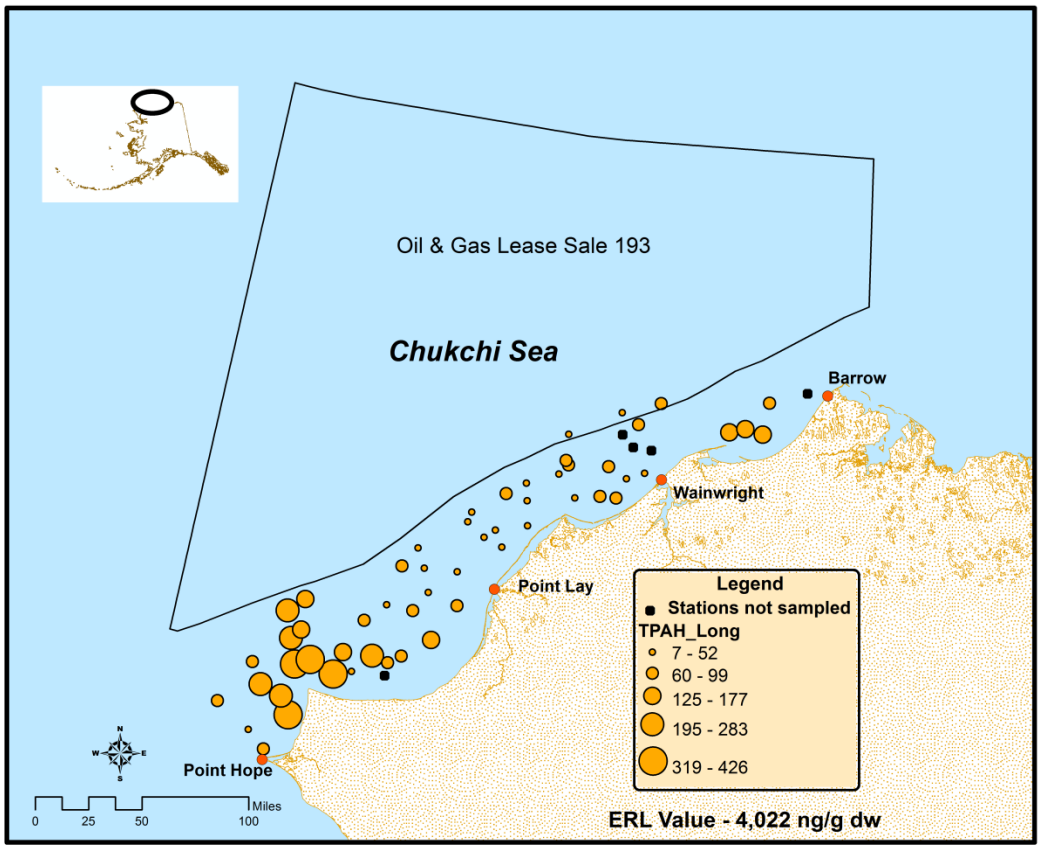
Alaska Monitoring and Assessment Program
2010 and 2011
Chukchi Sea Coastal Survey
Environmental Status



Prepared by University of Alaska Fairbanks, Institute of Marine Science and Alaska Department of Environmental Conservation, Division of Water, Water Quality Standards, Assessment, and Restoration

Alaska Monitoring and Assessment Program (January 2016)

Cover Map Credit & Description

The cover page map presents the individual AKMAP Chukchi Sea 2010 and 2011 survey results for each station in symbols proportional to the total polycyclic aromatic hydrocarbon (TPAH) sediment concentrations. The thirteen individual PAHs (Acenapthene, acenaphthylene, anthracene, fluorene, 2-Methylnapthalene, phenanthrene, benz(a)anthracene, benzo(a)pyrene, anthracene, chrysene, dibenzo(a,h)anthracene, fluoranthene, pyrene) used to develop the Effects Range Low (ERL) and Effects Range Median (ERM) were summed for the individual station TPAH. The map was done in ArcGis 10.3 by Douglas Dasher, University of Alaska, Institute of Marine Science, Fairbanks, AK.

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Preface

The Alaska Department of Environmental Conservation (DEC) Division of Water, Water Quality Standards, Assessment and Restoration and University of Alaska Fairbanks (UAF) Institute of Marine Science (IMS) conducted an Alaska Monitoring and Assessment Program (AKMAP) survey of the Chukchi Sea in 2010, 2011, and 2012. The National Oceanic and Atmospheric Administration joined this effort in 2011. The surveyed region lies within a 25 to 50 mile exclusion corridor between the near shore (~10-50 m depth) and the Bureau of Ocean Environmental Management (BOEM) oil/gas lease Sale #193. A spatial probabilistic survey design developed under the U.S. Environmental Protection Agency Environmental Monitoring and Assessment Program was used to assess the ecological status of this area. Over the summers of 2010 and 2011, 60 stations were surveyed as part of the probabilistic survey. Additional targeted stations were sampled: one in 2010; three in 2011; and 11 in 2012.

This report provides the status or "snapshot" of resource conditions, e.g. the percent of area for the sampled target population that meet Alaska Water Quality Standards or other indices. A companion document the *Alaska Monitoring and Assessment Program 2010 and 2011 Chukchi Sea Coastal Survey Statistical Summary* provided background details on the survey design and statistical analysis. Both documents may be found at http://dec.alaska.gov/water/wqsar/monitoring/chukchisea.html.

Suggested citation for this report is:

Dasher, D, Lomax, T, Jewett, S, Norcross, B., Holladay, B. and Blanchard, A. (2015) Alaska Monitoring and Assessment Program 2010 and 2011 Chukchi Sea Coastal Survey Environmental Status. Alaska Department of Environmental Conservation Division of Water, Water Quality Standards, Assessment and Restoration, Anchorage, AK, DEC AKMAP Chukchi Sea/2015.

The document can be downloaded at the following URL:
http://dec.alaska.gov/water/wqsar/monitoring/chukchisea.html

Acknowledgments

This project is funded in part with qualified outer continental shelf oil and gas revenues by the Coastal Impact Assistance Program, U.S. Fish and Wildlife Service, U.S. Department of Interior. Funding was provided by Shell Exploration and Production Company to support the sea bird and marine mammal observations. We appreciate support from National Oceanic and Atmospheric Administration which supported Ian Hartwell's participation on the AKMAP Chukchi Sea team in 2011 to assist with sediment and CTD operations.

