

**ANIMIDA Task 1
Core Contractor Program Management,
Logistics, Database, and Reporting**

Phase II Final Summary Report

Submitted to:
U.S. Department of the Interior
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Volume 1 of 1

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This Final Summary Report for the Arctic Nearshore Impact Monitoring in the Development Area (ANIMIDA) project Task 1 provides an overview of the ANIMIDA project and the background, objectives, and current status of each task. Additionally, the Executive Summaries for the Final Reports generated for Tasks 2, 4, 5, 6, 7, and 8 are attached in Section 3.0 of this report.

1.0 ANIMIDA Program Overview

The Outer Continental Shelf Lands Act (OCSLA) Amendments of 1978 (92 Stat. 629) established a policy for the management of oil in the Outer Continental Shelf (OCS) and for protection of the marine and coastal environments. The amendments authorize the Secretary of the Interior to conduct studies in areas of offshore leasing activities to assess potential impacts on the marine and coastal environments resulting from oil exploration, development, and production activities.

In 1998, MMS decided to conduct studies to characterize the pre-construction environment near the proposed Northstar and Liberty developments and to monitor selected parameters over time as part of a long-term project to assess potential spatial and temporal changes related to potential oil development and production near both the Northstar and Liberty sites. Information generated from these studies will be considered in post-leasing decisions to help understand and minimize potential impacts.

The project, *Arctic Nearshore Impact Monitoring in the Development Area* (ANIMIDA), was initially designed to carefully monitor perturbations specifically related to construction activities and oil recovery and transportation via pipeline from the gravel islands to the onshore processing facilities. Thus, the overall rationale of the project was to establish two site-specific monitoring efforts directed at the Northstar and Liberty developments. Priorities were placed on characterizing the pre-construction environment and establishing a scientific basis for post-construction and production monitoring. The ANIMIDA project was implemented in phases: Phase I focused on establishing pre-construction and development baselines; Phase II combined continued monitoring at Northstar along with the continuation of a regional baseline survey.

In the nearshore Alaskan Beaufort Sea, BP Exploration Alaska, Inc.'s (BPXA) offshore oil development has been completed and production activities ongoing at the Northstar site. The Liberty development was delayed by BPXA and has not been restarted as of this writing. At Northstar, the oil field was developed from a man-made gravel island. A sub-sea pipeline carries oil shoreward to a land-based connection with existing pipelines. Extensive Environmental Impact Statements (EISs) were prepared by the U.S. Army Engineering District, Alaska (USAEDA) for the Northstar area (USAEDA, 1999) and by the U.S. Department of the Interior (USDOI), Minerals Management Service (MMS) for the Liberty area (USDOI, 2002).

Over the past three decades, numerous onshore and offshore oil exploration and development projects have been conducted in both the Alaskan and Canadian Beaufort Seas. Discoveries and development include over 20 discoveries such as Endicott (an offshore field in state waters), Prudhoe Bay, Kuparuk, and Alpine. Because of these past activities, the ANIMIDA study area

cannot be considered pristine from a chemical perspective. Thus, ANIMIDA was designed to both carefully characterize the “baseline” (pre-Northstar and Liberty development) conditions and to develop sensitive measurement programs that could detect incremental change in these new development areas.

Phase I. Phase I of ANIMIDA was designed and implemented with a focus on the 1999 late-summer, open-water period and the winter 2000 ice-covered period. The late-summer 1999 sampling represented pre-construction baselines at both the Northstar and Liberty areas. The winter 2000 sampling represented the first construction-monitoring period for Northstar and another pre-construction data acquisition opportunity at Liberty.

The primary objectives of the ANIMIDA project were to characterize and monitor the physical environment of the Northstar and Liberty development areas to evaluate potential and actual impacts from these major offshore oil developments. The Phase I monitoring project was initiated and focused on those parameters that could be used to determine the existence, extent, and magnitude of environmental effects from the Northstar and Liberty oil development projects. Specifically, the Phase I project included baseline sediment and biota (bivalves and amphipods) monitoring for metal and organic contaminants (summer 1999), suspended sediment measurements and monitoring (summer 1999 and winter 2000), and acoustics monitoring during Northstar construction (winter 2000).

The summer 1999 and winter 2000 field sampling programs successfully obtained samples of surficial sediments, riverine sediments and peat, biota (clams and amphipods), suspended sediments, and ice cores in the ANIMIDA study area. Ancillary data on acoustics, currents, photosynthetically active radiation (PAR), and conductivity, temperature and depth (CTD) were also collected. The findings, interpretations and evaluations of the baseline Phase I data are reported in detail in the Phase I Final Reports (Boehm, et al., 2001; Shepard, et al., 2001).

Phase II. Part of the overall Phase I effort was to rapidly evaluate Phase I preliminary monitoring findings and to develop a set of recommendations for the Phase II project. The recommendations for the Phase II effort began to evolve at the ANIMIDA Phase I project’s annual meeting in October 1999, when a draft plan was discussed. Subsequent discussions with the scientific review board (SRB), the Alaska subcommittee of the MMS Scientific Committee, and MMS led to the issuance of Requests for Proposals (RFPs) for eight different task orders. The background and objectives of the eight proposed Phase II tasks are presented below in Section 2.0.

2.0 Task Background, Objectives, and Status

Task 1: ANIMIDA Phase II – Core Contractor Program Management, Logistics, Database, and Reporting

Background: Both offshore and onshore oil and gas development and production activities were planned for the Northstar and Liberty site in the nearshore Beaufort Sea. Coastal indigenous peoples were concerned about the long-term effects of these developments, as well as long-term effects of any development associated with offshore lease sales. Historical data in the region have been collected over several decades. Nonetheless, the sensitivity of the region

adjacent to Northstar and Liberty, and the highly variable and complex environmental conditions, made further monitoring necessary. In response to interagency reviews of related EISs and development and production plans, the ANIMIDA project was initiated as a comprehensive long-term project to monitor the spatial and temporal shifts in chemical and physical parameters associated with the construction and operations of the Northstar and Liberty developments. Phase II work involved concurrent performance of multiple tasks by multiple contractors. Task 1 provided for the Core Contractor to coordinate and manage logistics, data management and reporting elements of the overall ANIMIDA project.

Objectives: The ANIMIDA Phase II Core Contractor Support Task (Task 1) provided overall project management and logistics support for the tasks associated with the ANIMIDA project.

The specific objectives of the core contractor included:

1. Provide annual updates to the ANIMIDA Phase I literature review.
2. Provide logistics support and field personnel for Phase II field programs, including coordination of field activities, communications, transportation, and providing a skipper for the *MMS Launch 1273*.
3. Provide Science Review Board (SRB) for ANIMIDA.
4. Hold annual Public Workshops with MMS, other Phase II contractors, the SRB, and other government/academic representatives. The meetings included provisions for public involvement (local residents, industry, environmental and other public groups, etc.).
5. Develop and implement communication/involvement for North Slope residents.
6. Develop Phase II database design and analysis tools, import forms and metadata source file and integrate with the MMS Coastal and Offshore Resource Information System (CORIS) database.
7. Overall Phase II project management, including project management plan, data management plan, coordination of Phase II contractors, presentation slides, and quarterly progress reports.
8. Coordinate annual Phase II reports, including annual reports, final report, technical summary, and journal article.
9. Compile individual task reports into single annual or final report, adding introduction and executive summary.
10. Provide draft annual or draft final reports to SRB and Contracting Officer's Technical Representative (COTR) prior to annual Public Workshops. Provide revised reports to SRB and COTR prior to annual SRB meetings.

Status: This work was completed during FY 2005. The final field survey was successfully completed during the summer of 2002. The database design was finalized and the database was populated with project data.

Task 2: Hydrocarbon and Metal Characterization of Sediments, Bivalves, and Amphipods in the ANIMIDA Study Area

Background: The MMS initiated an environmental monitoring project in the Beaufort Sea in 1984 to assess the potential area-wide or cumulative effects of gas and oil exploration and development. The project was designed to detect and quantify long-term changes in the concentrations of metals and hydrocarbons in sediments and animal tissues. Its design was based on recommendations from a workshop conducted by MMS and the National Oceanographic and Atmospheric Administration (NOAA) in 1983. The initial phase of the monitoring study was a three-year project, with field sampling and analyses taking place in 1984, 1985, and 1986. Subsequent sampling was recommended for every third year, but took place only in 1989. Some data are also available from an MMS/University of Alaska Fairbanks, Coastal Marine Institute (CMI) study that sampled nearshore sediment stations in the vicinity in 1997 and from a BPXA study that sampled nine sediment stations near the proposed Northstar Development and pipeline route in February 1999.

The sensitivity of the region adjacent to Northstar and Liberty, and the highly variable and complex environmental conditions, made further monitoring necessary. Because current practice is to not discharge muds, cuttings, and formation waters during development and production, environmental concerns are shifting toward gravel-construction effects, such as may have occurred at Endicott, and to pre-potential spill baselines. During Phase I, chemistry measurements were made during the open-water season near the Northstar and Liberty sites, and at selected BSMP stations. A winter sampling program was also conducted under Phase I to collect data under ice-covered conditions. Task 2 provided the continuation of chemical monitoring in the nearshore Beaufort Sea to assess potential environmental contaminant inputs from the construction and development activities at Northstar and Liberty.

Objectives: Task 2 was designed to characterize potential contaminants in sediment and biota near ongoing and proposed offshore oil developments and to serve as a continuation of the Phase I organic and inorganic chemistry monitoring program. The specific objectives of the chemistry monitoring program included:

1. Perform annual or biannual field studies (FYs 2000 to 2003) for the monitoring of sediment and biota chemistry in the nearshore Beaufort Sea, focusing on potential inputs from the Northstar and Liberty developments.
2. Coordinate chemistry monitoring with other ANIMIDA Phase II tasks (biology and sediment transport), and with ANIMIDA-coordinated studies (e.g., physical oceanography).
3. Perform organic and inorganic chemical analyses that are consistent with previous measurements and thus capable of determining any observed incremental chemical inputs.

4. Collect and analyze sediment cores from the monitoring area to further evaluate trends of hydrocarbons and metals in the historical record (This objective was added to Task 2 based on the results of the summer 2000 field survey)

Status: This work was successfully completed during FY 2004. The final Task 2 field survey was successfully completed during the summer of 2002. The executive summary of the overall Task 2 Final Report is included in Section 3 and the findings of the sediment core work is included in a MMS Special Report (Brown et. al, 2003).

Task 3: Baseline Acoustic Monitoring: Bowhead Whale Migration Corridor

Background: Both offshore and onshore oil and gas development and production activities were planned for the Northstar and Liberty sites in the Beaufort Sea. Coastal indigenous peoples were concerned about the long-term effects of noise and vibration on nearshore biota. Historical data in the region have been collected over several decades. However, the highly variable and complex environmental conditions make site-specific evaluation the most reliable and robust approach. During Phase I, acoustic and vibration measurements were made in August 1999 and April 2000, at locations near both the Northstar and Liberty sites. Since ANIMIDA Phase I was initially designed, BPXA has undertaken a comprehensive noise and noise-effects monitoring program in the study area.

Objectives: The primary objective of Task 3 was to augment the BPXA design for acoustic monitoring of the bowhead migration offshore of Northstar by adding one to two seafloor recorder systems further offshore of BP recorders. Task 7 of *Technical Plan for Marine Mammal and Acoustic Monitoring during Construction of BP's Northstar Oil Development in the Alaskan Beaufort Sea, 2000*, dated August 20, 1999, presents the design for BP's efforts.

Status: The work on Task 3 was deferred indefinitely under the ANIMIDA Program. The findings of the Phase I project are included in the Phase I Final Report (Shepard, et al., 2001).

Task 4: Annual Assessment of Subsistence Bowhead Whaling Near Cross Island

Background: The effects that offshore development may have on subsistence activities, particularly bowhead whaling at and near Cross Island, are of primary concern to the Village of Nuiqsut. Therefore, an effort was made to monitor the subsistence whaling effort and its success.

Objective: To provide an annual narrative report showing the subsistence bowhead whaling activities, resources, and harvest on and near offshore Cross Island. The effort focused on where whalers go and where they have strikes.

Status: This work was successfully completed during FY 2004. Two years of monitoring were completed for this task (2000 and 2001) as part of the ANIMIDA Phase II project and a third year (2003) was funded by MMS beyond the ANIMIDA Phase II project. Executive summaries for both the 2001-2002 and the 2003 reports are included in Section 3.

Task 5: Sources, Concentrations, and Dispersion Pathways for Suspended Sediment in Areas of Oil and Gas Development along the Coastal Beaufort Sea

Background: A primary concern regarding oil and gas development in the coastal Beaufort Sea is increased turbidity during and after construction of offshore islands and pipelines. Suspended sediment may be released from storage areas on the ice (after the ice melts), from erosion of seafloor piles of sediment (removed from pipeline trenches) and/or from the island. Inputs of suspended sediment from these sources could increase turbidity, decrease the amount of available light for growth of marine plants, and/or increase sediment accumulation rates and thus alter benthic habitats. However, the sources and dispersion pathways for suspended sediment are not well defined and the annual contribution of suspended sediment to the study area from river inputs is not well known. Various, limited data sets for total suspended solids (TSS) and turbidity are available for open-water periods, with less information available for ice-covered periods. One model for dispersion of suspended matter was run for the Liberty area. Some TSS data from Endicott water-quality monitoring were also available from BPXA for inshore of the Liberty area. (Endicott currently monitors effluent TSS, but not ambient TSS). No data on chemical signatures existed that would help identify sources of suspended sediment. The Phase I effort of the ANIMIDA project made a first attempt at tracing sources of suspended sediment. Studies of construction and production activities at the Northstar and Liberty sites provided valuable opportunities to validate present models of sediment dispersion and to establish the spatial and temporal extent of suspended sediment dispersion.

