhabits the west coast of Banks Island and Amundsen Gulf and a second that is resident along the mainland coast from about Baillie Islands in Canada to approximately Icy Cape in Alaska. Polar bears throughout the Beaufort Sea and Amundsen Gulf were severely over harvested before the establishment of quotas in Canada in 1968 and the cessation of all but subsistence polar bear hunting in Alaska in 1972. Since then, both populations have recovered, and the population estimates currently used for management purposes are 1200 and 1800 for the Northern and Southern Beaufort populations, respectively. However, these population estimates are now dated and should be redone. Most female polar bears in the Beaufort Sea breed for the first time at 5 years of age, compared to 4 years of age in most other populations, and cubs normally remain with their mothers for 2.5 years prior to weaning. Heavy ice conditions in the mid-1970s and mid-1980s caused significant declines in productivity of ringed seals, each of which lasted about 3 years and caused similar declines in the natality of polar bears and survival of subadults, after which reproductive success and survival of both species increased again. The changes in the sea ice environment, and their consequent effects on polar bears, are demonstrable in parallel fluctuations in the mean ages of polar bears killed each year by Inuit hunters. In 1989, the decadal-scale pattern in fluctuations of ice conditions in the eastern Beaufort Sea changed in response to oceanographic and climatic factors, and this change has resulted in greater amounts of open water in recent years. In addition, climatic warming will be a major environmental factor if greenhouse gas emissions continue to increase. It is unknown whether the ecosystem will return to the pattern of decadal-scale change exhibited in previous decades, or how polar bears and seals will respond to ecological changes in the future, but research on these topics is a high priority.

Stout, J. H.; Trust, K. A.; Cochrane, J. F.; Suydam, R. S., and Quakenbush, L. T. 2002. Environmental Contaminants in Four Eider Species from Alaska and Arctic Russia. *Environmental Pollution*. 119(2).

Keywords: Alaska/ contaminants/ eider/ heavy metals/ sea ducks

Abstract: Population declines in four species of eider; common (*Somateria mollissima*), king (*Somateria spectabilis*), spectacled (*Somateria fischeri*) and Steller's (*Polysticta stelleri*), have raised concerns about exposure to contaminants. Livers and kidney tissues were collected from eiders in Alaska and Russia for organic and elemental analyses. Results showed that organochlorine and many elemental levels were below toxic thresholds; however, in many cases, cadmium, copper, lead and selenium appeared high relative to other waterfowl and may warrant concern. With the exception of lead, local anthropogenic sources for these elements are not known. Although adverse physiological responses have not been documented in eiders, these four elements cannot be ruled out as contaminants of potential concern for some eider species.

Suydam, R. S.; Dickson, D. L.; Fadely, J. B., and Quakenbush, L. T. 2000. Population Declines of King and Common Eiders of the Beaufort Sea. *Condor*. Feb; 102(1).

Keywords: Beaufort Sea/ common eider/ king eider/ mortality/ population trend/ *Somateria mollissima v-nigra*/ *Somateria spectabilis*/ Alaska

Abstract: King (*Somateria spectabilis*) and common eiders (*S. mollissima v-nigra*) wintering off western North America migrate past Point Barrow, Alaska and across the Beaufort Sea to nest in northern Alaska and northwestern Canada. Migration counts were conducted by various researchers at Point Barrow during 1953, 1970, 1976, 1987, 1994, and 1996. We examined population trends by standardizing the analysis of the migration counts in all years. Based on this standardized procedure, the king eider population appeared to remain stable between 1953 and 1976 but declined by 56% (or 3.9% year⁻¹) from approximately 802,556 birds in 1976 to about 350,835 in 1996. The common eider population declined by 53% (or 3.6% year⁻¹) from approximately 156,081 birds in 1976 to about 72,606 in 1996. Reasons for the declines are unknown.

Troy, D.M. 2000. Shorebirds, Chapter 14, pp. 277-303, *In: The Natural History of an Arctic Oil Field*. J. C. Truett and S. R. Johnson (Eds.). Academic Press, San Diego, CA, 422 pp.