Disclaimer

The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinion or policies of the U.S. Government. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. government.

Note that the design supports probability-based estimates of the percent area of the target population surveyed for particular ecological status defined by measured values of assessment indicators. However, this design does not provide for specific assessments of the ecological status within a particular estuary or coastal area.

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Executive Summary

The Alaska Department of Environmental Conservation (DEC) and the University of Alaska established the Alaska Monitoring and Assessment Program (AKMAP) in 2004. It focuses on conducting aquatic resource surveys of Alaska's waters. One of the most recent AKMAP surveys was in the Chukchi Sea, a marginal sea of the Arctic Ocean. AKMAP and National Oceanic and Atmospheric Administration (NOAA) conducted the Northeastern Chukchi Sea Survey from 2010-2011 with funding from the Coastal Impact Assistance Program. This survey focused on the near shore environment from Point Lay to Barrow, Alaska between water depths of 10-50 meters. It was conducted during open water time periods, typically August or September.

This report provides the statistical background for the 60 stations sampled that comprised the AKMAP Chukchi Sea probabilistic survey. This report is based on ecological indices developed for water, sediment, and biological data. Rankings of good, fair, or poor are given for each index by comparing sample results with Alaska Water Quality Standards or other criteria relevant to the sampled region. A rating of good means > 90% of samples meet the criterion, fair is between 90% and 50%, and poor is <50%. The overall environmental status for the nearshore Chukchi Sea region surveyed is ranked as good. This status includes both numeric rankings and best professional judgment. The water quality index is rated good, 96.8% of the surveyed area met the dissolved oxygen, dissolved inorganic phosphate and nitrate, dissolved oxygen, and chlorophyll-a criterion used to make up this index. The sediment quality index is rated as good, with 100% of surveyed area meeting sediment contaminants and total organic carbon criterion used to develop this index. The benthic index was rated as good, although no numeric criteria exist to compare our results with. Instead benthic data were evaluated based on best professional judgement using criteria such as species diversity, abundance and a species assemblage normal for the habitat. The rankings do not address the potential for both positive and negative ecological changes occurring due to changing climate or oceanographic conditions (e.g. acidification).

Figure 1 – Chukchi Sea and Clouds

Chapter 1 - Environmental Status of the Chukchi Sea Coastal Waters Executive Summary

1. Background

The Alaska Monitoring and Assessment Program (AKMAP) led by Alaska Department of Environmental Conservation (DEC) in partnership with the University of Alaska Fairbanks Institute of Marine Science (IMS) conducted a coastal aquatic resource survey of the Chukchi Sea coastal environment in 2010 and 2011 (Figure 2). This region was investigated because of the need for baseline data in an area expected to see increasing oil/gas resource survey and development pressure. In 2011, the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program (NS&T) joined this effort.

Principal funding for the AKMAP Chukchi Sea coastal survey - hereafter referred to as AKMAP survey - was provided through the Alaska Department of Natural Resources Coastal Impact Assistance Program (CIAP) (DNR, 2015). The Federal government provided CIAP funding to Outer Continental Shelf (OCS) oil and gas producing states to mitigate the impacts of OCS oil and gas activities. Additional support was provided by Shell Exploration and Production Company for conducting seabird and marine mammal surveys in 2010 and 2011 and for assistance with processing benthic samples from 2011.

The AKMAP survey design is based on the EPA survey approach developed under its Environmental Monitoring and Assessment Program (EMAP) (U.S. EPA, 2015a). EPA has since renamed EMAP to National Aquatic Resource Survey (NARS). This design utilized a spatial probabilistic selection of sample stations as part of a multi-tiered, integrated monitoring of environmental indicators. While the AKMAP survey followed NARS protocols is not part of the 2010 NARS National Coastal Condition, due to its alternate funding source.

The probabilistic sampling design provides for the interpretation of the ecological status of large areas with a relatively small number of sampling sites (McDonald 2000). Data are integrated from multiple environmental media, including water quality, sediment, biological, physical, and chemical parameters. This integrated data provides for a better evaluation and assessment of ecosystem status than more traditional monitoring which typically emphasize single media and a stand-alone approach.

2. Environmental Status

The overall goal of AKMAP surveys is to assess the condition of aquatic resources and provide a baseline for future trend assessments. Trends cannot be established for the AKMAP surveyed region until multiple surveys have been conducted. This AKMAP survey focuses on reporting the environmental status or "snapshot" of resource conditions, e.g., the percent of area for the sampled target population that meets Alaska Water Quality Standards (DEC, 2015) or other indices across the surveyed region shown in Figure 2. Three indices of regional environmental status are developed from data collected during the survey: a water quality index, sediment quality index, and benthic index. An assessment of contaminant concentration in fish tissue is also presented, but due to limited number of fish analyzed, no inference is made to regional status. This report is used to support DEC's reporting on the status of Alaska's waters under requirements of the Federal Clean Water Act.