Objectives: The overall objectives of Task 5 were to detect changes to the quantity and quality of suspended particulates from oil development.

The specific objectives for Task 5 were to:

1. Determine concentrations of suspended sediment at varying distances from construction-related deposits of gravel and related material during open-water and ice-covered periods and as a function of time during and after construction.
2. Help validate previous models of dispersion pathways and distances for suspended sediment in the study area.
3. Determine sources of suspended sediment in the areas of the Northstar and Liberty projects and to discriminate among various sources.
4. Contribute to an effort to determine the amount of sediment introduced to the coastal Beaufort Sea from rivers.
5. Use data from the Northstar and Liberty studies to predict net and cumulative changes in suspended sediment levels from additional offshore islands and pipelines.

Status: This work was successfully completed during FY 2004. The final Task 5 field survey was successfully completed during the summer of 2002 and data interpretation and reporting were completed for this task in FY 2004. The executive summary for the Task 5 Final Report is included in Section 3.

Task 6: Monitoring the “Boulder Patch” as part of the Arctic Nearshore Impact Monitoring In the Development Area (ANIMIDA) Program (Phase II)

Background: The “Boulder Patch” area in Stefansson Sound, adjacent to the proposed Liberty development, is characterized by the only known kelp community on the Alaskan arctic coast (in an area where boulder and cobble cover greater than 10 percent is found). Growth and production of the endemic arctic kelp *Laminaria solidungula*, which is abundant throughout the area, is regulated primarily by PAR (photosynthetically active radiation) availability during the summer open-water period. Variation in underwater PAR, caused by changes in water transparency, can have significant effects on the annual productivity of this species. Although the physiological responses of *L. solidungula* to changes in PAR are well described, the relationship between PAR and water turbidity (measured in terms of total suspended solids [TSS]) is poorly understood. With the potential construction of the Liberty production island adjacent to the Boulder Patch, there is increased potential for impacts and effects on this biological community.

Objective: The objective of Task 6 was to conduct a program to monitor the potential effects of a future Liberty Island and pipeline construction on the Boulder Patch community. In an attempt to further the understanding of the relationship between TSS and light availability, the inherent optical properties (IOPs) of Stefansson Sound waters including absorption, scattering, and attenuation, in conjunction with TSS concentrations were to be measured for a two-week period in summers 2001 and 2002. These data were then used in a radiative transfer equation (RTE), and a TSS concentration specific attenuation coefficient was determined and used in a productivity model to estimate daily kelp production throughout the Boulder Patch.

Status: This work was successfully completed during FY 2004. The final Task 6 field survey was completed during the summer of 2003 and a final report was submitted in FY 2004 Final Report (Executive Summary included in Section 3).

Task 7: Partitioning of Potential Contaminants between Dissolved and Particulate Phases in Waters of the Coastal Beaufort Sea

Background: Considerable interest has been expressed in selected metal and organic contaminants in waters of the coastal Beaufort Sea. These contaminant metals and organic substances may be particulate, colloidal, or dissolved in form, with the dissolved contaminants generally being more biologically available. During resuspension of bottom sediments by storm events, some contaminants may be released from sediment particles and added to the water column, while others may be adsorbed to particles and removed from the water column. Little or no data are available on dissolved contaminants in the coastal Beaufort Sea. No data are available to predict and model the behavior and uptake or release of contaminants from resuspended sediments. One ongoing MMS CMI study, *Kinetics and Mechanisms of Slow PAH Desorption from Lower Cook Inlet and Beaufort Sea Sediments*, is examining longer-term kinetics (1 to 180 days) for polynuclear aromatic hydrocarbons (PAH).

Objectives: The specific objectives for Task 7 are the following:

1. To determine concentrations of selected metals and organic substances in dissolved and particulate forms in waters of the coastal Beaufort Sea

2. To determine partition coefficients (particulate/dissolved) for selected metals and organic substances in waters of the coastal Beaufort Sea
3. To determine the equilibrium kinetics for release or uptake of selected metals and organic substances during sediment resuspension events

Status: This work was successfully completed during FY 2004. The final Task 7 field survey was successfully completed during the summer of 2002. Final data interpretation and reporting were completed for this task in the FY 2004 Task 7 Final Report (Executive Summary included in Section 3).

Task 8: Baseline Characterization of Anthropogenic Contaminants in Biota Associated with the Alaska OCS Liberty and Northstar Oil and Gas Production Units in the Nearshore Beaufort Sea

Background: Biomarker and contaminant analyses of marine mammals, birds, and fish provide an opportunity to learn more about the effects of bioaccumulation of anthropogenic compounds in Arctic food chains. Anthropogenic contaminants of Arctic concern are persistent organic pollutants (POPs) and metals. The POPs include polycyclic and polyhalogenated aromatic hydrocarbons and are globally distributed. However, due to their chemical characteristics and atmospheric transport, rates of deposition are much greater than rates of production in the Arctic. Some POPs are poorly metabolized, and may bioaccumulate or biomagnify in tissue. Although PAHs can be metabolized in mammal tissues, lessening their concentrations, PAH concentrations in edible tissue are still a concern, because of subsistence use and potential local or regional oil industry or spill sources.

Some aromatic compounds found in the Arctic induce enzyme P4501A in fish, birds, and marine mammals. The induction of this enzyme facilitates metabolism of aromatic compounds and the intermediate reaction products can react with cellular molecules, such as deoxyribonucleic acid (DNA), causing cellular damage. Measurement of P4501A may provide evidence of exposure to these compounds, their metabolism, and the subsequent risk to induced animals. In addition, analyses of a variety of tissues and cell types can indicate the route of uptake and exposure.

Strandings of both beluga and pilot whales in temperate climates have shown that induced cytochrome P4501A1 occurs in cetacean liver. Recently a correlation was described between hepatic CYP1A content and the content of co-planar PCBs in the blubber of beluga whales consistent with an environmental chemical induction in these animals. The extent of such induction in extrahepatic organs of cetaceans was not known until recently, when a variety of tissues from stranded pilot whales were collected, analyzed, and found to have P4501 induction. If correlations of P4501A induction were to be found with the concentrations of polyhalogenated aromatic hydrocarbons in Arctic whales, seals, birds, or fish, for example, then these compounds are the most likely proximate cause of such effects.

Regional studies of contaminants in marine mammals in the Beaufort Sea are presently being performed by the North Slope Borough (NSB) and by the Alaska Marine Mammal Tissue Archival Program (AMMTAP). The United States Geological Survey (USGS) Biological Resource Division (BRD) has collected and stored blood samples from polar bears for several

years, as well as from common eiders, oldsquaw, and nonviable eggs from common eiders in the ANIMIDA area and adjoining shoreline, starting in 1999.

Objectives: The objective of Task 8 was to detect changes or impacts from oil development and other contaminant sources.

Specific objectives include:

1. Determine baseline levels of anthropogenic compounds and contaminant biomarkers in representative upper-trophic biota (e.g., fish).
2. Evaluate whether the concentration of contaminants and/or biomarker responses indicate significant contaminant exposure to subsistence consumers.
3. Provide the essential background data and a framework for long-term monitoring of local biota if warranted by initial results of this study.

Status: This work was completed during FY 2004. The final Task 8 field survey was successfully completed during the summer of 2001. The Executive Summary of the Final Report submitted in FY 2004 is included in Section 3.

3.0 Executive Summaries

Task 2: Hydrocarbon and Metal Characterization of Sediments, Bivalves and Amphipods in the ANIMIDA Study Area – Executive Summary

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Overview

The Arctic Nearshore Impact Monitoring in the Development Area (ANIMIDA) Program was designed to assess potential environmental contaminant inputs from oil and gas developments in the Beaufort Sea, namely the Northstar and Liberty developments. The Phase I Report (Boehm et al. 2001b) presented the initial findings on the ANIMIDA Program associated with the pre-Northstar construction environment. Based on Phase I results, several tasks were recommended for implementation in Phase II and accepted by Minerals Management Service (MMS). The tasks included Task 2- Continue Chemical Monitoring Effort: "Hydrocarbon and Metal Characterization of Sediments, Bivalves and Amphipods in the ANIMIDA Study Area. The resulting information from Task 2 will be used to:

- Assess environmental conditions prior to Northstar and Liberty oil development and production activities,
- Monitor temporal and spatial changes in sediment and biota chemistry associated with Northstar and Liberty oil development and production activities, and
- Provide information needed in post-leasing decisions to help minimize these changes.

Phase II – Task 2 sampling activities began during the summer of 2000 and were completed during the summer of 2003. The associated Task 2 findings for the summer field sampling programs conducted in 1999 (Phase I), 2000, 2001, and 2002 are reported and discussed in this report. For Task 2, data were acquired on surficial sediments, riverine sediments and peat, biota (clams and amphipods), semi-permeable membrane devices (SPMDs), caged mussels, and sediment cores in the ANIMIDA study area. The results and discussion associated with the sediment core program (2001 field program) are contained in a separate MMS Report (Brown, et al., 2003) and briefly addressed in this report.

Phase II was designed to monitor the spatial and temporal shifts in chemical parameters associated with the construction and operation of the Northstar and Liberty developments. Northstar construction began in late 1999, island construction was completed in early 2000, and the first Northstar oil was produced at the end of 2001. The Liberty development was delayed by British Petroleum Exploration Alaska (BPXA) and has not been restarted as of this writing. Organic and metal parameters were analyzed to investigate the hypothesis that there was a shift in these parameters associated with the island construction and oil production activities at Northstar. The summer 1999 survey data represent pre-construction activities at Liberty and Northstar, the summer 2000 and 2001 survey data represent post-construction, pre-production measurements at Northstar and additional pre-construction measurements at Liberty, and the summer 2002 survey data represent post-construction, and ongoing production measurements at Northstar and additional pre-construction measurements at Liberty. Thus, the data collected and the results reported here represent the monitoring of the Northstar development during the construction of the gravel island, pipeline, and facility; the monitoring of the Northstar development during continued oil production; and continued pre-construction monitoring at the Liberty prospect area.

Objectives

The ANIMIDA Program was designed to address a series of scientific questions concerning the potential for shifts in environmental chemistry parameters associated with the Northstar and Liberty developments.

Each question can then be turned into a testable hypothesis, which guides the design of the technical program. The key questions, which drive Task 2 of ANIMIDA, are as follows:

Question 1. What are the background levels of chemicals of concern (*i.e.*, the organic and trace metal contaminants) that are known to be associated with historic oil exploration, development, and production activities, and do the concentrations of these chemicals increase as a result of the Northstar and Liberty developments?

Question 2. If concentrations of organic and/or metal pollutants do increase in the environment as a result of the Northstar and Liberty developments, do these increases pose an ecological “threat” or “risk”?

Task 2 addresses the first question and Task 2 along with two additional ANIMIDA Tasks (Task 6 and Task 8) are needed collectively to address the second question.

To provide the data needed to address these questions, the specific objectives of Task 2 include:

- Perform annual field studies (Fiscal Years [FYs] 1999 - 2002) to monitor sediment and/or biota chemistry in the nearshore Beaufort Sea, focusing on potential contaminant inputs from the Northstar development.
- Coordinate chemistry monitoring coupled with other ANIMIDA Phase II tasks (biology, sediment transport), and with ANIMIDA-coordinated studies (e.g.; physical oceanography).
- Perform organic and inorganic chemical analyses and analysis of data to document any incremental input of contaminants.

It is an explicit goal of the ANIMIDA Program to examine temporal and spatial changes and to determine if any observed changes in concentration and/or composition are related to the Northstar development.

ANIMIDA Task 2 Study Design

To meet the objectives of the ANIMIDA project, the study design of Task 2 focused on measuring those parameters that would be leading indicators of, or related to environmental contaminant inputs from the Northstar and Liberty oil development projects. The elements of primary focus included:

- Hydrocarbons and associate polycyclic aromatic hydrocarbons (PAHs), and metals as primary contaminants of concern
- Sediment contamination
- Bioaccumulation of contaminants
- Other natural and anthropogenic sources of chemicals of concern

The study design for Phase II built on the Phase I design (Boehm et al. 2001b) and involved several components:

- Design of a site-specific radial array sampling grid around each development centroid
- Selection of area-wide stations that had previously been sampled as part of the MMS Beaufort Sea Monitoring Program (BSMP; Boehm et al. 1991)
- Location and sampling of reference stations
- Identification of source samples for collection (e.g. river sediments)
- Addition of Phase II sampling stations along the pipeline route.

Findings

Sediments

As part of ANIMIDA Phase II, surficial sediment samples were collected from the ANIMIDA study area during the summers of 2000 and 2002 and sediment core samples were collected during the summer of 2001. All samples were analyzed for PAH, saturated hydrocarbons (SHC), steranes/triterpanes (S/T), metals, grain size, and total organic carbon (TOC). The sediment core samples were also analyzed for radionuclides for age-dating. This report also presents surficial sediment sample data collected in the 1980's as part of the BSMP (Boehm et al. 1991) and in 1999 as part of ANIMIDA Phase I (Boehm et al. 2001b).

Sediment Characteristics. Comparison of grain size data from 1999 with data from 2000 shows some inter-annual shifts in the texture of surficial sediment throughout the study area as well as some possible influences from Northstar Island. The largest changes in grain size distribution occurred at nearshore stations, landward of Northstar Island. During 1999, surficial sediment at stations N11-N14 was essentially all sand and gravel. In contrast, the 2000 samples were dominated by silt and clay (Figure 1). Although the exact mechanism for this shift is unknown, the 1999 samples were collected after a 6-day storm with winds >25 knots that may have eroded away finer-grained material. No such storms preceded collection of the 2000 samples that probably contained finer-grained material carried in by the Kuparuk River during the spring of 2000. At stations N06 and N10 (Figure 1), both close to Northstar Island, much finer-grained particles were collected during 1999 than 2000, possibly resulting from inputs of coarser material at these sites in association with construction of the island. Most importantly, Figure 1 depicts the marked patchiness in sediment composition and the spatial and temporal variability of sediment in the area.