Keywords: Alaska/ North Slope/ Arctic Coastal Plain (ACP)/ Arctic National Wildlife Refuge (ANWR)/ National Petroleum Reserve/ shorebirds/ plovers/ sandpipers/ population density/ petroleum development impacts/ habitat loss/ predation

Abstract: In northern Alaska, where shorebirds dominate the avifauna in numbers of individuals and species, two families regularly occur – the plovers (Charadriidae) and the sandpipers (Scolopacidae). At least 18 species nest on Alaska's Arctic Coastal Plain (ACP) in the area of existing and potential petroleum development between the Colville and Channing Rivers. Arctic-breeding shorebirds undertake extensive migrations, with wide ranges onto other continents, and wide ranges during the breeding season, extending into Canada and Russia. Breeding occurs after snowmelt in late May or early June.

Distribution within the ACP oil-field region is not uniform. Extensive studies in the Prudhoe Bay oilfield have exhibited abundance gradients both perpendicular to and parallel with the

coast. Abundances generally decline proceeding eastward into the Arctic National Wildlife Refuge from the area between Milne Point and the Sagavanirktok River. To the west, in the National Petroleum Reserve, densities tend to be higher than in the central ACP.

With the exception of the Dunlin, which has exhibited a decline in abundance throughout northern Alaska in recent years, data from Prudhoe Bay agree with population data from other regions: that shorebird species appear to have stable, long-term population trends.

Impacts upon populations from human activity and oil-field development may occur due to road and pad development (e.g., gravel fill), alterations to adjacent areas (changes in drainage pattern, fugitive dust, thermokarsting, noise, and traffic) and from general habitat fragmentation. Since shorebirds of the ACP are all parts of large, widespread breeding populations, there is a general presumption that population level threats from human development are minimal. Within the oilfields, the extent to which the network of roads and facilities has affected the number of shorebirds is unresolved. Since numerous mammalian and bird predators pose a significant threat to shorebird breeding success by preying on eggs, and since these predators typically have enhanced populations in areas of human development (due to supplemental food supplies), it is suggested that efforts to minimize the impact of predation may be of greater benefit to shorebird populations than would be efforts to minimize habitat loss.

United States Department of Energy (USDOE). 2000. Potential Oil Production from the Coastal Plain of the Arctic National Wildlife Refuge. Report SR/O&G/2000-02. Energy Information Administration, Office of Oil and Gas, U.S. Department of Energy, Washington, D.C. May.

Keywords: Energy Information Administration/ petroleum/ oil & gas reserves/ Alaska/ North Slope/ Arctic National Wildlife Refuge (ANWR)/ 1002 area/ petroleum production estimates

Abstract: The Energy Information Administration (EIA) Office of Oil and Gas Reserves and Production Division, is a policy-neutral agency within the U.S. Department of Energy. EIA projections of future daily production rates for recoverable natural gas and oil are presented for the Arctic National Wildlife Refuge (ANWR) coastal plain. The coastal plain includes 1.5 million acres designated as the 1002 area, comprising 8% of total ANWR lands, and extending out to the 3-mile limit offshore. Representing the largest unexplored, potentially productive onshore basin in the United States, it lies along the geologic trend that is productive in the Prudhoe Bay area, 60 miles to the west.

The U.S. Geological Service made the following estimates in 1998 of technically recoverable oil and gas from the ANWR coastal plain: 1) a 95% probability that at least 5.7 billion barrels of oil are recoverable; 2) a 5% probability that at least 16 billion barrels of oil are recoverable; and 3) a mean (expected value) estimate of 10.3 billion barrels of recoverable oil. For comparison, total U.S. proven reserves of crude oil in 1998 were estimated to be 21 billion barrels.

EIA estimates of yearly development rates for this region were: 1) yearly development rates ranging from 250 to 800 million barrels; 2) peak ANWR production rates ranging from 650,000 to 1.9 million barrels per day; 3) a projection that initial ANWR production could occur around

2010, if leasing approval occurred within the next few years; and 4) potential ANWR oil recovered would have a value between \$125 and \$350 billion (in 1998 dollars), based upon a projected refiner acquisition cost of \$22.04 (1998 dollars) in the year 2020.