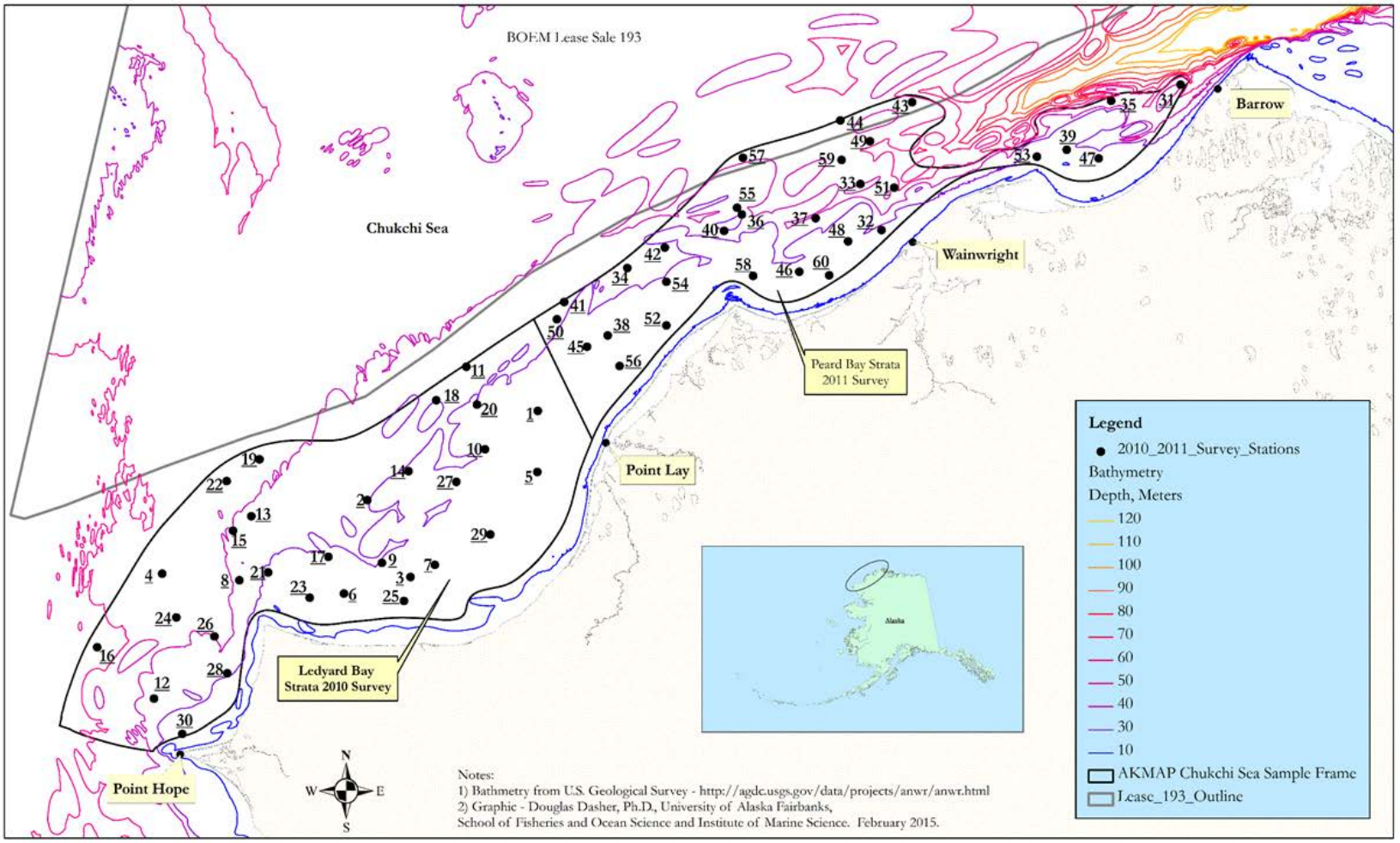

Figure 2 – AKMAP Survey 2010 – 2011 Station Map

These indices do not address all of the environmental characteristics that may be of concern to Alaskans, but their use is an attempt to assess the data in the context of the Alaska Water Quality Standards. The water quality index component indicators are dissolved inorganic nitrate as nitrogen and phosphate as phosphorus, chlorophyll *a*, and dissolved oxygen. Sediment quality index component indicators are sediment contaminants and total organic carbon. The results are then ranked against cutpoints providing for relative ratings of good, fair, or poor for each index. The cutpoints are based on specific Alaska Water Quality Standardsand/or numeric criteria. In cases where these are not available, i.e., nutrients, chlorophyll *a*, benthic invertebrate's, best professional judgment was used to establish the cutpoints. Chapter 3 discussed the indexes, cutpoints and components in more detail. Indexes were then ranked as good, fair, or poor based on overall scores.

Table 1 – Description of Indices and Component Indicators

Index	**Source**
Water Quality Index	Best professional judgment, existing Chukchi Sea nutrient and chlorophyll *a* data, and DEC Water Quality Standards.
Sediment Quality Index	DEC Water Quality Standards, DEC Contaminated Sites Program, U.S. EPA, and best professional judgment.
Benthic Index	Best professional judgment and consultation with experts.
Fish Tissue Contaminant Index	U.S. EPA, 2006.
Component Indicator	**Source**
Nitrate as Nitrogen (NO_3-N mg/l)	No DEC Water Quality Standards. Selected nutrient and chlorophyll *a* data for Chukchi Sea waters were obtained from the NOAA National Oceanographic Data Center (NODC) estimate background values for the cutpoints.
Phosphate as Phosphorus (PO_4-P mg/l)	
Chlorophyll *a* (µg/l)	
Dissolved Oxygen (DO) mg/l	DEC Water Quality Standards
Sediment Contaminants	Long et al., 1995.
Sediment Total Organic Carbon (TOC %)	U.S. EPA National Condition Assessment Report IV.

3. Limitations of Available Data

Results of the AKMAP survey for summers of 2010 and 2011 provide a "snapshot" of the Chukchi Sea coastal environmental condition but do not address changes or trends in environmental condition. Climate change has contributed to significant warming of the Arctic Ocean at approximately three times the global average and has the potential to affect the Chukchi Sea coastal ecosystem through water temperature changes; variations in nutrient input, changes in ice cover distribution and extent, and ocean acidification (Kedra et al., 2015, Mathis et al., 2015). As the Arctic ice pack recedes increased ship traffic introduces the risk of hydrocarbon or other spills that can impact the near shore ecosystems. Additionally, any future oil and gas development in the Chukchi Sea introduces potential for hydrocarbon spills, potentially impacting all associated ecosystems.

It is important to note that at present the Chukchi Sea is a region is considered to represent a reference condition (Mineral Management Services, 2007). Reference condition typically describes an ecosystem that is relatively unaffected by human disturbances. While the Chukchi Sea is not removed from all human disturbances i.e., prior offshore drilling and exploration activities, vessel traffic, atmospheric deposition and ocean transported pollutants, it remains relatively pristine. The reference condition of this area must be considered when elevating our data against derived indexes and rankings. The rankings typically allow for comparisons to Alaska Water Quality Standardsor

some other derived index, but in this case represent variation in natural conditions rather than any identifiable impacts from human disturbances. The AKMAP survey of the Chukchi Sea region provides a baseline to understanding environmental change and for the development of appropriate responses to protect this important ecosystem.