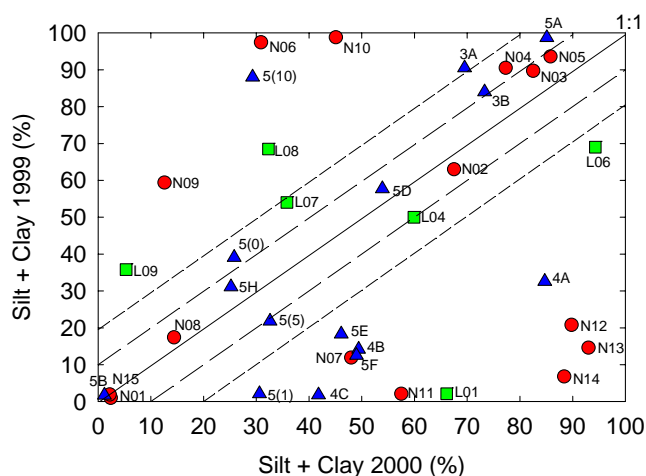


Figure 1. Values for silt + clay in surficial sediment from the coastal Beaufort Sea for 2000 versus 1999 with data from Northstar area (circles) Liberty Prospect (squares) and adjacent areas (triangles).

The largest changes in grain size distribution observed during this study occurred between 1999 and 2000. Differences in grain size distribution between the 2000 and 2002 sampling are less than observed between 1999 and 2000.

The most important finding derived from the grain size data is that sediments in many locations throughout the ANIMIDA study area are regularly shifting and that the sediment grain sizes found during one year may shift prior to sampling during a subsequent year. Thus, techniques that normalize sediment chemistry to account for differences in grain size need to be used.

Hydrocarbons. In contrast to a crude oil composition (Figure 2), the surficial sediments in the Northstar area and indeed for the whole region (e.g., Figure 3) exhibit a mixture of primarily terrestrial biogenic hydrocarbons and lower levels of petroleum hydrocarbons. This assemblage is clearly dominated by plant wax normal (i.e., straight-chain) alkanes in the n-C27 through n-C33 carbon range. This is further demonstrated by carbon preference index (CPI) values that range from two to seven for most samples, which is characteristic of sediments influenced by terrigenous plant inputs (Wakeham and Carpenter, 1976; Boehm, 1984).

The PAH distributions for most of the surficial sediments (e.g., Figure 3) show that the PAHs are primarily of a combined fossil fuel origin (i.e., petroleum and coal) with a biogenic component (perylene), and lesser contributions of pyrogenic or combustion-related compounds (e.g., 4-, 5-, and 6-ring PAHs). The petrogenic PAHs account for approximately 90 percent of the Total PAH less perylene throughout the study area (Figure 4). Perylene was abundant in surficial sediments, often the most abundant single PAH compound in the overall PAH distribution.

Concentrations of hydrocarbons in the sediments adjacent to Northstar and Liberty are generally within the observed historical range for these parameters in the overall study area. Background concentrations of Total PAHs (a sum of 2 to 6 ringed parent and alkylated PAHs) in recent Alaskan surficial sediment studies range from <10 parts per billion (ppb) to 1000 ppb. Typically PAH profiles indicate significant levels of a fossil fuel-type signature, which appears to be sourced in organics shales brought to the sediments from river runoff and coastal peat. PAH compositional results (i.e., petrogenic PAHs vs. pyrogenic PAHs) (Figure 4), illustrate no significant changes in PAH composition year over year related to Northstar construction and production activities.

The observation that the Northstar 1999 sediments may be depleted in hydrocarbons relative to the other 1999, 2000 and 2002 sediments is supported by a Total PAH less perylene versus silt + clay regression plot for all the 1999, 2000, and 2002 sediment data. In this plot (Figure 5), the regression and 95% prediction intervals are shown for all data. The plot shows a small cluster of Northstar 1999 samples which are below the 95% prediction interval, indicating that these samples are significantly lower in PAH versus silt + clay than the overall population of 1999, 2000 and 2002 samples. An analysis of the comparison of the Northstar 2000 and 2002 samples versus the BSMP and Liberty 2000 and 2002 samples resulted in no significant difference for all bulk hydrocarbon parameters and most of the diagnostic ratios. The results of this analysis are illustrated by a PAH regression plot (Figure 6) which shows complete overlap between the regression lines and 95% prediction intervals (i.e., no significant difference) for the Northstar, BSMP, and Liberty sediments for 2000 and 2002. No evidence of any inputs of Northstar-related petroleum hydrocarbons were observed in the surface sediments. Additionally, a comparison of the Total PAH from all ANIMIDA sediments from the study region in 1999, 2000, and 2002 to the Effects Range Low (ERL) and Effects Range Median (ERM) sediment quality guidelines reveals that none of the Total PAH concentrations determined in this study exceed the guidelines.

Figure 2. Northstar Oil – GC/FID Chromatogram (top), PAH Distribution Histogram (middle), Triterpane Ion Chromatogram (bottom)

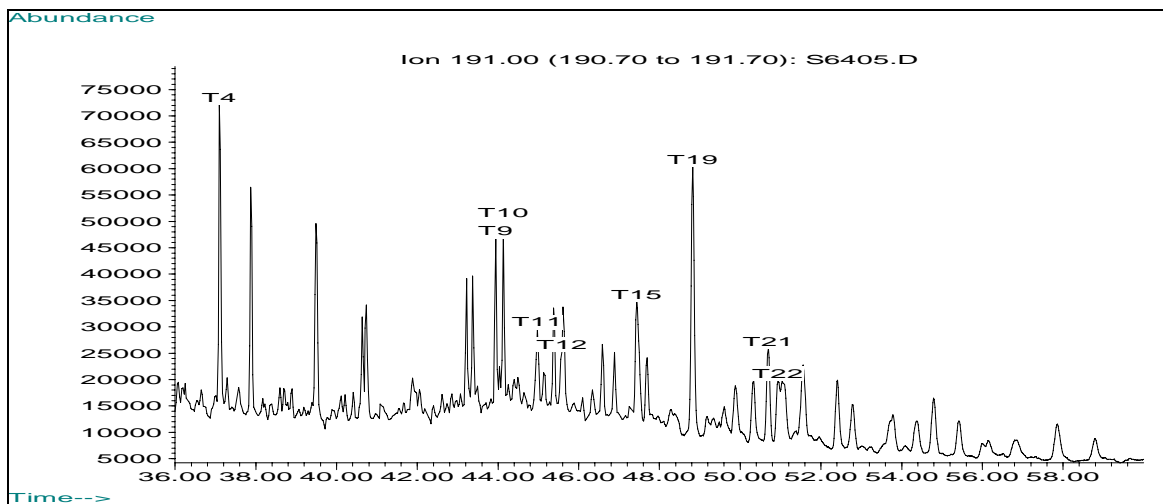
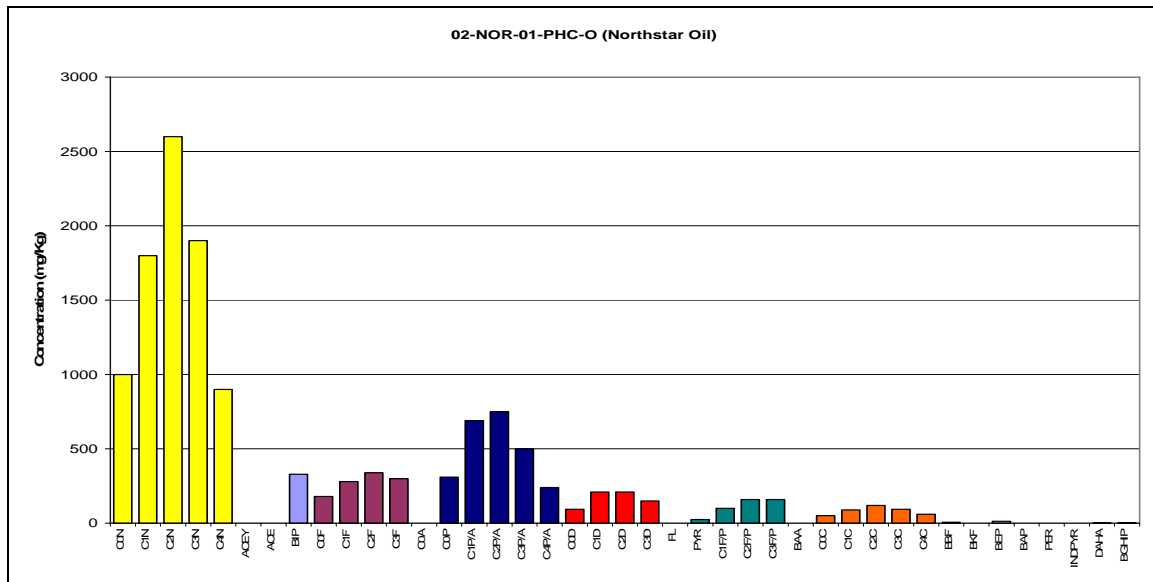
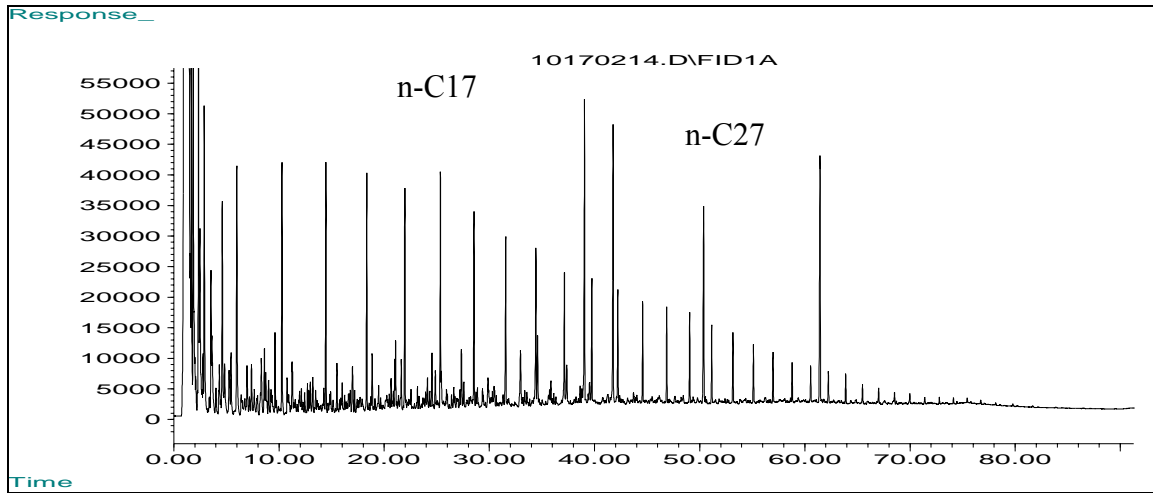
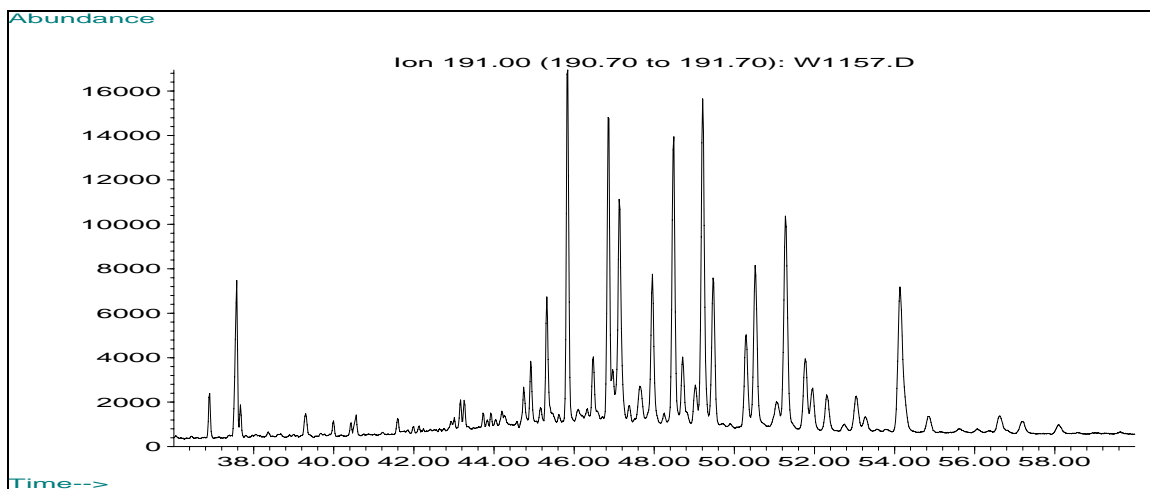
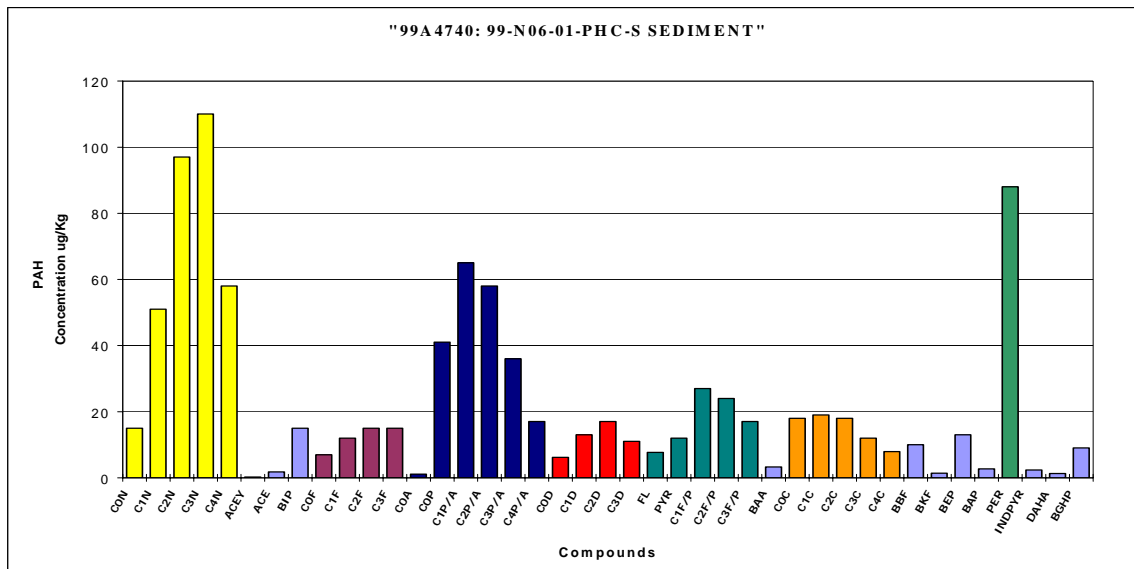
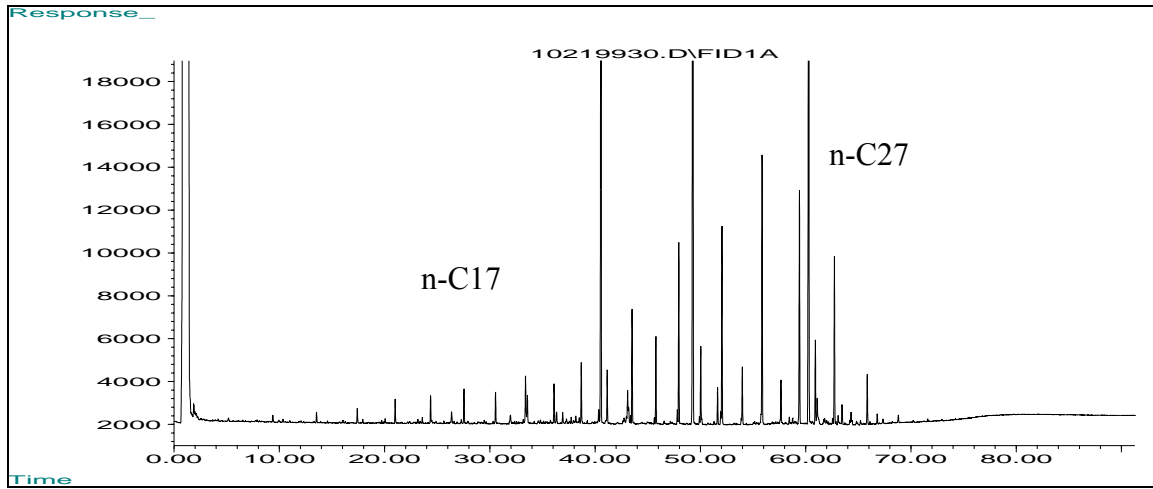