United States Department of Energy (USDOE). 2001. Future Oil Production for the Alaska North Slope. Report DOE/EIA-0627, Distribution Category UCC-950. Energy Information Administration, Office of Oil and Gas, U.S. Department of Energy, Washington, D.C. May.

Keywords: Energy Information Administration/ petroleum/ oil & gas reserves/ Alaska/ North Slope/ Arctic National Wildlife Refuge (ANWR)/ National Petroleum Reserve-Alaska (NPR-A)/ petroleum production estimates

Abstract: The Energy Information Administration (EIA) Office of Oil and Gas Reserves and Production Division, is a policy-neutral agency within the U.S. Department of Energy. The EIA provides a range of plausible production scenarios for the North Slope area of Alaska based on the decline of existing production, the anticipated start-up of identified field development projects and future discovery and development of the remaining undiscovered oil resources for the area. Production of oil (total liquids) from Alaska North Slope (ANS) oil has declined from the 1988 peak rate of over 2.0 million barrels per day (MMbbl/d). In 2000 production was 1.1 MMbbl/d, accounting for 16% of total domestic production. Cumulative ANS production through 2000 was 13.306 billion barrels (Bbbls). In the absence of additional development, 3.707 Bbbls remain to be produced from the currently on-stream fields.

USGS data were utilized to provide estimates of undiscovered resources for the area between the Arctic National Wildlife Refuge (ANWR) and the Northeast National Petroleum Reserve-Alaska (NPR-A). Production projections are derived from three inputs: anticipated future production from currently on-stream fields, production from anticipated development of identified fields, and projected volumes of production from technically recoverable undiscovered resources. Production scenarios are based on USGS 95% probability of occurrence criteria.

The range of remaining and undiscovered ANS oil is 6.1 to 13.3 Bbbl with a mean (expected) value of 8.9 Bbbl. Ultimate recovery will range from 19.4 to 26.6 Bbbl. Identified development will stabilize ANS production at approximately 1.0 MMbbl/d until 2005. If identified development is delayed by factors such as low oil prices or environmental issues, production will begin declining before the year 2005. Production of undiscovered NPR-A is assumed to begin in 2010, causing production to remain close to 1.0MMbbl/d for another five years.

United States Fish & Wildlife Service. 2001. Water Fact Sheet, Coastal Plain (1002 area), Arctic National Wildlife Refuge. *From:* Workshop Proceedings, Cumulative Effects of North Slope Oil and Gas Activities, Deadhorse, Alaska, July 9-14. U.S. National Academy of Sciences, Division on Earth and Life Studies. 6 pp.

Keywords: Beaufort Sea/ Alaska/ North Slope/ Arctic National Wildlife Refuge/ ANWR/ 1002 Area/ coastal plain/ rivers/ Barter Island/ weather conditions/ spring melt/ British Petroleum Alaska/ Phillips Petroleum Alaska/ water resources/ petroleum development

Abstract: The Arctic National Wildlife Refuge (ANWR) coastal plain is an arctic marine habitat characterized by short, cool summers, with continuous daylight and winters that are long, dark, and extremely cold. Average temperature for the warmest month on Barter Island is 43°F, with daily temperatures varying from below freezing to a record high of 78°F. Average January temperatures for Barter Island are variable, ranging from 4.5°F in 1981 to -21.8°F in 1983. A record low of -59°F was recorded in February 1950. Annual precipitation at Barter Island averages 6.3 inches, occurring as light rain or drizzle in summer and light snow in winter.

Ten small-size rivers and 14 named streams characterize the ANWR 1002 area, which includes the coastal habitat, comprising 8 percent of ANWR and extending about 100 miles from the Aichiik River in the east to the Canning River in the west and 15 to 20 miles inland from the coast. The western boundary of the 1002 area lies about 50 miles east of Prudhoe Bay. The larger rivers are braided with extensive gravel bars along the coastal plain. The Arctic climate and permafrost are the dominant factors controlling water resources along the Arctic slope. Freeze-up typically occurs in mid- to late September. All rivers in the coastal plain freeze to substrate. Spring breakup of the ice is the significant hydrological event of the year. Permafrost limits infiltration of snowmelt, allowing water to move rapidly to stream channels. In most years more than 50% of the average annual discharge to the coastal zone occurs during a 2- to 3-week breakup period.