4. Lack of Benthic Criteria & Sediment Quality Guidelines

The AKMAP survey assessed and compared the invertebrate communities throughout the Chukchi Sea area shown in Figure 1. Alaska Water Quality Standards have not adopted indices of benthic community condition that can be used for ranking (DEC, 2015). However, studies in Port Valdez and Norton Sound provide a basis for interpreting benthic community characteristics for responses to anthropogenic stressors. For this survey the results were assessed using best professional judgment to rank the benthic habitat current condition. Based on historic macroinvertebrate data sets and results of the sediment chemistry for 2010 and 2011 little evidence exists to find that the benthic habitat is currently impacted by human activities (Blanchard et al, 2015, unpublished). Relative to the studies in Port Valdez and Norton Sound, there is no evidence of stress (e.g., increased proportions of stress tolerant species) in the AKMAP Chukchi Sea study area (Blanchard et al. 2002, 2003, 2010, 2011; Blanchard and Feder 2003; Jewett et al., 1999). Given the strong linkages and high similarity of fauna in the Chukchi Sea with those of Alaska's southern coastal waters (Blanchard, 2014), the results of the environmental studies elsewhere in Alaska are relevant and highly significant to inferences in the Chukchi Sea. The data sets gathered during the AKMAP survey provide further information that can help with future development of benthic indices for the various marine ecosystems in Alaska. Benthic habitat index for the AKMAP Survey coastal waters was rated good based on best professional judgment of species abundance and diversity.

While DEC does not have specific numeric sediment guidelines the AKMAP survey uses the Effects Range Low (ERL) and Effects Range Median (ERM) values (Long et al., 1995) to assess sediment contamination. ERM is the median concentration (50th percentile) of a contaminant observed to have adverse biological effects in the literature studies examined. A more protective indicator of contaminant concentration is the ERL, which is the 10th percentile concentration of a contaminant represented by studies demonstrating adverse biological effects in the literature. Concentrations below the ERL represent a minimal effects range where effects would be rarely observed, but are not absent; ranges between the ERL and ERM are presented as possible effects range where effects would occasionally occur and ERM and above concentrations reflect a probable effects range with frequent occurrences (Long et al., 1995).

AKMAP, NOAA Status and Trends, Cook Inlet Regional Citizens Advisory Committee, Prince William Sound, University of Alaska IMS and others are conducting studies of the marine environment that can be utilized in developing Alaska specific water quality indices and guidelines.

5. AKMAP Lack of Repeated Surveys

AKMAP survey designs are meant to be periodically repeated to allow for the assessment of trends or changes in the environment and assess potential causes for these changes. This AKMAP survey and this report remains just a "snapshot" in time and does not evaluate possible changes from previous studies in the region nor does it represent smaller areas, such as the Ledyard Bay Critical habitat for molting spectacled eiders, necessarily at an appropriate spatial scale to assess their specific

environmental status. In planning future AKMAP surveys of this region, important factors to consider are incorporating new research findings, assessment methods, and indicators.

6. Overall Environmental Status

Overall the regional environmental status in relation to the Alaska Water Quality Standardsand indices discussed in Chapter 3 is ranked as good (Figure 3). This status includes both numeric rankings and best professional judgment. The ranking does not address the potential for both positive and negative ecological changes occurring due to changing climate or oceanographic conditions. Numerous peer-reviewed publications and reported traditional ecological knowledge are documenting changes overtime in the Chukchi. Trends or changes may become apparent if the AKMAP survey is repeated periodically, which is one goal of AKMAP surveys.

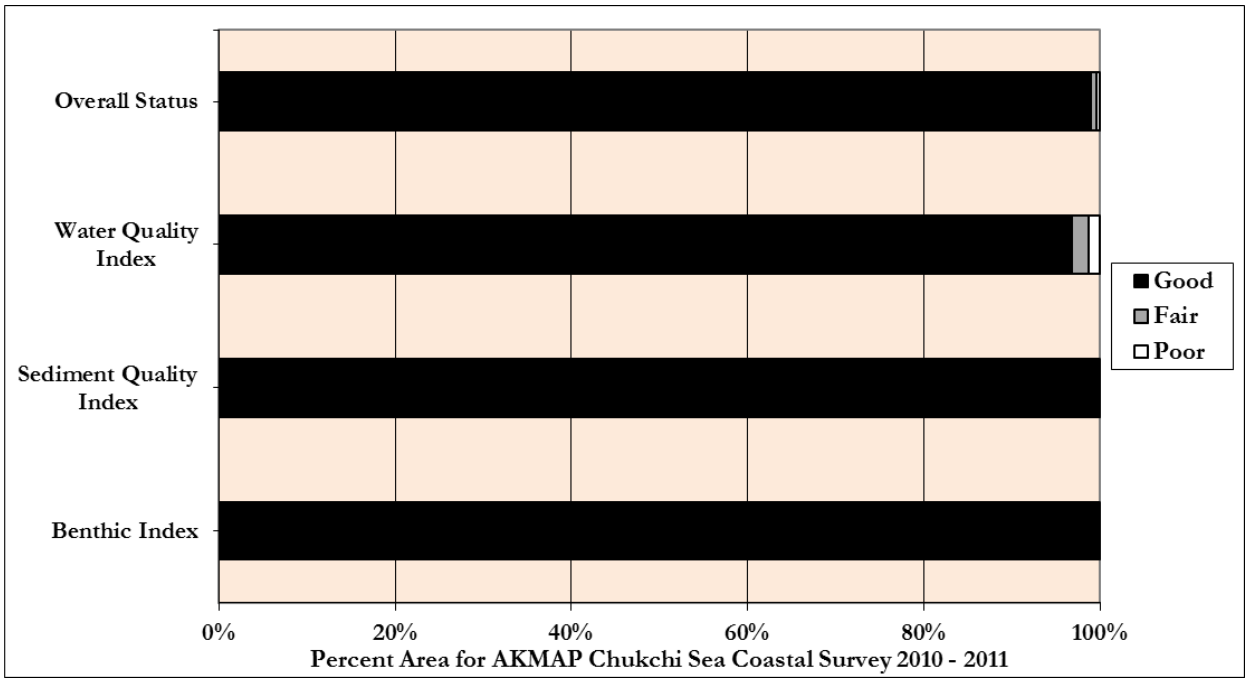

Figure 3 – Overall Status

7. Scientific Studies – Utilization of the AKMAP Survey Data

The data resulting from the AKMAP survey has broad application for the use in better understanding the ecology and environmental conditions beyond the initial assessment here. Numerous presentations and peer-reviewed papers have resulted and are in process that will add important information for environmental impact studies and long term understanding of this region. Appendix A contains a current listing of presentations and publications that have resulted from the use of the AKMAP survey data.