Figure 3. Northstar Station 6 Sediment, Year 1999 – GC/FID Chromatogram (top), PAH Distribution Histogram (middle), Triterpane Ion Chromatogram (bottom)



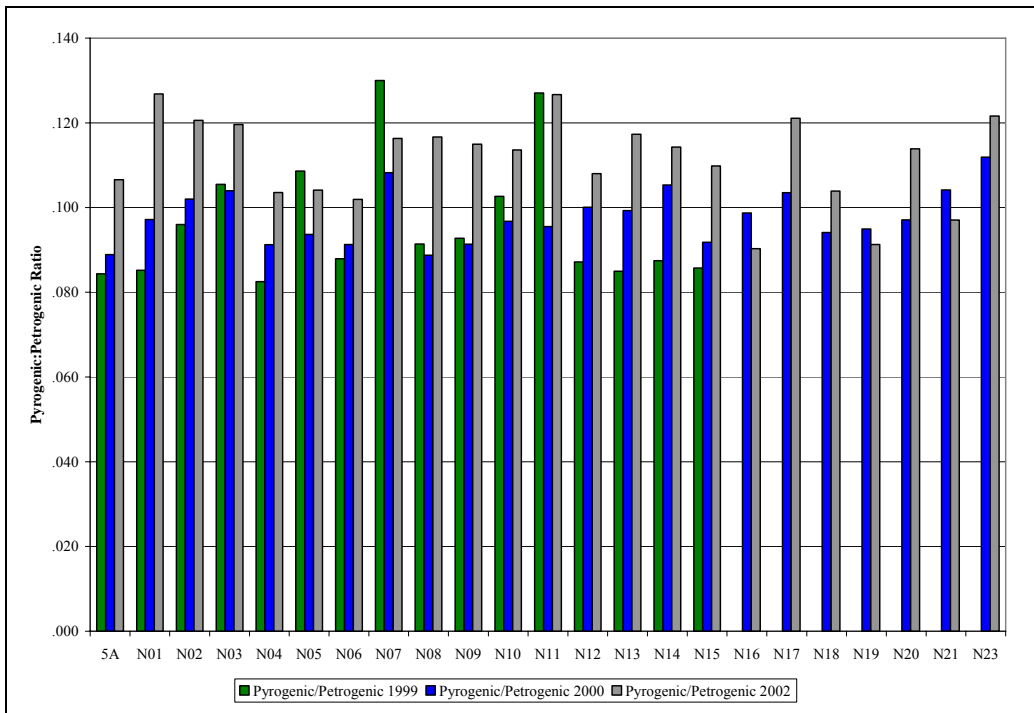


Figure 4. Pyrogenic:Petrogenic Ratios of Northstar Surficial Sediment Samples for 1999, 2000, and 2002

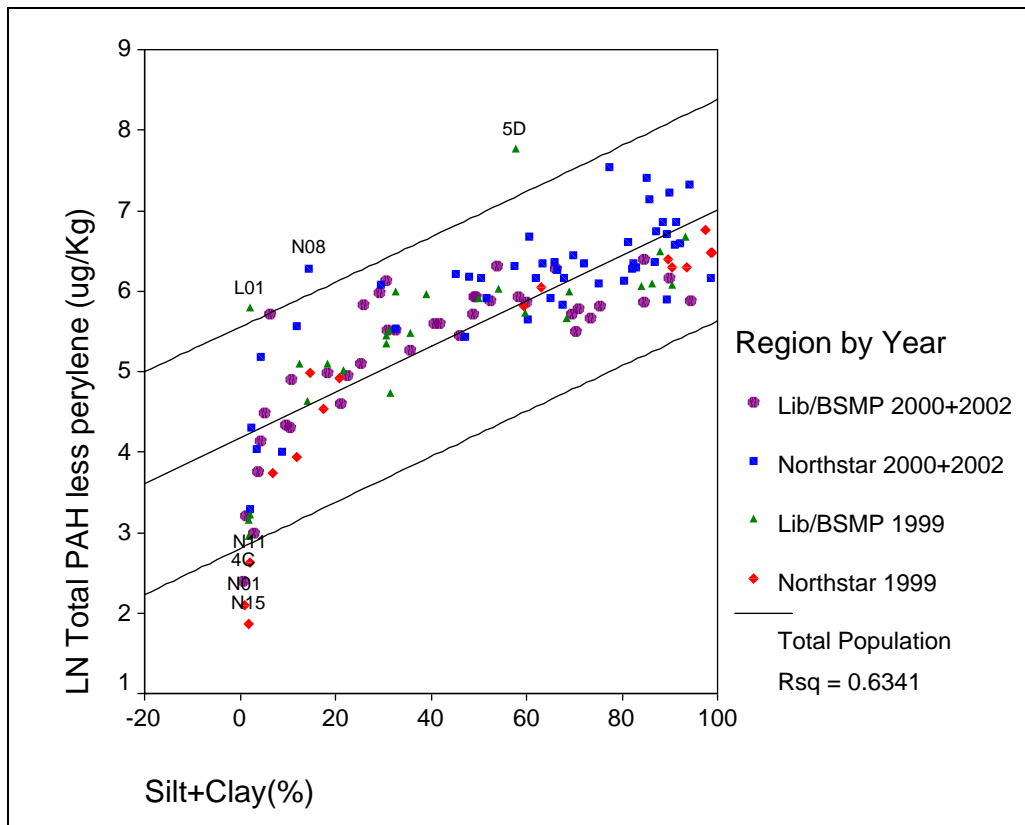


Figure 5. Regression Plot of Total PAH less Perylene versus Silt + Clay for all 1999, 2000, and 2002 Northstar, Liberty and BSMP Sediments

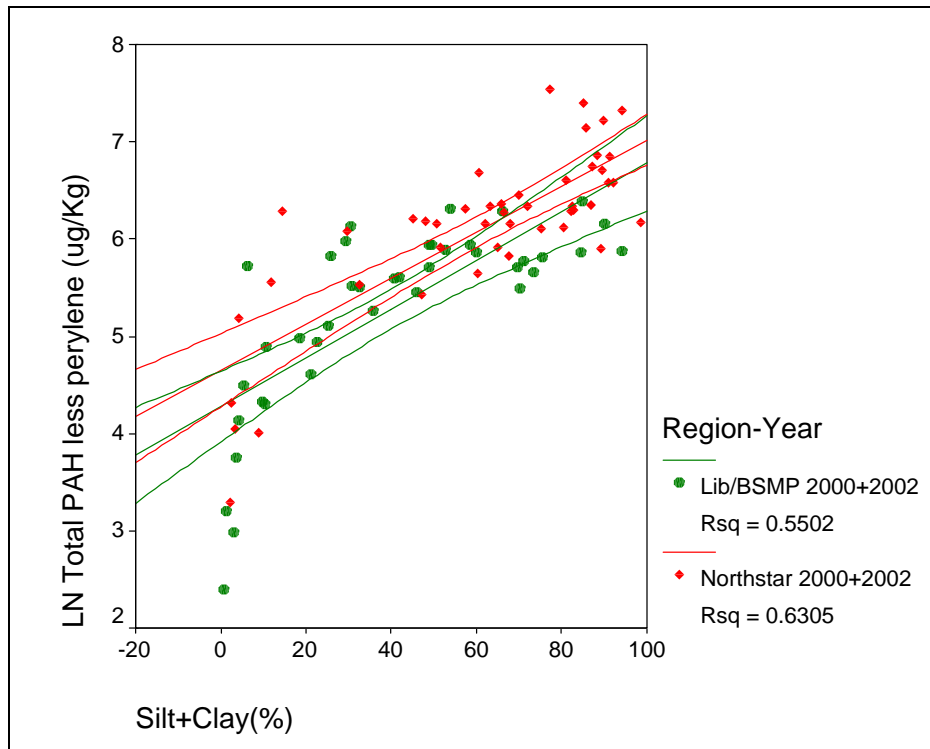


Figure 6. Regression Plot of LN Total PAH less Perylene versus Silt + Clay for all 2000 and 2002 Northstar, Liberty and BSMP Sediments. The lines, R_{sq} , and 95% prediction intervals are from linear regression and related statistical calculations.

Trace Metals. Concentrations of metals in sediment help identify spatial and temporal trends in the distribution of potential anthropogenic chemicals. Fourteen metals (Ag, As, Be, Cd, Co, Cr, Cu, Hg, Ni, Pb, Sb, Tl, V and Zn - element symbols are defined in Table 2-6) were analyzed in sediment from this study because of their potential as pollutants. Four other metals (Al, Fe, Ba, and Mn) were included in the study as indicator metals because they provide insight to sediment composition (Al in clays and Fe in iron oxide coatings), the presence of drilling discharges (Ba in barite, a common additive in drilling fluids), and sediment redox conditions (Mn, a redox-sensitive metal).

A spatial patchwork in concentrations of metals in sediment was observed as a function of variability in the distribution of sediment texture as described above. However, concentrations of trace metals generally correlated well with concentrations of Al and Fe because concentrations of most metals are very low in quartz sand or carbonate shell material and much higher in fine-grained, metal-bearing aluminosilicates. Anthropogenic processes rarely affect Al and Fe concentrations because these major elements are naturally present at percent levels in most sediment relative to part per million (ppm) levels for trace metals. Thus, Al and Fe provided a valuable normalization tool for this study that incorporated the metal-controlling variables of grain size, organic carbon content and mineralogy. In the ideal case, a good linear correlation was observed between concentrations of a trace metal and Al and/or Fe. Significant, positive deviations from this linear trend helped identify metal contamination.

Concentrations of all trace metals in sediment from all study years have been plotted versus Al. Each plot has been fit with a linear regression line and a 99% prediction interval. These plots serve as templates for identifying past and future metal contamination. Each plot reveals a consistent pattern of Al versus metal for the study period. For example, the Al versus Cr plot (Figure 7a) shows that all data points fit the 99% prediction interval very well and thus no anthropogenic inputs of Cr to the study area were encountered. The graph for Al versus Ba (Figure 7b) shows a reasonably good fit for most of the

data; however, several data points plot at more than 10% above the upper prediction interval. The anomalous points were from sites where minor inputs of Ba via runoff from land operations or from activity at Northstar Island or as remnants of prior exploratory drilling may have occurred, as explained in the report. A few other instances of slightly elevated levels of Hg (Figure 7c), Ag, Sb and Zn were found in a total of ~10 instances or only 0.8% of the >1200 data points for metals in sediment. Although these various anomalies are minor, and are generally identified at low levels of Al, they do support the sensitivity of Al versus Ba graphs and help identify locations where future monitoring efforts can be focused.