Based upon operational plans by British Petroleum and Phillips Alaska, Inc., water requirements for offshore ice road construction and maintenance for petroleum exploration activities in the 1002 area will be 1.54 million gallons per mile of road. Ice pad construction may require up to 3.6 million gallons per pad, while airstrip construction and maintenance and drill rig use (per 75 days) will require an estimated 8.0 and 1.5 million gallons, respectively.

United States Geological Service (USGS). 2001. Arctic National Wildlife Refuge, 1002 Area, Petroleum Assessment, 1998, Including Economic Analysis. USGS Fact Sheet FS-028-01 (Supersedes FS-040-98). April. 6 pp.

Keywords: Arctic/ Alaska/ Arctic National Wildlife Refuge/ ANWR/ 1002 area/ National Petroleum Reserve/ economically recoverable petroleum

Abstract: Using a methodology similar to that used in previous U.S. Geological Survey (USGS) assessments in the Arctic National Wildlife Refuge (ANWR) and the National Petroleum Reserve, Alaska, the USGS estimates that the total quantity of technically recoverable oil in the coastal ANWR 1002 area is 7.7 billion barrels, mean value, which is distributed among 10 plays. Plays are volumes of rock that contain similar geological parameters (such as petroleum charge, reservoir, and trap).

Most of the oil is estimated to occur in the western, undeformed ANWR 1002 area, which is closest to existing infrastructure. The oil is expected to occur in a number of accumulations rather than a single large accumulation. Estimates of economically recoverable oil, expressed by probability curves, show increasing amounts of oil with increasing price. At prices less than \$13 per barrel, no commercial oil is estimated, but at a price of \$30 per barrel, between 3 and 10.4 billion barrels are estimated. Economic analysis includes the costs of finding, developing, producing and transporting oil to market based on a 12 percent after-tax return on investment, all calculated in constant 1996 dollars.

The amounts of in-place oil estimated for the ANWR 1002 area are larger than previous USGS estimates. The increased estimate is primarily due to improved resolution of reprocessed seismic data and geologic analogs provided by nearby oil discoveries.

URS Corporation. 2001. Liberty Development 2001, Sediment Quality Study. Final Report, For: BP Exploration (Alaska), Inc. By: URS Corp. Anchorage, Alaska. Aug. 3, Doc. 74-0000034.00 Task 4000.

Keywords: Arctic/ Beaufort Sea/ Foggy Island Bay/ Prudhoe Bay/ petroleum development/ Liberty Oil Field/ BP Exploration (Alaska)/ dredged material/ sediment/ grain size/ ammonia/ total organic carbon (TOC)/ total volatile solids (TVS)/ sulfides, metals (antimony, arsenic, barium, cadmium, calcium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, zinc)/ high and low molecular weight polycyclic aromatic hydrocarbons (HPAH, LPAH)

Abstract: The Liberty Development oil and gas production facilities to be developed by BP Exploration (Alaska), Inc. (BPXA) will be placed on an artificial gravel island located at a depth of 22 feet in federal waters within Foggy Island Bay, Beaufort Sea, located on Alaska's north slope, east of Prudhoe Bay. A subsurface (buried) oil pipeline will connect to an onshore segment to transport oil to the Badami Sales Oil Pipeline. The Liberty Development has been evaluated by the U.S. Minerals Management Service (MMS, Anchorage, Alaska) in the *Liberty Development and Production Plan Draft Environmental Impact Statement* (MMS, 2001). The Draft EIS evaluated multiple pipeline routes and production island locations, including the applicant's proposed Liberty Island route.