8. AKMAP Chukchi Sea Program Highlight: Monitoring Seabirds and Marine Mammal

The Chukchi Sea has one of the highest rates of primary productivity in the world ocean (Grebmeier et al. 2006). This extraordinary productivity supports rich benthic and planktonic communities that in turn support large communities of apex predators such as seabirds, pinnipeds, and whales. Due to the importance of the seabirds and marine mammals within the AKMAP Chukchi Sea region being surveyed, additional funding support was sought to add seabird and marine mammal monitoring to our 2010 and 2011 field work. Shell Exploration and Production Company, Anchorage, AK, provided funding to support these additions.

Summary results of the seabird and marine mammal surveys are presented in comparison with historic data in maps. Figure 4 shows the distribution of benthic-feeding whales in the AKMAP study area for 2010 – 2011 combined with historic data back to 1976 (Morgan et al., 2012).

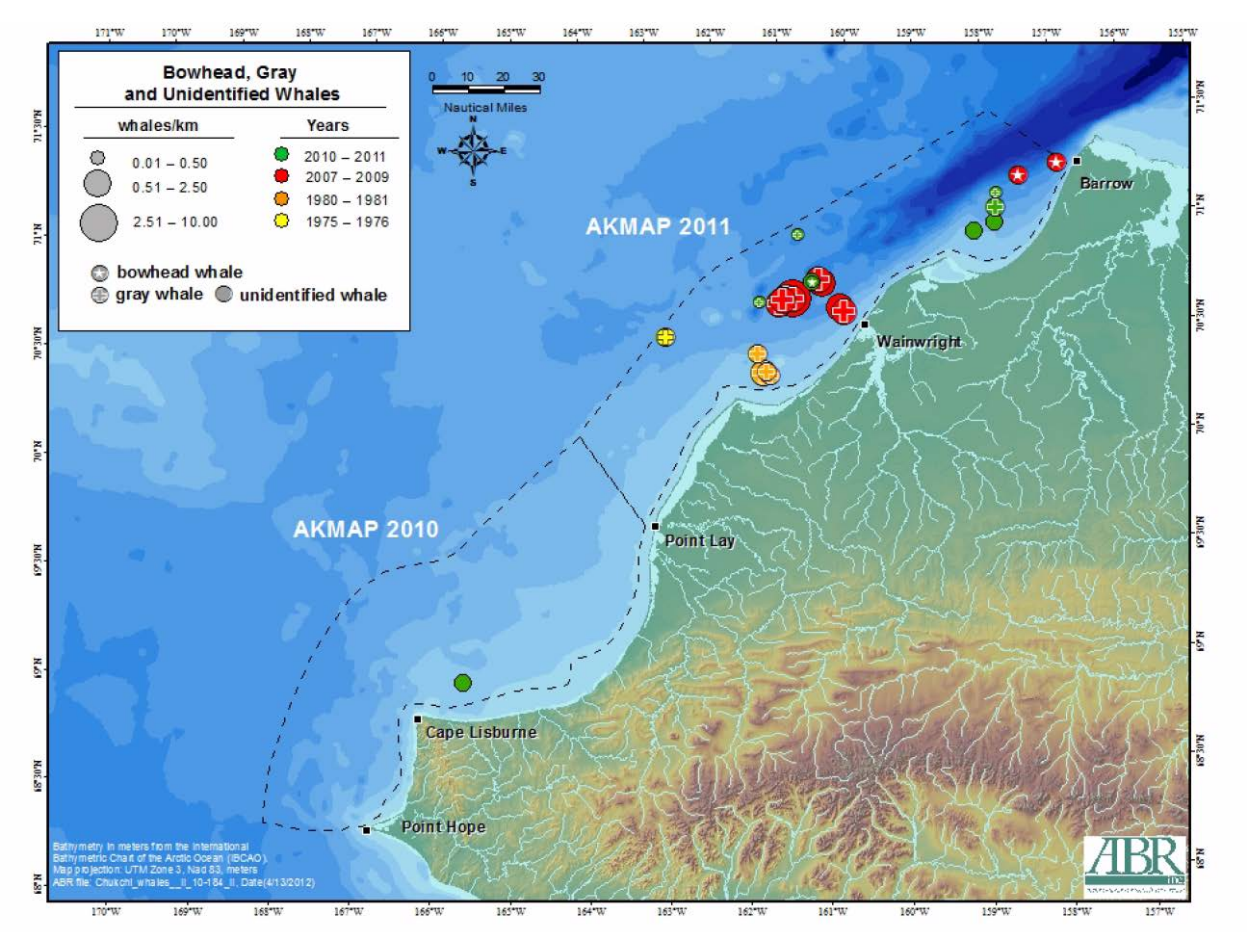

Figure 4 – AKMAP Survey 2010 – 2011 Bowhead, Gray and Unidentified Whale Distribution

(continued)

Combining this information with the results of the AKMAP survey can provide insights into the ecology of this environment. The amphipod *Anoxy nugax* (Figure 5) is a gray whales prey species especially when present in large numbers (USGS, 1987, Moore and DeMaster, 1998, Budnikova et al., 2012). Opportunistic gray whale feeding in the Chukchi Sea on swarms of epibenthic crustaceans (mysids, ampipods, and shrimp) has been reported (Liungblad, 1987). The AKMAP survey of epifauna, animals living on or slightly above the sediments, beam trawl data for *Anoxy nugax* are plotted for abundance per square kilometer (km^2) in Figure 6.