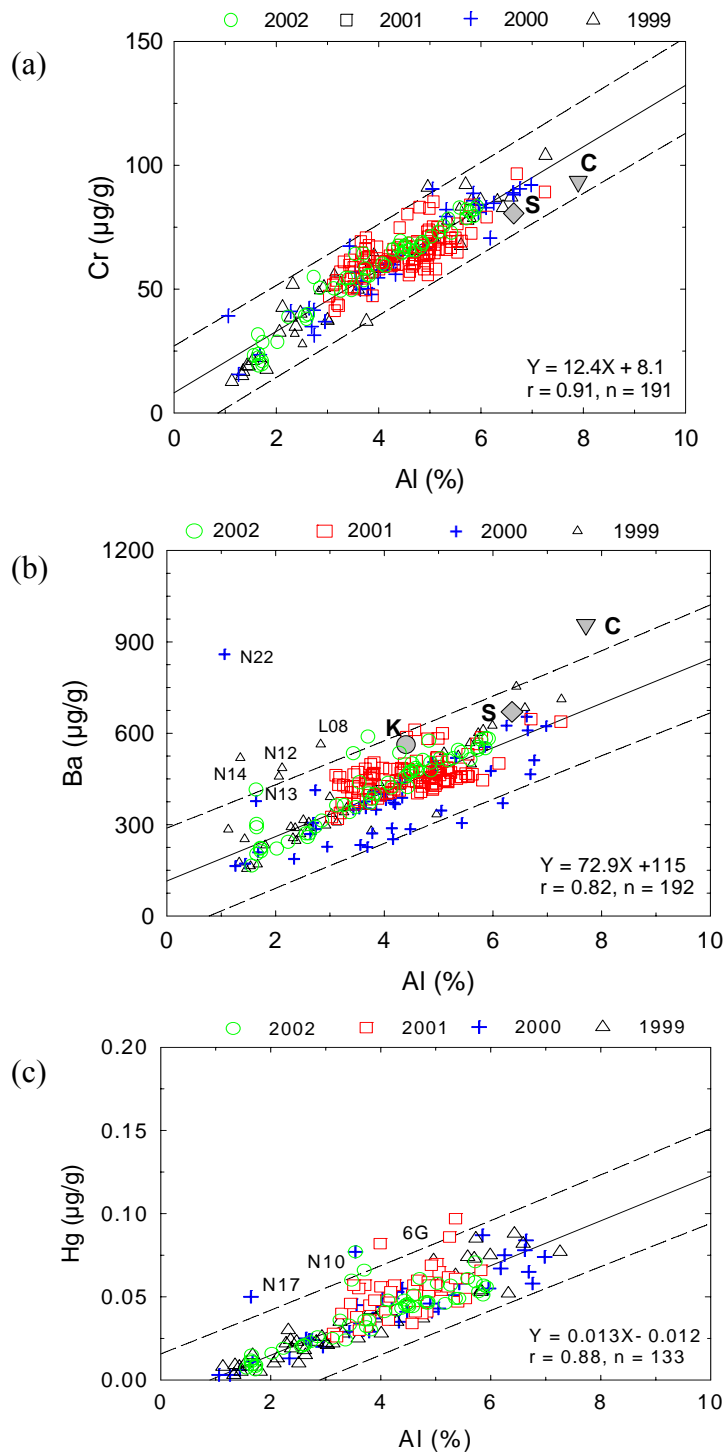


Figure 7. Concentrations of aluminum versus (a) chromium, (b) barium, and (c) mercury for sediment from the ANIMIDA study area. Equations are from linear regression calculations and r is the correlation coefficient. Dashed lines show the 99% prediction interval. Points marked with large letters are for suspended sediment from the Sagavanirktok (S), Kuparuk (K) and Colville (C) rivers. Data for sites identified on the graphs were not included in the regression calculations.

Biological Samples

As part of ANIMIDA Phase II, biota samples were collected from the ANIMIDA study area during the summers of 2000 and 2002. All samples were analyzed for PAH, SHC, S/T, and metals. This report also presents biota sample data collected in the 1980's as part of the BSMP (Boehm et al. 1991) and in 1999 as part of ANIMIDA Phase I (Boehm et al. 2001b).

Hydrocarbons. As with the pre-construction (1999) data, the amphipods (*Anonyx*) and clams (*Astarte sp.*) indicate that hydrocarbons in the sediment system are not readily bioavailable as these species exhibit little ability to bioaccumulate saturated and aromatic hydrocarbons from sediment or from the overlying water column. PAH levels are very low, showing consistent concentrations of contaminants over time in the study area.

Metals. Mean concentrations of Ba, Cu, Pb, V and Zn in clams (*Astarte sp.*) sampled during 1986, 1989, 1999, 2000, and 2002 are relatively uniform among years. Such uniformity is encouraging with respect to using body burdens for metals as long-term indicators of metal availability. This uniformity also indicates that no detectable shifts in metal levels in *Astarte* occurred between 1986 and 2000. However, the standard deviation for a given metal in an individual year is sometimes large. Such variability limits statistical discrimination of changes in metal levels.

Among the metals for which data are available for all five years, concentrations of Cu and Zn in the amphipod *Anonyx* are highest, yet, most uniform. Levels of these two essential metals are controlled by osmoregulation within the organism and anomalous body burdens for these metals may imply a physiological imbalance. However, the results based on these two metals indicate no imbalance at this time. Concentrations of Pb, a non-essential metal, are low, yet, reasonably uniform. The data for 1999, 2000 and 2002 for Ba, Cd, Cu, Pb, V, and Zn in *Anonyx* (Figure 8) as well as the other trace metals show marked similarity among years and no influence of anthropogenic input from the Northstar development. Overall, the metal data for the amphipods provide a useful baseline for monitoring shifts in concentrations over time.

SPMDs

The SPMDs from the reference site and from the Northstar site showed no significant differences in most of the key PAH parameters measured. The Total PAH concentrations in the SPMDs were low (210 – 260 ng/g). An evaluation of the PAH distribution in the SPMD samples (Figure 9) reveals composition of primarily petroleum PAH in both the Northstar and reference SPMDs, mixed with trace levels of pyrogenic PAH.

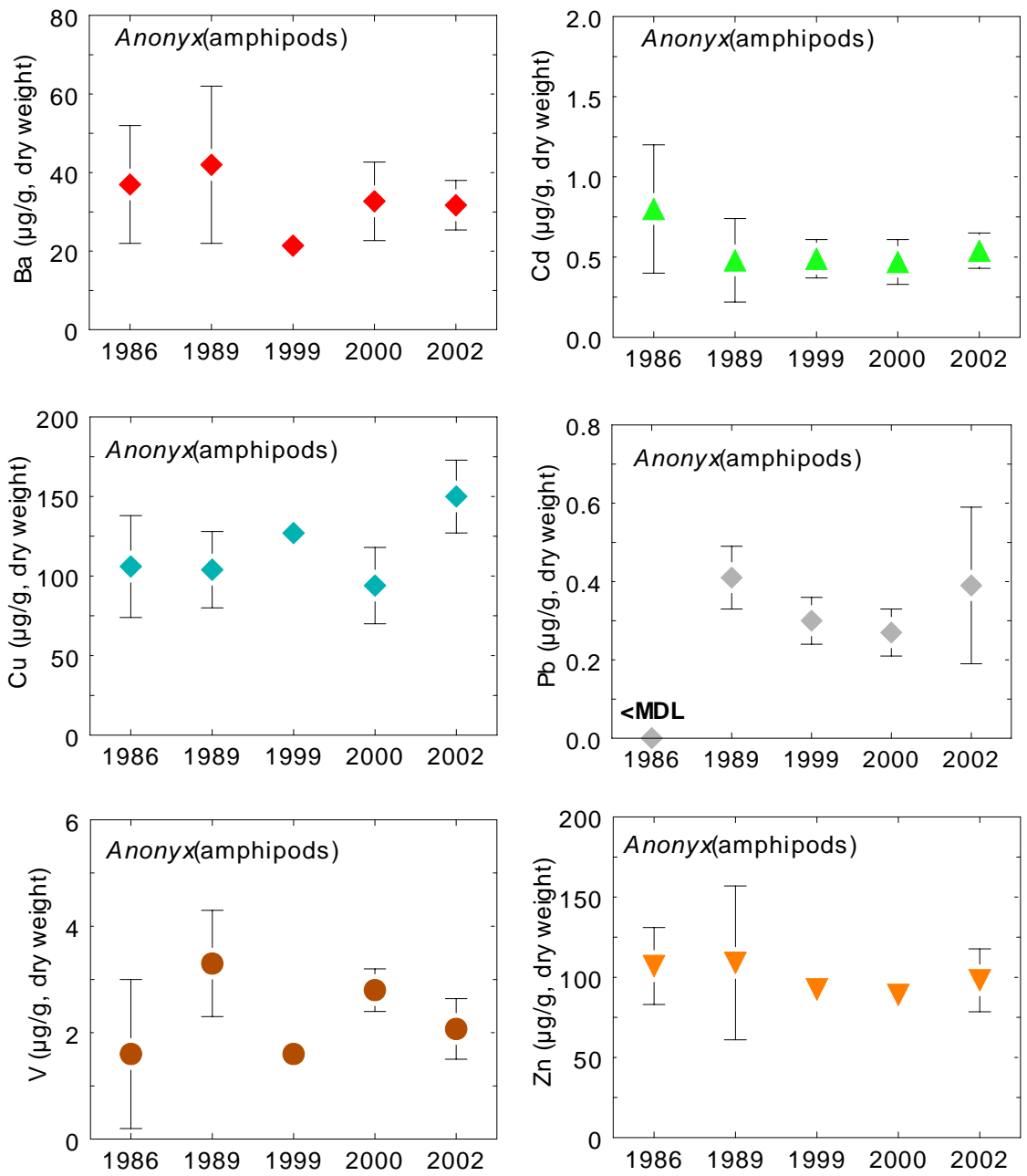


Figure 8. Mean concentrations (\pm standard deviation) of Ba, Cd, Cu, Pb, V and Zn in amphipods (*Anonyx*) collected from sites in the BSMP during 1986, 1989 and for ANIMIDA during 1999, 2000 and 2002.

Caged Mussels

The caged mussels from the Northstar and reference deployments showed no significant differences in most of the key hydrocarbon parameters measured. The PAH concentrations in the mussels were very low (13 – 17 ng/g Total PAH), however, the concentrations were substantially higher than the pre-deployment reference levels indicating that the mussels bioaccumulated trace levels of hydrocarbons. No significant differences were observed between concentrations of metals in samples from the reference site in the coastal Beaufort Sea versus Northstar Island.

Summary

Phase II sampling efforts began with the summer 2000 field survey and proceeded through the summer of 2002. Phase I sampling was conducted during the summer of 1999. During this period, construction of the Northstar Island and pipeline was completed in 2000 and production of oil began 2001.

Overall, the results of the ANIMIDA Phase I and II, Task 2 effort indicated that no significant contaminant inputs from Northstar development activities were detected and that any observed changes in the monitored environmental conditions were well within the natural variability of the study area. At the same time, the results, coupled to increased knowledge of the chemistry of natural sources of hydrocarbons and metals, indicated that the monitoring and data interpretation approaches as designed are very sensitive to changes and that if inputs were to occur, the measurement systems set in place would be powerful and sensitive enough to detect such inputs.

Task 4: Annual Assessment of Subsistence Bowhead Whaling Near Cross Island, 2001 and 2002 – Executive Summary

Michael Galginaitis, Applied Sociocultural Research
Dale W. Funk, LGL Alaska Research Associates, Inc.

This Task Order, funded by the Minerals Management Service (MMS) describes subsistence whaling as currently conducted near Cross Island by residents of Nuiqsut. While “traditional” subsistence whaling has been well documented in a number of locations, contemporary subsistence whaling is not as well documented, especially in terms of change over time. This effort is designed to measure basic parameters of Cross Island whaling so that observed changes (if any) can in the future be analyzed in relation to such factors as oil and gas activities, weather and ice conditions, or other variables. Observations, and the narrative annual report summarizing them, focus on descriptive measures of activities associated with whaling. Special attention is devoted to geospatial information through the sharing of GIS information by participating whaling crews. Project reports are only for the purposes of reporting information collected, with no analysis of the information either as a self-contained database or in conjunction with the many pertinent external databases (for example, weather records, sea ice condition remote sensing photographs, AEWK historical bowhead whale harvest records). Also, the project is designed as a collaborative effort of MMS and its contractor, Applied Sociocultural Research (ASR), the subsistence whalers from Nuiqsut, and the Alaska Eskimo Whaling Commission (AEWC). Beyond the goal of two (now expanded to six) years of descriptive information on Cross Island subsistence whaling activities, the project will develop a system for collecting such information that local whalers themselves can adopt, adapt, and maintain.

Three methods of information collection were employed – systematic observations, collection of daily vessel locational information from handheld GPS units, and whalers’ self-reports and perceptions. Emphasis has been placed on such measures as:

- Number of crews actively whaling (observation)
- Size and composition of crews, and fluctuation over the whaling season (observation)
- Number of whales harvested (observation, self-report)
- Days spent whaling, and days prevented from whaling (observation, self-report)
- Days suitable for whaling when whaling did not occur (observation, self-report)
- Subsistence activities occurring other than whaling (self-report, observation)
- Location of whale searching, whale sightings, and whale harvest (GPS, self-report)
- Local weather and ice conditions (observation, self-report)
- Bowhead whale behavior in the Cross Island area, and differences from past experience (self-report)
- Changes in access or other issues related to the whale hunt, such as increased effort for the same (or reduced) harvest, increased risk, increased cost (self-report)

In 2001, four whaling crews from Nuiqsut whaled from Cross Island. At least 1 boat went whaling on 12 different days. Whalers were on Cross Island a total of 24 days (counting day of arrival and day of departure). Weather prevented whaling on 7-8 days, 3 days were devoted to butchering a whale taken the prior day, and 2 days were devoted to travel. Three whales were harvested. The report and attached daily vessel trip forms present information on boat crew size (3 to 6 per boat per day) and daily trip characteristics (duration, GPS track, marked points, self-report of sightings and other perceptions). In 2002, three whaling crews from Nuiqsut whaled from Cross Island. At least 1 boat went whaling on 15 different days. Whalers were on Cross Island a total of 24 days (counting day of arrival and day of departure). Weather prevented whaling on 3 to 5 days, 3 days were devoted to butchering a whale taken the prior day, and 2 days were devoted to travel. Four whales were harvested, and one was struck and lost. Two of the harvested whales sank when killed, and were recovered later as “stinkers”. The report and attached daily vessel trip forms present information on boat crew size (2 to 6 per boat per day, most

commonly 3 to 5) and daily trip characteristics (duration, GPS track, marked points, self-report of significant sightings and other perceptions). The report also summarizes Nuiqsut whalers' observations and perceptions on how whale behavior in 2001 and 2002 was different from that of other years, and the implications of those differences for subsistence whaling.