Geotechnical exploration surveys in 1997 and 1998 along potential pipeline routes collected 18 sediment borings (exceeding 20 feet) and described seafloor sediments as consisting of three primary horizons: an upper Holocene non-plastic silt; an intermediate Pleistocene clayey silt; and an underlying granular sand and gravel. No frozen sediments were encountered. Sediments typically consisted of sand, silty sand with some soft silt, and many pockets and layers of peaty soil.

Pipeline construction permits administered by the U.S. Environmental Protection Agency (EPA) and U.S. Army Corps of Engineers Alaska District (Corps) require that physical and chemical properties of sediments be evaluated for potential environmental impacts resulting from pipeline trench excavation and fill activities and possible ocean disposal of spoils. In compliance with this permitting process, a sediment sampling program was conducted in April and May 2001.

Utilizing EPA- and Corps-approved methodologies, chemical analyses of sediment borings (to 15 feet) were collected at 11 sampling stations spaced along three alternative pipeline routes, including Southern Island and Tern Island alternate routes (Transects B and C) and the applicant's proposed Liberty Island route (Transect A). Sediments were analyzed from near surface and approximately five-foot intervals from the sediment core.

Chemical analyses conducted on all subsurface and surface samples included ammonia (as nitrogen), TOC, TVS, sulfides, metals (antimony, arsenic, barium, cadmium, calcium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, zinc), and high and low molecular weight polycyclic aromatic hydrocarbons (HPAH, LPAH). Four additional surface samples were collected from three stations along Transect A, and an isolated station to the west of all three transects for additional analyses, including pesticides, polychlorinated biphenyls (PCBs), semivolatile organic compounds (SVOCs) and select volatile organic compounds (VOCs).

The EPA and Corps do not have specific sediment chemistry guidelines for evaluation of dredged sediments in Alaska. EPA Region X (Seattle, Washington) applied guidelines from the *Dredged Material Evaluation Framework, Lower Columbia River Management Area* (1998) to the Liberty Development sampling plan and evaluation of results. The evaluation framework provided screening levels for all chemicals of concern.

Ranges for the following sediment chemistry categories, given without comment on screening levels, were: ammonia (0.7 to 3.3 mg/kg), TOC (8,000 to 40,400 mg/kg), TVS (12,700 to 46,500 mg/kg), and sulfides (51.6 to 882 mg/kg).

The following sediment chemistry categories were evaluated in relation to screening levels: 1) All sediment metals were measured in surface and subsurface samples at concentrations lower than the screening levels prescribed in the *Dredged Material Evaluation Framework*, 2) Measured PAH concentrations were all below the screening level in subsurface samples. In surface samples, with the exception of 14 µg/kg phenanthrene measured on the Liberty Transect (Sta. ASO3), all polycyclic aromatic hydrocarbon compounds (LPAH and HPAH) were not detected at levels above the method reporting limit.

The majority of additional analytes measured in surface samples were not present in measurable quantities. Others did not exceed screening levels. Sediment grain-size characteristics along transects A, B, and C, with estimated volume removals from pipeline entrenchment, were: Transect A – 60% silt and clay (fines), 419,036 cubic yards (cy); Transect B – 52% fines, 292,984 cy; and Transect C – 63% fines, 489,677 cy.

Wayland, M.; Garcia-Fernandez, A. J.; Neugebauer, E., and Gilchrist, H. G. 2001. Concentrations of Cadmium, Mercury and Selenium in Blood, Liver and Kidney of Common Eider Ducks from the Canadian Arctic. *Environmental Monitoring and Assessment*. Oct; 71(3).

Keywords: Arctic/ blood/ cadmium/ common eider/ kidney/ liver/ mercury/ metals/ sea ducks/ selenium/ *Somateria mollissima*/ tissue distribution/ spectacled eiders/ Western Alaska/ diving