Figure 5 – *Anoxy nugax*

Gray whales were observed historically and during 2011 within the region with a high density of *Anoxy nugax* between 400,000 to over 1,000,000 per km^2 as shown in Figure 6. Another gray whale prey *Ampelisca sp.* a benthic tube dwelling amphipod was also present in high numbers. This information is relevant when considering location for pipeline corridors and other development that may potentially occur within the region.

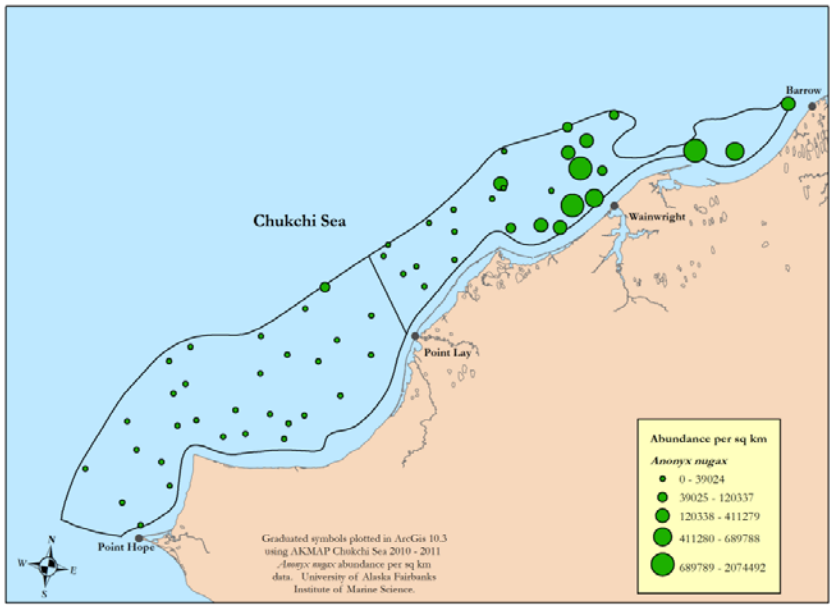

Figure 6 - *Anonyx nugax* Abundance per square kilometer

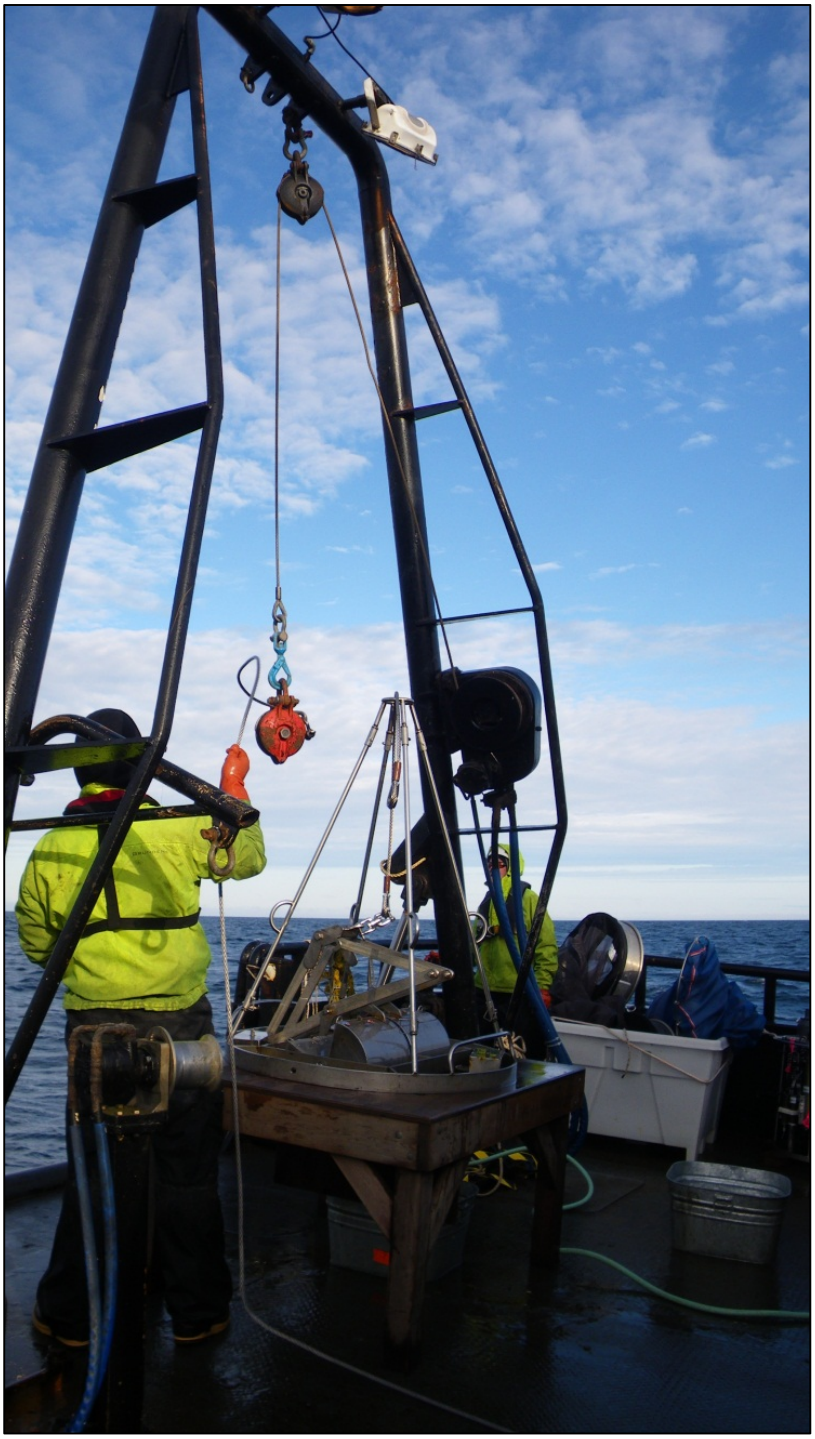

Figure 7 – A-Frame on stern of the Norseman II used for deploying sampling equipment

Chapter 2 - AKMAP 2010 – 2011 Chukchi Sea Coastal Survey Background

1. Background

A United States Geological Survey Report ranked Arctic Alaska as the second most likely Arctic region to contain major deposits of undiscovered oil, gas, and natural gas liquids (Gautier et al., 2009). The Chukchi Sea region is projected to contain recoverable oil resources on the order of 1 billion barrels along with the large quantities of natural gas (MMS, 2007). With the current world economic structure heavily dependent on declining oil and gas resources, federal and state agencies must understand the environment to help guide responsible development. This overview on the Northern Chukchi region provides a background to place the AKMAP survey in perspective. The chapter ends with a list of web resources that can provide more in depth information.