Task 4: Annual Assessment of Subsistence Bowhead Whaling Near Cross Island, 2003 – Executive Summary

Michael Galginaitis, Applied Sociocultural Research
Dale W. Funk, LGL Alaska Research Associates, Inc.

This Task Order, funded by the Minerals Management Service (MMS) has as its broad objective the description of subsistence whaling as currently conducted near Cross Island by residents of Nuiqsut. This effort is designed to measure basic descriptive parameters of Cross Island whaling so that observed changes (if any) can be analyzed in relation to such factors as oil and gas activities, weather and ice conditions, or other variables. Special attention is devoted to geospatial information through the sharing of GIS information by participating whaling crews. Project reports are only for the purposes of reporting information collected, with no analysis of the information either as a self-contained database or in conjunction with the many pertinent external databases. As a second broad objective, the project is designed as a collaborative effort of MMS and its contractor, Applied Sociocultural Research (ASR), the subsistence whalers from Nuiqsut, and the Alaska Eskimo Whaling Commission (AEWC). The project will develop a system for collecting information that local whalers themselves can adopt, adapt, and maintain. This report documents the results of the third and final year of this component of the ANIMIDA project. It will be continued by at least three (possibly four) years of additional data collection as a component of the cANIMIDA project.

Three methods of information collection are employed – systematic observations, collection of daily vessel locational information from handheld GPS units, and whalers’ self-reports and perceptions. Emphasis has been placed on such measures as:

- Number of crews actively whaling (observation)
- Size and composition of crews, and fluctuation over the whaling season (observation)
- Number of whales harvested (observation, self-report)
- Days spent whaling, and days prevented from whaling (weather, equipment failure or repair, etc.) (observation, self-report)
- Days suitable for whaling when whaling did not occur (observation, self-report)
- Subsistence activities occurring other than whaling (self-report, observation)
- Location of whale sightings and whale harvest (GPS, self-report)
- Location of whale searching (GPS, self-report)
- Local weather and ice conditions (observation, self-report)
- Bowhead whale behavior in the Cross Island area, and indicated differences from past experience (self-report)
- Changes in access or other issues related to the whale hunt, such as increased effort for the same (or reduced) harvest, increased risk, increased cost (self-report)

In 2003, four crews from Nuiqsut whaled from Cross Island. At least two boats went whaling on seven different days. At least one crew was on Cross Island a total of nineteen days (counting day of arrival and day of departure). Weather prevented whaling on seven days, three days were devoted to butchering and preparations to leave Cross Island after the community quota was taken, and two days were devoted to travel. Four whales were harvested. Weather conditions were poor during the 2003 season, and Nuiqsut whalers scouted for whales on all days when conditions allowed (including the day after the first whale was taken). The final three whales were taken in two days and butchered in sequence. The number of crew members in each vessel scouting for whales varied 2 to 6 per boat per day (most commonly 3 or 4). Scouting trips varied in duration from one hour nine minutes to nine hours six minutes. Total trip distance varied from 25 to 66 miles (with the exception of aborted trips due to mechanical problems) with a greatest distance from Cross Island of from 5.5 to 22.6 miles. Whales were struck from 5.2 to 12.2

(average 9.3) miles from Cross Island. Other daily trip characteristics -- GPS tracks, marked points, self-report of significant sightings, and other perceptions – were also collected and are discussed in the report.

Task 5: Sources, Concentrations and Dispersion Pathways for Suspended Sediment in the Coastal Beaufort Sea – Executive Summary

John H. Trefry, Robert D. Rember and Robert P. Trocine, Florida Institute of Technology
Mark Savoie, Kinnetics Laboratories, Inc., Anchorage

The Arctic Nearshore Impact Monitoring in the Development Area (ANIMIDA) Program was developed to monitor potential environmental changes related to oil and gas development in the Beaufort Sea with a special focus on the Northstar and Liberty developments. A variety of biological and chemical studies were included in the ANIMIDA Program. This report presents the results from study of suspended sediment. The study was designed to address the possibility that oil and gas activities might increase levels of suspended sediment in the coastal Beaufort Sea.

The concentrations and composition of suspended particles in the coastal Beaufort Sea directly influence a variety of important processes including the following:

- (1) Penetration of light in the water column and the rate of primary productivity.
- (2) Transport and fate of trace metals and organic substances in the water column.
- (3) Adsorption of dissolved trace metals from seawater and partial control of concentrations of the more biologically available dissolved metals.

To better understand the sources and distribution of suspended sediment as they relate to the diverse processes listed above, the goals for this Task 5 study included the following:

- (1) Determine the amounts and composition of suspended sediment carried to the coastal Beaufort Sea by the Sagavanirktok, Kuparuk and Colville rivers.
- (2) Determine the concentrations, distribution patterns, composition and fate of suspended particles in the coastal Beaufort Sea, especially in areas such as Northstar Island and Liberty Prospect where construction activities now or in the future may influence concentrations of suspended sediment.

One goal of this effort was to understand the importance of river inputs and storm activity to the transport, distribution, composition and fate of suspended sediment in the coastal Beaufort Sea. In other words, natural processes and natural variations in levels of suspended sediment must be understood before attempting to identify anthropogenic perturbations. Field activities for this Task 5 study included sampling rivers during spring breakup in May-June 2001 and 2002 (Figure ES-1), through ice sampling of the Beaufort Sea during spring floods (2001 and 2002) and sampling rivers and offshore waters during the open-water periods of June-August 2000, 2001 and 2002.

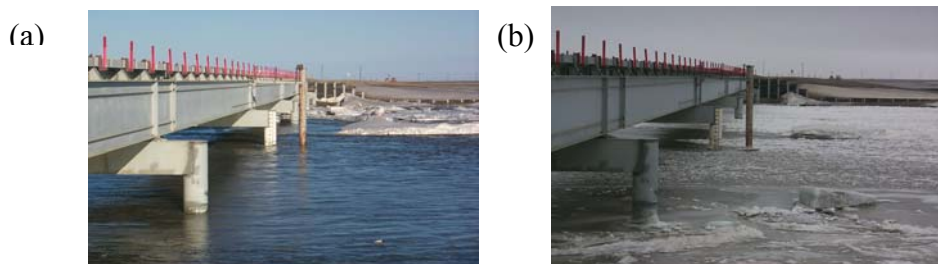


Figure ES-1. The Sagavanirktok River at a bridge near the Prudhoe Bay Operations Center (a) flowing on May 22, 2002 and (b) re-frozen on May 29, 2002.

Rivers are an important source of water and sediment to the study area during the period of spring runoff and on an annual basis. Determining the amounts and composition of river-borne suspended sediment was a key task during 2001 and 2002. The Sagavanirktok River was sampled daily during late May and June and the other two rivers were sampled every two to five days as logistics permitted. Samples of water and suspended sediment from the Sagavanirktok River also were collected at mile 401 on the Dalton Highway and at a gauging station maintained by the U.S. Geological Survey, about 100 miles south of Deadhorse (mile 327 on the Dalton Highway).

Concentrations of total suspended solids (TSS) in the Sagavanirktok River near the Prudhoe Bay Operations Center (PBOC) increased from ~40 mg/L on June 1 when flow began to 600 mg/L on June 12, 2001, and then decreased to ~30 mg/L by June 18 (Figure ES-2). During late July and August 2001, concentrations of TSS were ~2 mg/L. Concentrations of TSS followed similar trends for the Colville River with maximum levels of about 600 mg/L on June 13, 2001. In contrast, concentrations of TSS reached peak values of only 60 mg/L in the Kuparuk River on June 10, 2001 and decreased to <5 mg/L after June 16, 2001. Peak flow recorded for the Kuparuk River was about 600 m³/sec on June 12, 2001, decreasing to <50 m³/sec after June 28, 2001. During 2002, the same trend of increasing concentrations of TSS was observed; however, freezing temperatures led to refreezing of the rivers and put a hiatus in the spring flood for the Sagavanirktok River (Figure ES-2). However, the dramatic two-day flood of the Kuparuk River in 2002 occurred during the period prior to refreezing.

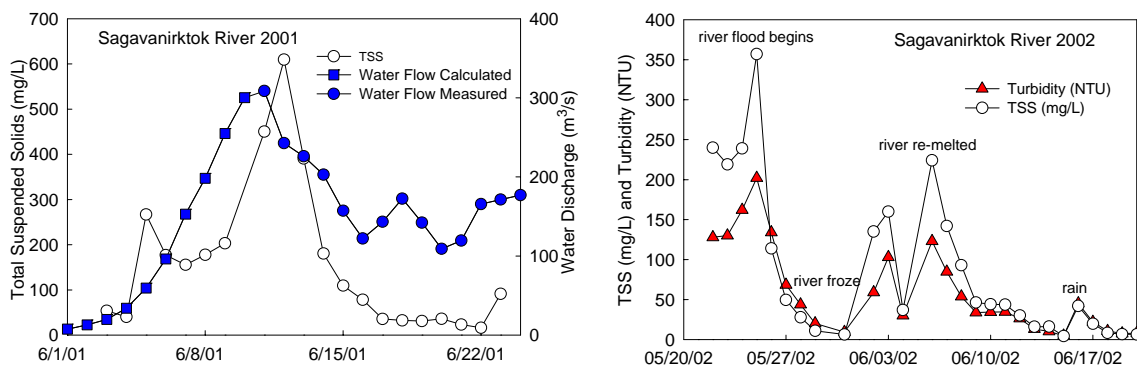


Figure ES-2. Water discharge (from U.S. Geological Survey), turbidity and concentrations of total suspended solids (TSS) in the Sagavanirktok River near the Prudhoe Bay Operations Center during May-June 2001 and 2002.

For the Sagavanirktok River, the calculated annual sediment transport was ~0.33 million metric tons for 2001, with ~87% of the annual transport of suspended sediment occurring during just 12 days in June. Total transport of suspended sediment by the Kuparuk River was 0.02 million metric tons for 2001 with ~90% of the annual sediment load of the river being carried during just three days in June. Previous estimates for the Colville River of 5 million metric tons of sediment per year are supported by recent measurements during high flow. These natural inputs by rivers can be compared with ~1.6 million metric tons of sand and gravel used to construct Northstar Island [(800,000 yd³ x 0.76 m³/yd³ x 2.6 metric tons/m³ = 1.6 million metric tons). Coastal erosion also is an important source of sediment to the coastal Beaufort Sea, including the ANIMIDA study area. Estimates from previous studies state that coastal erosion may contribute sediment to the coastal Beaufort Sea at levels that are equal to or several times greater than inputs of sediment by rivers. Studies of erosion were not part of the ANIMIDA project; however, available results are reviewed in this report.

Samples of suspended sediment also were collected under the ice, seaward of the rivers during the early days of spring runoff in 2001 and 2002 when the coastal Beaufort Sea was still ice covered. Concentrations of TSS averaged ~40 mg/L in a 2-m thick lens of freshwater immediately under the ice that extended >10 km offshore (Figure ES-3). The suspended sediment was very rich in fine-grained aluminosilicates as shown by the levels of Al and other metals in the particles. Metal/Al ratios in suspended particles collected under the ice showed that the composition of river-borne particles was similar to that found for bottom sediment.

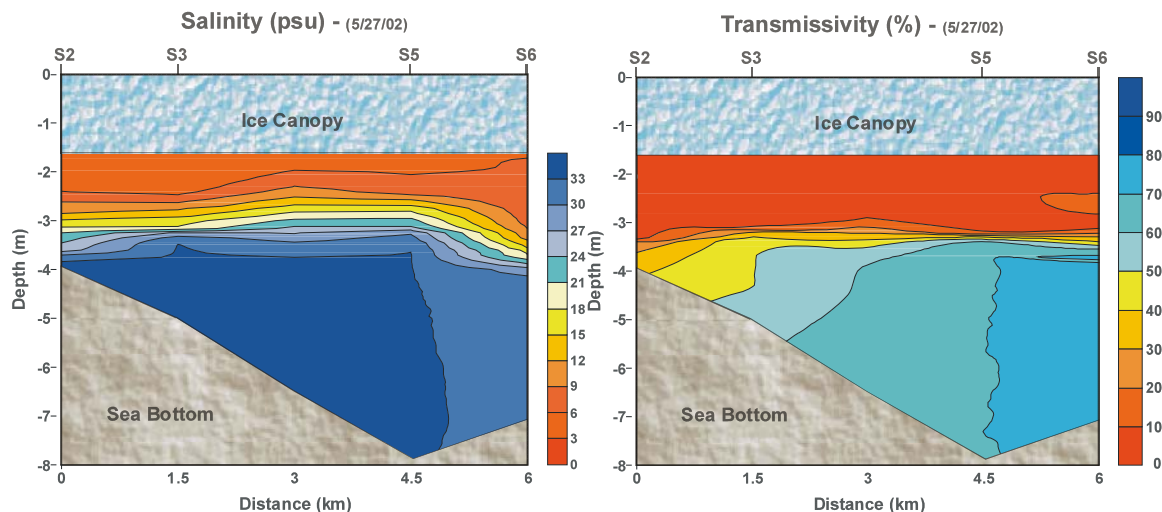


Figure ES-3. Vertical profiles for salinity and transmissivity (turbidity) along a transect (distances on lower x axis) seaward of the Sagavanirktok River for May 27, 2002.