ducks/ wild birds/ lead/ contaminants/ accumulation

Abstract: We determined concentrations of selected trace elements in livers, kidneys and blood samples from common eiders (*Somateria mollissima borealis*) from the eastern Canadian arctic during 1997 and 1998. Concentrations of total mercury and organic mercury were generally low in the livers of these birds (less than 6 and 4 $\mu\text{g g}^{-1}$ dry wt, respectively). Selenium ranged between 11-47 $\mu\text{g g}^{-1}$ in livers. Renal cadmium concentrations were among the highest ever published for this species (range: 47-281 $\mu\text{g g}^{-1}$). The regressions of log-transformed concentrations of these trace elements in blood samples on those in liver or kidney were significant (all P-values < 0.05) and positive. However, except for organic mercury ($R^2 = 0.83$), the co-efficients of determination were low to moderate (range of R^2 : 0.26-0.52), suggesting poor to moderate predictive capability. Furthermore, the relationships between total mercury in blood and liver changed between 1997 and 1998, suggesting that it would not be possible to predict consistently, concentrations of mercury in blood from those in liver based on samples taken in one year. Blood samples can be used to determine concentrations of these trace elements in common eiders (and probably other sea duck species as well). The use of blood samples is especially warranted when it is undesirable to kill the animal such as when working with rare or endangered sea duck species or when the objective is to relate trace element exposure to annual survival rates. However, the predictive equations developed here should not be used to predict expected concentrations in one type of tissue from those in the other.

Werner, I. 2000. Faecal Pellet Production by Arctic Under-Ice Amphipods - Transfer of Organic Matter Through the Ice/Water Interface. *Hydrobiologia*. May 15; 426(1-3).

Keywords: faecal pellets/ Amphipoda/ sea ice/ feeding/ carbon flux/ Greenland Sea/ Southwestern Beaufort Sea

Abstract: The underside of Arctic sea ice is inhabited by several autochthonous amphipod species (*Apherusa glacialis*, *Onisimus spp.*, *Gammarus wilkitzkii*). The amphipods graze on ice-bound organic matter, such as ice algae, detritus and ice fauna, and release faecal pellets into the underlying water column, thus forming a direct link between the sea ice and the pelagic ecosystems. Experiments on faecal pellet production rates showed species-specific differences, which were related to size of the animals. The smallest species, *A. glacialis*, produced the highest mean number of pellets (15.4 pellets ind.⁻¹ d⁻¹), followed by *Onisimus spp.* (2.7 pellets ind.⁻¹ d⁻¹) and the largest species, *G. wilkitzkii* (1.1 pellets ind.⁻¹ d⁻¹). Relative carbon content of the pellets was very similar in all species (21.2-22.6% dry mass). Juvenile amphipods (*Onisimus spp.*, *G. wilkitzkii*) produced more pellets with less POC than adults. Based on field determinations of the POC concentration in the lowermost 2 cm of the sea ice (mean: 36.4 mg C m⁻²) and mean amphipod abundances (*A. glacialis*: 33.8 ind. m⁻²), *Onisimus spp.*: 0.5 ind. m⁻², *G. wilkitzkii*: 9.4 ind. m⁻²) in the Greenland Sea in summer 1994, the amount of POC transferred from the ice to the water by faecal pellet production was estimated (0.7 mg C m⁻² d⁻¹) or almost 2% of ice-bound carbon). Since this process probably takes place in all ice-covered Arctic regions as well as during all seasons, grazing and pellet production by under-ice amphipods contributes significantly to matter flux across the ice/water interface.

Winsor, P. 2001. Arctic Sea Ice Thickness Remained Constant during the 1990s. *Geophysical Research Letters*. Mar 15; 28(6).

Keywords: Arctic Ocean/ North/ ice cover

Abstract: The ice cover of the Arctic Ocean is considered to be a sensitive indicator of global climate change. Recent research, using submarine-based observations, suggests that the Arctic ice cover was thinner in the 1990s compared to an earlier period (1958-1979), and that it continued to decrease in thickness in the 1990s. Here I analyze subsurface ice thickness (draft) of Arctic sea ice from six submarine cruises from 1991 to 1997. This extensive data set shows that there was no trend towards a thinning ice cover during the 1990s. Data from the North Pole shows a slight increase in mean ice thickness, whereas the Beaufort Sea shows a small decrease, none of which are significant. Transects between the two areas from 76 degrees N to 90 degrees N also show near constant ice thicknesses, with a general spatial decrease from the Pole towards the Beaufort Sea. Combining the present results with those of an earlier study, I conclude that the mean ice thickness has remained on a near-constant level around the North Pole from 1986 to 1997.