The AKMAP Chukchi Survey 2010 and 2011 design boundaries or target population as designed falls within two geographically descriptive areas.

- The Chukchi Sea section of the Beaufort and Chukchi Sea coastal ecoregion (Piatt and Springer, 2007) are shown in Figure 8.
    - An ecoregion is considered to have similarities in oceanographic and biological characteristics that delineate it from other regions. (Piatt and Springer, 2007).

- The marine deferral corridor shown in Figure 9 excluded oil and gas lease sales as part of the Mineral Management Service (MMS) 2007 – 2012 lease sale program for the Chukchi Sea oil and gas lease sale 193 (BOEM, 2012).
    - This corridor was established to reduce potential impacts from oil and gas development on subsistence hunting activities and wildlife species (MMS, 2007).

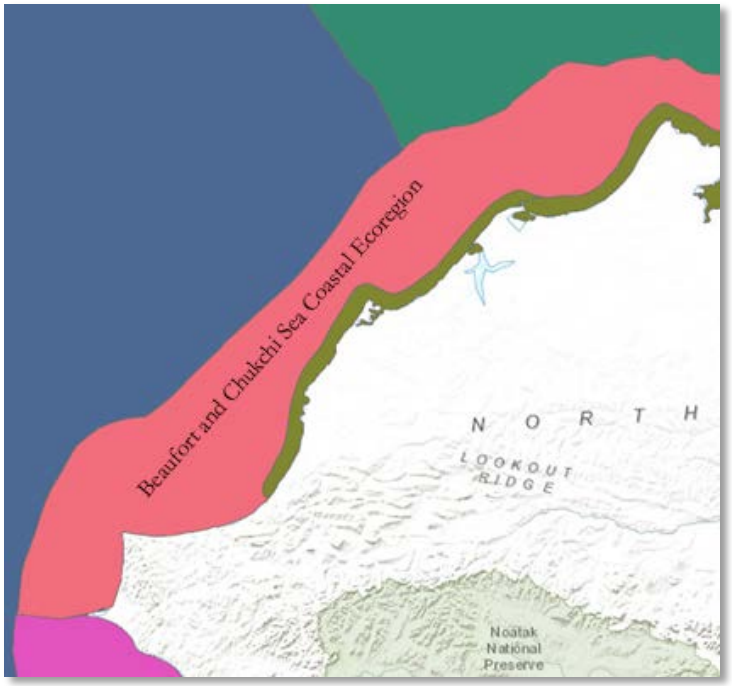

Figure 8 – Beaufort and Chukchi Coastal Ecoregion

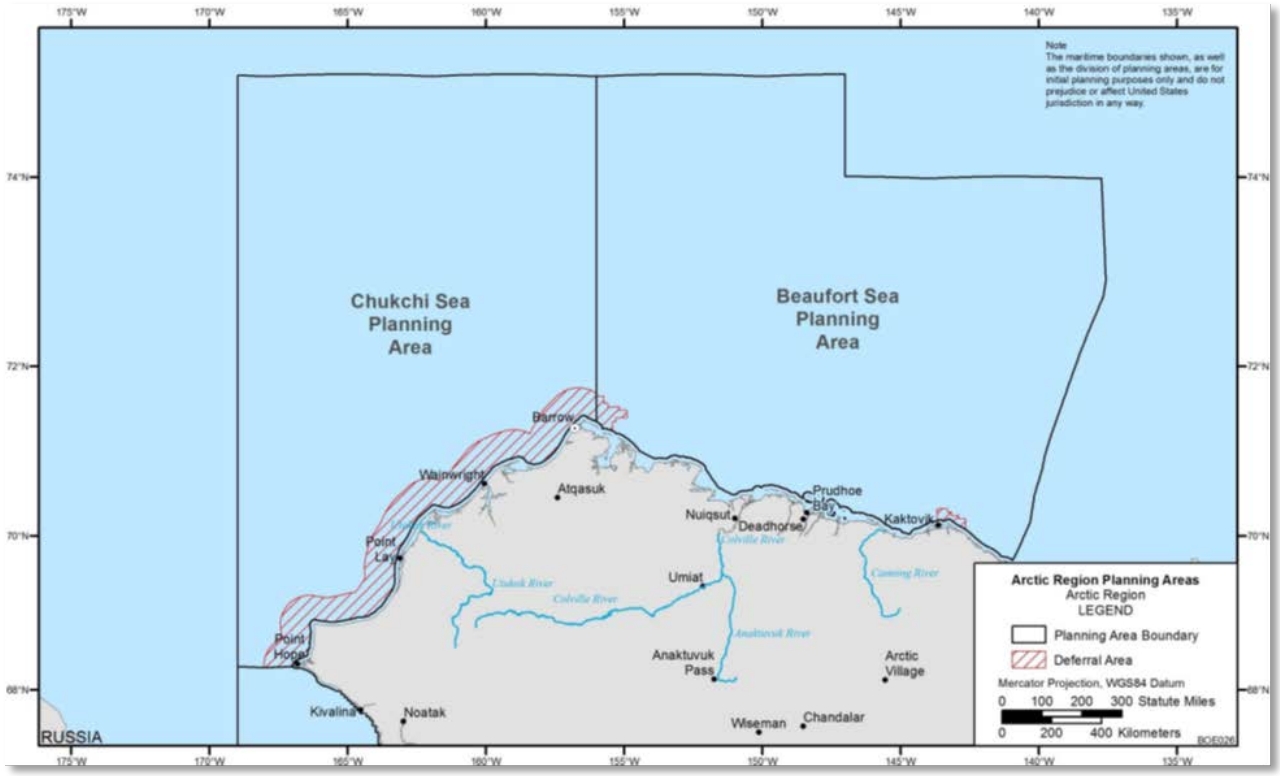

Figure 9 – Hashed Area Delineates the Exclusion Corridor or Deferral Area (BOEM, 2011)