During the open-water period in 1999-2002, numerous vertical casts and horizontal tows in the water column were made throughout the coastal Beaufort Sea to measure turbidity, salinity, temperature and current speed and direction. Turbidity was measured by in situ turbidimeter, by laboratory turbidimeter using discrete samples and by filtration/gravimetry using discrete samples.

The day-to-day turbidity and distribution of TSS in the coastal Beaufort Sea were dependent on river flow, ice cover and sea state. In the protected, relatively quiescent waters under ice during most of the year, levels of TSS were low at a few tenths of a milligram per liter relative to average levels of ~40 mg/L in surface waters under the ice during the spring floods. During the brief open-water period, after the spring floods, concentrations of TSS were typically <20 mg/L and varied as a function of sea state and the presence of floating sea ice. Sea state was directly related to the strength and duration of winds. Concentrations of TSS increased to >50 mg/L during the summer only following a period of several days with winds greater than 20 knots. In contrast, levels of TSS <2 mg/L were observed under conditions where calm water had prevailed for several days. This later condition was most likely to occur when floating ice dampened any wind effects. No significant deviations in levels of turbidity were observed adjacent to Northstar Island during 2000-2002 while towing a turbidimeter-CTD package along transects at distances as close as 100-500 m from the island.

The chemical composition of river suspended sediment was compared with results for bottom sediment to help identify possible anthropogenic inputs of suspended sediment or contaminant metals to the coastal environment. Differences in the elemental composition of suspended sediment were observed among rivers. The Colville River contained greater amounts of particulate Al, Fe and trace metals relative to the more Ca-rich particles of the Sagavanirktok River and the more organic carbon-rich particles of the Kuparuk River. However, the metal/Al ratios for all elements, except Ca, were not significantly different among rivers and bottom sediment from the coastal Beaufort Sea.

Concentrations of trace metals also were determined for samples of suspended matter collected from the coastal Beaufort Sea. The fine-grained aluminosilicates suspended in the water column were enriched with Al and trace metals. However, concentrations of most metals in suspended sediment for 2000 and 2001 plotted within the 99% prediction intervals for metals versus Al that were developed using data for bottom sediment. Thus, in most instances, concentrations of trace metals associated with suspended particles were within the limits established for uncontaminated sediment. Suspended particles are potentially a more sensitive indicator of recent metal contamination than sediment because the small amounts of suspended particles typically found in the water column lead to a larger relative enrichment of anthropogenic metal concentrations. This sensitivity was demonstrated with several samples of suspended sediment that were collected very near Northstar Island during construction in August 2000 and contained Pb at levels that were 20-50% above background.

With respect to sedimentation, the ANIMIDA area appears to be a net erosional environment at this time. Based on our observations, much of the large sediment load of the rivers is carried across the nearshore environment to deeper waters of the Beaufort Sea along a freshwater channel under the ice during spring or with summer and fall storms. Therefore, sediment monitoring for contaminants must be coordinated with measurements of radionuclides such as ^{137}Cs , excess ^{210}Pb , ^{234}Th or ^7Be that help ensure that samples are recent and not relict deposits.

Overall, no significant differences in concentrations of TSS that could be directly linked to oil and gas operations were observed in the ANIMIDA area. Periodic enhancement in levels of TSS in the coastal Beaufort Sea can be related to river runoff and resuspension of bottom sediment by strong winds. Natural inputs of suspended sediment from runoff and erosion are large relative to any anthropogenic inputs of sediment.

Task 6: Linking Water Turbidity and Total Suspended Sediment Loading to Kelp Productivity within the Stefansson Sound Boulder Patch – Executive Summary

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The Stefansson Sound Boulder Patch, located 20 km northeast of Prudhoe Bay in the Alaskan Beaufort Sea, supports the only known kelp bed on the Alaskan arctic coast that is characterized by high benthic diversity associated with an abundance of boulders, cobbles, and pebbles. Growth and production of the endemic arctic kelp *Laminaria solidungula*, which is abundant throughout the area, is regulated primarily by PAR (photosynthetically active radiation) availability during the summer open-water period. Variation in underwater PAR, caused by changes in water transparency, can have significant effects on the annual productivity of this species (Dunton, 1990). Although the physiological responses of *L. solidungula* to changes in PAR are well described, the relationship between PAR and water turbidity (measured in terms of total suspended solids [TSS]) is poorly understood. Consequently, our ability to assess the effects of changes in water transparency, whether caused by natural or anthropogenic events, is significantly compromised.

In an attempt to further our understanding of the relationship between TSS and light availability, we measured the inherent optical properties (IOPs) of Stefansson Sound waters, including absorption, scattering, and attenuation, in conjunction with TSS concentrations for a two-week period in summers 2001 and 2002. These data were used in a radiative transfer equation (RTE), and a TSS concentration specific attenuation coefficient [$K_d^*(\lambda, H)$] was determined. The attenuation coefficient was inserted into a productivity model to estimate daily kelp production throughout the Boulder Patch. Our model output agreed well with previously published measurements of annual kelp production based on the number of hours of saturating irradiance available to the kelp under average water transparency conditions.

The highest TSS levels (23.0 – 24.2 mg L⁻¹) occurred in nearshore areas during summer 2001 and were coincident with increased light attenuation (11.4 – 14.0 m⁻¹). In both years, lower TSS concentrations and lower light attenuations were measured in areas furthest from the coast within the Boulder Patch kelp community. Although light attenuation through the water column decreased in summer 2002, attenuation and TSS were significantly correlated ($p < 0.01$).

Our results clearly demonstrate that suspended sediment concentrations have varying but substantial effects on light availability, and subsequent kelp production, during the summer open-water period. Increasing average TSS concentrations from 1 to 10 mg L⁻¹, within ranges measured *in situ*, decreased annual production by an order of magnitude. Even under an array of surface irradiance budgets, production estimates and rates changed substantially under different TSS concentrations. Production, modeled under a variety of summer surface light regimes, was always higher at lower TSS concentrations and estimated kelp production was higher in offshore locations, despite deeper depths, because they are characterized by lower TSS.

The accuracy of the model was tested using previously recorded surface irradiance data from 1990 and 1991. In both years, model estimated production coincided well with annual production calculated from blade length data. Similar accuracy was demonstrated when the model was used to estimate annual production for 2001. Although previous years' estimates coincided with those calculated using blade length data, estimates for 2002 production were distinctly different. This was most likely the result of temporal sampling bias. Low TSS concentrations recorded during a two-week period in summer 2002 were probably not representative of water conditions for the entire summer open water season in 2002.

Consequently, reasonable estimates of kelp production using this model are dependent on TSS, IOP, and surface light measurements reflective of overall summer conditions.

Task 7: Partitioning of Potential Anthropogenic Chemicals between Dissolved and Particulate Phases in Arctic Rivers and the Coastal Beaufort Sea – Executive Summary

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The Arctic Nearshore Impact Monitoring in the Development Area (ANIMIDA) Program was developed to monitor potential environmental changes related to oil and gas development in the Beaufort Sea with a special focus on the Northstar development. The ANIMIDA Program included a variety of biological and chemical studies. This report presents results from study of the partitioning of potential anthropogenic chemicals between dissolved and particulate phases in arctic rivers and the coastal water of the Beaufort Sea.

In the dissolved form, trace metals and organic substances are generally more biologically available and have a greater chance to induce toxic effects in organisms. In general, concentrations of dissolved trace metals in coastal seawater are controlled by river runoff, adsorption on suspended sediment and biological uptake. During 2001 and 2002, concentrations of dissolved metals were determined for the Sagavanirktok, Kuparuk and Colville rivers and for coastal water of the Beaufort Sea. The underlying theme in this effort was to understand the natural sources, transport pathways and concentrations of dissolved metals in the coastal Beaufort Sea. The natural processes that help regulate concentrations of dissolved substances must be understood before attempting to identify anthropogenic perturbations.

Field activities for ANIMIDA Task 7 included sampling of rivers and offshore water during open-water periods of July-August 2000, 2001 and 2002 plus through-ice and river break-up efforts during May-June 2001 and 2002. Rivers are a major source of dissolved metals to the study area. The Sagavanirktok River was sampled daily during June 2001 and 2002 and the other two rivers were sampled every two to five days as logistics permitted. Samples of water and suspended sediment from the Sagavanirktok River also were collected at mile 401 on the Dalton Highway, and at the site of a gauging station maintained by the U.S. Geological Survey (U.S.G.S.), about 100 miles south of Deadhorse.

Concentrations of the following dissolved and particulate metals: arsenic (As), barium (Ba), calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), nickel (Ni), lead (Pb) and zinc (Zn), particulate aluminum (Al) and dissolved and particulate organic carbon (DOC and POC) were determined for the three rivers during June to August 2001 and 2002.

Concentrations of dissolved trace metals were low, but different among the three rivers. For example, in the Sagavanirktok River, the following average concentrations of dissolved metals were determined: Pb at 15 ng/L, Cu at 0.6 µg/L and Ba at 32 µg/L whereas in the Colville River these three metals were found at concentrations of 60 ng/L, 2 µg/L and 50 µg/L, respectively.

The most striking trend in the dissolved data was found for DOC with maximum levels of DOC in the Sagavanirktok River >8 mg/L during peak flow relative to 2 mg/L at lower flow (Figure ES-1). Concentrations of Fe, Mn, K and Cu followed trends for DOC quite

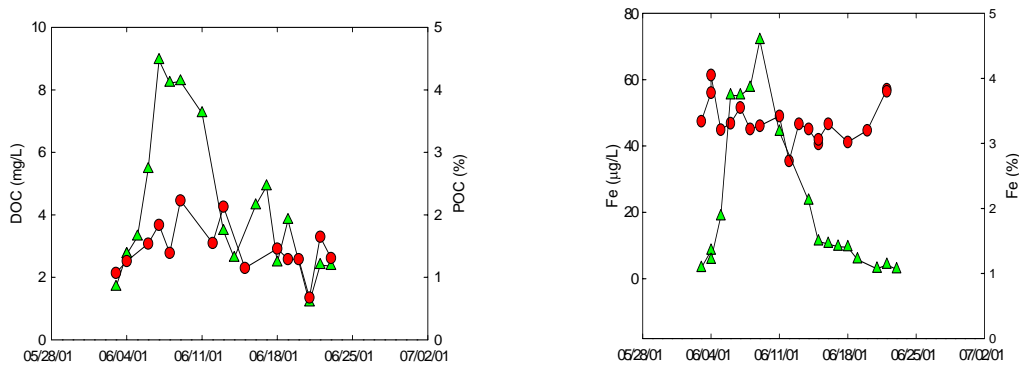


Figure ES-1. Concentrations of dissolved (triangles) and particulate (circles) organic carbon (DOC and POC) and dissolved (triangles) and particulate (circles) iron (Fe) in the Sagavanirktok River during June 2001.

well (e.g., Fe in Figure ES-1). These trends are consistent with a pulse of exuded, DOC-rich water from thawing soils in the drainage basin that occurred shortly after the initial melt event during the period of peak flow. Trends for dissolved Fe, Mn and K, also derived from thawing soils, matched the trend observed for DOC. Concentrations of dissolved Cu followed DOC relatively well; however, the magnitude of change was somewhat less than observed for the other elements. For dissolved Ba, Ni and Pb, concentrations shifted only slightly in response to the increase in levels of DOC. Concentrations of particulate metals (on the basis of $\mu\text{g metal/g}$ suspended sediment) were rather uniform during June 2001 and fit metal/Al ratios defined for bottom sediment in the coastal Beaufort Sea. In most cases, very little (<10%) of the metal burden of the rivers was in the dissolved phase during the June period of high flow.

The forms of the metals and controls on concentrations of dissolved metals in rivers are important to understanding subsequent behavior in the saline water of the coastal Beaufort Sea. Concentrations of dissolved and particulate Ba varied directly among the rivers (Figure ES-2) and thus a simple distribution coefficient (K_d) was used to explain observed concentrations, where

$$K_d = \frac{\text{(concentration of particulate metal in } \mu\text{g metal/g particles)}}{\text{(concentration of dissolved metal in } \mu\text{g metal/g water)}}$$

When this approach was used for Ba, the fit was quite good with the K_d for Ba averaging $2.4 \pm 0.5 \times 10^4$ for all the rivers (Figure ES-2). This trend supports the concept that concentrations of Ba in suspended sediment regulate concentrations of dissolved Ba. The same approach also was applied to Pb and Cu; however, the fit was less consistent, suggesting that other factors, such as complexation with organic matter influences concentrations of dissolved Pb and Cu.

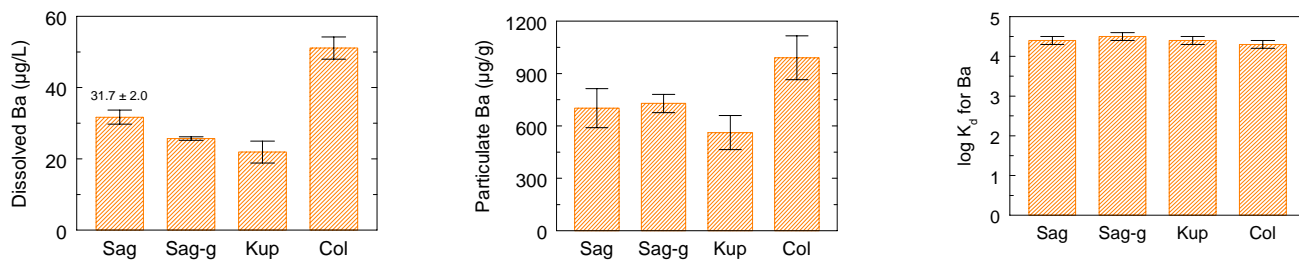


Figure ES-2. Concentrations of dissolved and particulate barium (Ba) in the Sagavanirktok (Sag), Kuparuk (Kup) and Colville (Col) rivers during summer 2001 and log of the distribution coefficient (K_d) for Ba. Sag-g identifies upstream location at site of U.S.G.S. gauge.