Woshner, V. M.; O'Hara, T. M.; Bratton, G. R.; Suydam, R. S., and Beasley, V. R. 2001. Concentrations and Interactions of Selected Essential and Non-Essential Elements in Bowhead and Beluga Whales of Arctic Alaska. *Journal of Wildlife Diseases*. Oct; 37(4).

Keywords: *Balaena mysticetus*/ beluga whale/ bowhead whale/ cadmium/ cetaceans/
Delphinapterus leucas/ elements/ marine mammals/ mercury/ molar ratio/ selenium/ silver/
heavy metals

Abstract: In this study, we evaluated concentrations of twelve essential and non-essential elements (As, Cd, Co, Cu, Pb, Mg, Mn, Hg, Mo, Se, Ag, and Zn) in tissues of bowhead (*Balaena mysticetus*) and beluga (*Delphinapterus leucas*) whales from arctic Alaska (USA) and northwestern Canada. Tissue samples were collected between 1983 and 1997, mostly in 1995-97. The essential elements are reported to develop reference ranges for health status determination, and to help assess known or suspected interactions affecting toxicoses of cadmium (Cd) and mercury (Hg). In some tissues, Cd, Hg, and selenium (Se) were present at concentrations that have been associated with toxicoses in some domestic animals. Nevertheless, tissue levels of all elements were within ranges that have been reported previously in marine mammals. While mean Ag concentrations in beluga whale liver were relatively high (15.91 µg/g ww), Ag was not associated with hepatic Se levels or age, contrary to previous findings. Significant associations included: Cd with age, Zn, or Cu; Cu with age, Zn or Ag; and Hg with age, Se, Zn, or Cu. This study found hepatic Hg:Se molar ratios to be consistently lower than unity and different between species. Possible explanations for observed elemental correlations (i.e., interactions) and ancillary mechanisms of Cd and Hg detoxification are discussed.

Yang, J. Y.; Comiso, J.; Krishfield, R., and Honjo, S. 2001 Synoptic Storms and the Development of the 1997 Warming and Freshening Event in the Beaufort Sea. *Geophysical Research Letters*. Mar 1; 28(5).

Keywords: Arctic Ocean/ ice/ Layer/ halocline/ model

Abstract: The climatic state in the Beaufort Sea in 1997 was characterized by warmer atmosphere, smaller areal coverage of sea ice in summer than average, and an oceanic mixed layer with a relatively low salinity that persisted into fall and early winter. The most remarkable change occurred near the end of 1997 when both salinity and temperature in the upper layer varied dramatically in a short-time period. The evolution of the air-sea-ice condition was observed by an autonomous buoy. The buoy observation revealed that deep mixing that penetrated through the Arctic halocline occurred in response to enhanced wind-stress forcing associated with an intense storm and was mainly responsible for the abrupt change of temperature and salinity in the mixed layer near the end of 1997. Similar events were inferred from storms in the Eurasian basin in 1994. We postulate that synoptic storms play a very important role in the variations of the heat and salt budgets in the upper Arctic Ocean.

Yunker, M. B.; Backus, S. M.; Pannatier, E. G.; Jeffries, D. S., and MacDonald, R. W. 2002. Sources and Significance of Alkane and PAH Hydrocarbons in Canadian Arctic Rivers. *Estuarine Coastal and Shelf Science*. Jul; 55(1).