Concentrations of dissolved trace metals in the saline water of the coastal Beaufort Sea were generally lower than found in the rivers with the following observations: Pb at 4-7 ng/L, Cu at 0.5 µg/L and Ba at 13 µg/L. Concentrations of total Hg in the coastal Beaufort Sea also were low at about 0.5-0.8 ng/L. Schematic representations for the distributions of dissolved As and Ba are shown in Figure ES-3. Concentrations of As increased from the rivers to the sea and concentrations of Ba decreased.

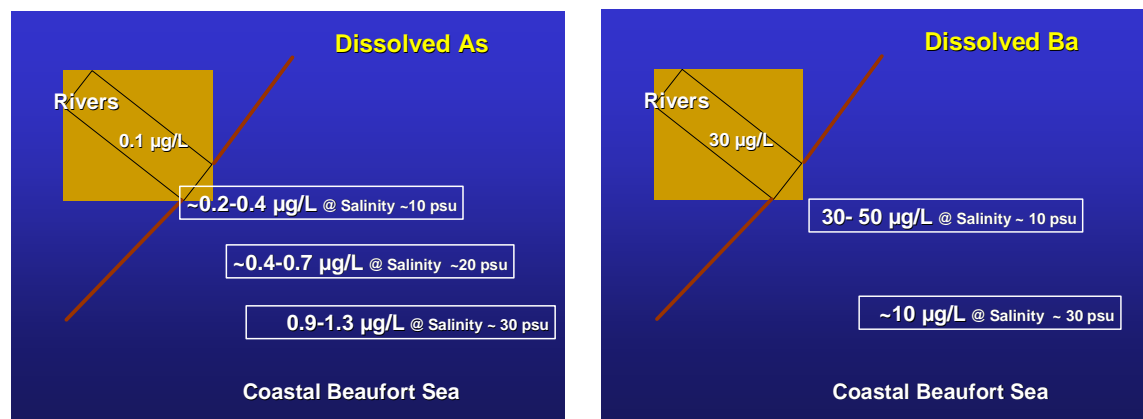


Figure ES-3. Generalized distributions of dissolved arsenic (As) and barium (Ba) in source rivers and coastal water of the Beaufort Sea.

The Total PAH (TPAH) concentrations in whole seawater samples (dissolved + particulate fractions) were low and ranged from 22 to 68 ng/L. The TPAH of the particulate fraction of the seawater samples ranged from 13.2 to 18.5 ng/L. The PAH distribution for the particles shows a petrogenic or petroleum hydrocarbon composition, characterized by a predominance of the 2- and 3-ringed alkyated PAH compounds, with a lower abundance of 4-, 5- and 6-ringed PAH. The PAH in the seawater samples were primarily associated with suspended sediment. The composition of the PAH in the suspended sediment was similar to that observed for riverine and benthic sediment in the ANIMIDA study area. Analysis of the dissolved fraction showed no detectable PAH in the dissolved phase in support of the statement that the PAH are bound to suspended sediment and do not partition to any great extent into the dissolved phase.

The main conclusions from ANIMIDA Task 7 are as follows: (1) concentrations of dissolved trace metals and PAH in the study area are very low and characteristic of pristine water, (2) concentrations of some metals can be modeled with a simple distribution coefficient, and (3) active physical, chemical and biological processes are at work to create a dynamic, yet predictable, distribution of dissolved trace metals in the study area. Such information will be useful for long-term monitoring (years, decades and centuries) and will provide an evolving capability for predicting impacts from any spills or other releases of chemicals within the drainage basin or the coastal sea.

Task 8: Baseline Characterization of Anthropogenic Contaminants in Biota Associated with the Alaska OCS Liberty and Northstar Oil and Gas Production Units in the Nearshore Beaufort Sea – Executive Summary

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The bioaccumulation of trace substances, including anthropogenic contaminants, was investigated in five species of fish in and near the North Slope oil field developments, including the Northstar project area and the Liberty prospect. The fish species studied were: Arctic Cod, Arctic Cisco, Four Horn Sculpin, Broad Whitefish and Humpback Whitefish. We collected fish from a total of five sites (from west to east): Stump Island, Northstar, Point Brower, Liberty and Bullen Point. Whole body concentrations of polynuclear aromatic hydrocarbons (PAH), organochlorine compounds (PCBs and 12 pesticides) and 12 trace metals were determined. Two biomarkers of contaminant exposure were also evaluated: P4501A in liver hepatocytes and gut epithelial cells and bile hydrocarbon metabolites.

The PAH, and many of the metals are potential contaminants arising from oil field operations, such as drilling, production, transportation of personnel and materials, dock construction, and onshore support operations. These contaminants also have local natural sources and distant anthropogenic sources. The organochlorines are normally not expected to result from oil field operations and most of the organochlorines undoubtedly have their ultimate sources far from the North Slope of Alaska, from where they are carried in winds and haze as volatile gases or absorbed to aerosols. However, some organochlorine data were needed for interpretation of biomarker data and their analysis did not incur much extra cost to the project. In addition, the Arctic Marine Assessment Program (AMAP), a multi-national program to assess contaminants in the Arctic, has recommended that organochlorines be measured in and around oil field operations and sites of historic military operations, e.g., Bullen Point near the development area. Further, Presidential Executive Order 12898 mandates measurement of contaminants in subsistence resources as a matter of environmental justice. In addition, distant anthropogenic sources of metals are likely making some contributions to the metals measured in biota in the development area.

The two biomarkers, P4501A induction and bile metabolites of PAH, both respond to exposure to PAH, and because of PAH metabolism, are in fact, more relevant to PAH exposure than measures of these compounds in tissues.

Site-by-site comparisons were also carried out by analysis of variance for each species to see which sites had statistically higher concentrations of contaminants. Other analyses of variance were carried out to determine if weight of fish explained a significant amount of variability in the contaminant concentration data. We report a number of different patterns of variability in which there were differences in trace substance concentrations in fish due to site and discuss site-to-site differences and whether they may be related to anthropogenic inputs. The site-to-site comparisons of trace substance concentrations in various species of fish are based on relatively small numbers of samples, so the relationships found should be interpreted cautiously, i.e. they may change with larger sample numbers. About 10% of the significant site differences in individual trace substances could be due to chance. These data and their analysis should be the basis for further investigation and monitoring. However, the data provide a good overall picture of trace substance concentrations in fish in the development area.

Perhaps the strongest evidence for anthropogenic influences from petroleum development are the concentrations of PAH and the two biomarkers that respond to PAH, particularly in the Four Horn Sculpin. While there were no effects of site on total PAH or low-molecular weight PAH in any species of fish, there were differences seen in high-molecular-weight PAH between sites for Arctic Cisco and Four

Horn Sculpin. The sites where there were elevated concentrations in these two species were Stump Island and Point Brower. In Four Horn Sculpin P4501A induction in liver varied significantly with site, with Point Brower and Stump Island having the highest responses. In Arctic Cod, Northstar fish had significantly greater P4501A content than Liberty fish. Hydrocarbon metabolites in the bile also had a pattern of differences that is somewhat consistent with P4501A induction. Phenanthrene equivalents in the bile varied significantly with site in Four Horn Sculpin, with Bullen Point, Stump Island, and Liberty having the higher responses than Point Brower. Benz(a)pyrene equivalents in the bile of this species also varied significantly with site with Stump Island clearly having the highest concentrations. Arctic Cisco also had benz(a)pyrene equivalents that varied significantly with site, with Bullen Point having the highest measured concentrations.

Both of these bile hydrocarbon components occur in extracted petroleum, and probably in drill cuttings from the developed formations, but they also have potential natural sources, particularly benzo(a)pyrene. If anthropogenic activities are responsible or contributing to these responses in Four Horn Sculpin, and given the sites at which they occur, then it is more likely that they are not directly related to drilling at the platform sites. Rather, it may be the activity to the east of Stump Island at West Dock, e.g., motorized vessels, that may be the source. There also may be some influence of the nearby Endicott Causeway on fish caught at Point Brower. At Bullen Point, historical activities at the military site may be responsible for the observed responses.

Among the chlorinated hydrocarbons and pesticides, a variety of patterns were observed. Data on site differences in these anthropogenic compounds were interpreted as to whether they may indicate distant sources, e.g., transport from lower latitudes, or some local source. In the case of PCBs, Arctic Cisco varied significantly with site; fish from Stump Island had the highest concentrations. A similar trend was seen for total pesticides, except that Stump Island and Point Brower were the two sites with the higher concentrations. However, for other individual classes of pesticides making up the total pesticide category, there were significant differences due to site with one or more species. For Chlordanes, DDTs, Endosulfans and Endrins, Stump Island had consistently high concentrations relative to the other sites. It was also mainly the Arctic Cisco that had significant site differences for these groups of compounds (save for DDTs). The Four Horn Sculpin had site differences for Chlordanes. Humpback Whitefish had site differences for Endrins. Arctic Cod had site differences for HCHs. Taken together these data suggest that there are elevated concentrations of several pesticides in the area of Stump Island and Point Brower over the general background for the area and there might be a low-level source there for pesticides. We do not know what the potential local source for this low-level elevation over background might be, but Arctic Rivers can carry significant amounts of contaminants from distant sources that are deposited on the land and washed into the rivers during the summer. Point Brower is in the delta of the Sagavanirktok River.

Also consistent with the known long-range transport in the atmosphere from lower latitudes to the Arctic, PCBs were generally uniformly distributed among sites for four of the five species of fish analyzed, the exception being Arctic Cisco at Stump Island. We have, however, recognized two patterns of relative congener abundance in the fish from this study: a mixture dominated by high-molecular-weight congeners, and a second pattern including a similar congener composition of high-molecular-weight compounds, but also has significant, and sometimes dominant, low-molecular-weight components (e.g. IUPAC congener 8). The low-molecular-weight congeners in such mixes have been reported previously from Beaufort Sea samples.

Interpreting anthropogenic contributions of metals poses a particular problem, as the metals being analyzed all occur in the sediments and fish tissues naturally and it is possible to have residual concentrations in the gut of the fish being analyzed. We can probably discount anthropogenic loadings of nickel that did not differ with change of site. However, most of the metals did show significant

differences due to site in one or two species: arsenic, barium, cadmium, chromium, iron, lead, mercury, selenium, vanadium and zinc.

The high concentrations of arsenic in Four Horn Sculpin occurred at Stump Island, Liberty and Point Brower. The reason for this pattern is not know, as it did not appear to be significantly elevated in sediments anywhere in the area on an iron-normalized basis. It is not known if there is an anthropogenic source of arsenic in the area.

Analysis of the ratios of barium to iron in the fish data suggests that sediment may have played a role in trace metals detected in Four Horn Sculpin. We therefore ascribe no other particular interpretation to the site effect seen with this element in Four Horn Sculpin. In addition, the barium sulfate used in drilling mud is not very biologically available to marine organisms.

Site effects were found for cadmium in Arctic Cisco and Humpback Whitefish. In the former species, Point Brower, Liberty and Stump Island fish had higher concentrations than Bullen Point. Stump Island Humpback Whitefish had greater concentrations of cadmium than Point Brower fish. Cadmium bioavailability can change with salinity, but it is not known if salinity was a factor in determining site differences in these two species.

There was only one species where the variation in iron content differed significantly between sites: Arctic Cod. Again, it is not known whether this is attributable to development activity at the Northstar location, but further consideration may be in order for this element as well. Since Cod are bottom feeders, at least part of the time, sediments in the gut may have influenced this outcome. Iron is an essential element and is therefore physiologically regulated in fish. It seems unlikely that without a very large biologically available source that iron would appreciably accumulate in fish beyond the range that is physiologically required.

Humpback Whitefish was the only species where site differences were seen for lead concentrations, with Stump Island fish having higher concentrations than Point Brower.

One species showed significant variation in mercury: Arctic Cisco. Point Brower Cod had greater concentrations than the other sites, but the differences in means were very little. At this stage, we cannot rule out a slight difference in natural or anthropogenic influence on mercury in this species. Nor can we rule out random variability in a small sample set (n=5-11 per site) as an explanation of this finding.

For selenium there was one species for which site had a significant effect on whole-body concentrations: Arctic Cod from Liberty had greater concentrations than those from Northstar. Again, this is based on a very small sample size (n=7-8) and we have no reason to attribute this to anthropogenic activities.

Vanadium is another element for which Arctic Cod showed significant differences due to site. In this case the Liberty fish had higher concentrations than the Northstar fish. Again the potential influence of sediments in the gut may as well as small sample size may be a factor, as there are no known sources of Vanadium at Liberty.

For zinc, the Arctic Cisco was the only species in which site had an influence on whole-body concentrations. In this case, Point Brower, Liberty and Stump Island had higher concentrations than Bullen Point. We attach no particular significance to this finding.

Based on high site-trace contaminant and site-biomarker differences, we recommend the Four Horn Sculpin as a candidate species for further monitoring of possible anthropogenic releases of trace substances that may be bioaccumulated by fish. The Four Horn Sculpin, along with the Arctic Cod, appear to be the two species that are most appropriate for monitoring at the offshore platform areas, while

the two species of Whitefish and the Arctic Cisco are anadromous and more closely tied to the inshore portions of the development area. In this regard, we present and discuss the relative power of different sized collections of Four Horn Sculpin to detect changes in various trace contaminants and the number of years required to detect different percentage change with a fixed number of fish per site. For example, if Four Horn Sculpin were to be analyzed for PAH by collecting 20 fish per site per year, it is estimated that it would take 4 to 7 years of data to detect a 50% change in concentrations. The analysis of variation also indicated that 50% differences in concentrations of most analytes can be detected with fewer than 15 fish.

4.0 ANIMIDA OCS Study Reports

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