Keywords: PAH/ alkane/ petroleum/ water quality guideline/ sediment quality guideline/ hopane/ sterane/ Arctic rivers/ polycyclic aromatic hydrocarbons/ Beaufort Sea/ dissolved hydrocarbons/ source identification/ organic geochemistry/ mass spectrometry/ coastal sediment/ Mackenzie River/ lake sediments/ crude oils

Abstract: Hydrocarbon measurements have been made on dissolved, suspended particulate and sediment samples collected in 1987, 1993 and 1994 from the Mackenzie River delta and shelf and in 1993 from 10 smaller Northwest Territories and Nunavut rivers that drain into the Canadian Archipelago or Hudson's Bay. Suspended particulate samples from all rivers have a resolved higher alkane pattern with a well-defined odd-even predominance consistent with a major source in terrestrial, vascular plant material. Particulate samples from the 10 smaller rivers have alkane concentrations that are similar to the Mackenzie River during summer, but PAH (polycyclic aromatic hydrocarbon) concentrations are approximately 10 times lower for the parent PAHs and 100 times lower for alkyl PAHs. PAHs on suspended particulate from the Mackenzie River exhibit a uniform composition typical of mature petrogenic sources, while PAHs in the smaller rivers are typical of combustion. The virtual absence of petrogenic PAHs in the smaller rivers is the single most important difference between these and the Mackenzie River. During summer the alkane and PAH composition of suspended particulate in the Mackenzie River is sufficiently homogenous to estimate directly the hydrocarbon load from the particulate load. Mackenzie River particulates and sediments have the hopane and sterane ratios characteristic of immature bitumens, shales or coals from the Devonian Canol formation that outcrops in the lower Mackenzie River valley. The erosion of organic-rich rocks from this formation is likely the source of the refractory petrogenic material found in the Mackenzie River

delta and shelf. Data are insufficient to determine whether the petrogenic lower alkanes and PAHs have the same source or whether more mature petroleum also contributes. Because sediment samples (suspended and bed) from the Mackenzie delta have natural PAH concentrations that exceed the level where adverse biological effects are expected to occur, there is an urgent need to establish whether these petroleum-derived PAHs are bioavailable and if they are inducing effects in bottom fish and other biota.

Zhang, J. L.; Rothrock, D., and Steele, M. 2000. Recent Changes in Arctic Sea Ice: the Interplay between Ice Dynamics and Thermodynamics. *Journal of Climate*. Sep 1; 13(17).

Keywords: North Atlantic oscillation/ Southern Canadian Basin/ numerical model/ Fram Strait/ sea ice/ ocean/ cover/ variability/ motion/ water/ flux

Abstract: It is well established that periods of high North Atlantic oscillation (NAO) index are characterized by a weakening of the surface high pressure and surface anticyclone in the Beaufort Sea and the intensification of the cyclonic circulation in the eastern Arctic Ocean. The response of Arctic sea ice to these atmospheric changes has been studied with a thickness distribution sea-ice model coupled to an ocean model. During a period of high NAO, 1989–96, the model shows a substantial reduction of ice advection into the eastern Arctic from the Canada Basin, and an increase of ice export through Fram Strait, both of which tend to deplete thick ice in the eastern Arctic Ocean and enhance it in the western Arctic, in an uneven dipolar pattern we call the East–West Arctic Anomaly Pattern (EWAAP). From the period 1979–88 with a lower-NAO index to the period 1988–96 with a high-NAO index, the simulated ice volume in the eastern Arctic drops by about a quarter, while that in the western Arctic increases by 16%. Overall, the Arctic Ocean loses 6%. The change from 1987 to 1996 is even larger—a loss of some 20% in ice volume for the whole Arctic. Both the model and satellite data show a significant reduction in ice extent in the eastern Arctic and in the Arctic Ocean as a whole. There are corresponding changes in open water and therefore in ice growth, which tend to moderate the anomaly, and in lateral melting, which tends to enhance the anomaly. During the high NAO and strong EWAAP period, 1989–96, the eastern (western) Arctic has more (less) open water and enhanced (reduced) winter ice growth, so ice growth stabilizes the ice cover. On the other hand, the increased (decreased) open water enhances (reduces) summer melt by lowering (increasing) albedo in the eastern (western) Arctic. The nonlinearity of ice–albedo feedback causes the increased summer melt in the eastern Arctic to dominate the thermodynamic response and to collaborate with the ice advection pattern to enhance the EWAAP during high NAO.

3.0 Literature Cited

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.



The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the Offshore Minerals Management Program administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS Royalty Management Program meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.