2. Environment of the AKMAP Survey Chukchi Sea Region

The AKMAP Survey lies within the BOEM Chukchi Sea planning area within the relatively shallow Beaufort and Chukchi Sea Coastal Ecoregion off the northwest coast of Alaska. Figure 10 shows major currents occurring within the Chukchi Sea with the Alaska Coastal Current the primary current within the AKMAP Survey region (Woodgate et al., 2015). The Alaska Coastal Current (ACC) water mass is largely comprised of Alaska Coastal Water (AWC) which is derived from the Yukon River and Alaska coastal drainages south of the Chukchi Sea. In comparison with the other water mass flows entering the Chukchi Sea the ACC is relatively warm (> 2^{O}C), lower in salinity (<31.8%), and carrying a higher sediment load (Feder et al., 1994).

Between December and May, much of the Chukchi Sea is almost totally ice-covered though the extent of ice has decreased. Much of the AKMAP survey region is within the land fast ice and pack-ice zone with areas of open water or polynyas between the land fast ice and pack-ice and numerous lead opening in the spring time.

The melting of the sea ice in the spring and the long hours of sunlight in the Chukchi Sea lead to the large production of ice algal and zooplankton much of which settles to the seabed floor where it provides a rich food source for the benthic organisms and the associated food web. The increased flux of organics to sediments in the Chukchi Sea results in rich benthic faunal resources (Grebmeier et al., 2006). Figure 11 shows existing sea ice linked benthic food web with a possible new food web that could occur with reduced in sea ice distribution (Kedra et al., 2015).

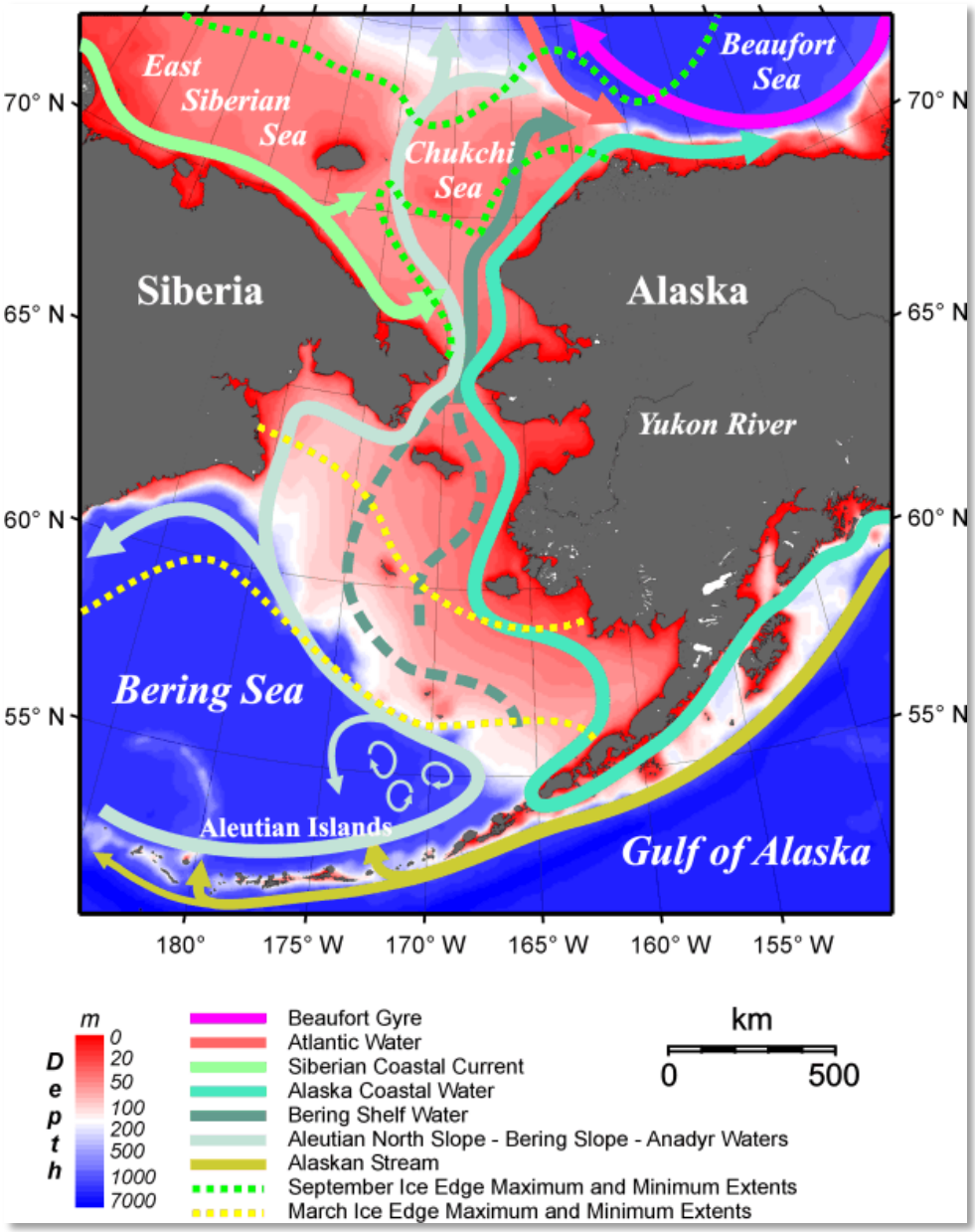

Figure 10 – Ocean Currents with the Alaska Coastal Water Current

Many of the benthic invertebrates in the Chukchi Sea represent important food sources for fish, marine mammals, and sea birds. Correspondingly the fish, marine mammals, and sea birds represent important Alaska Native subsistence food species. Bi-valve mollusk and amphipods are important food resources respectively for walrus and gray whales and bearded seals (NOAA, 2015a; Figure 12).

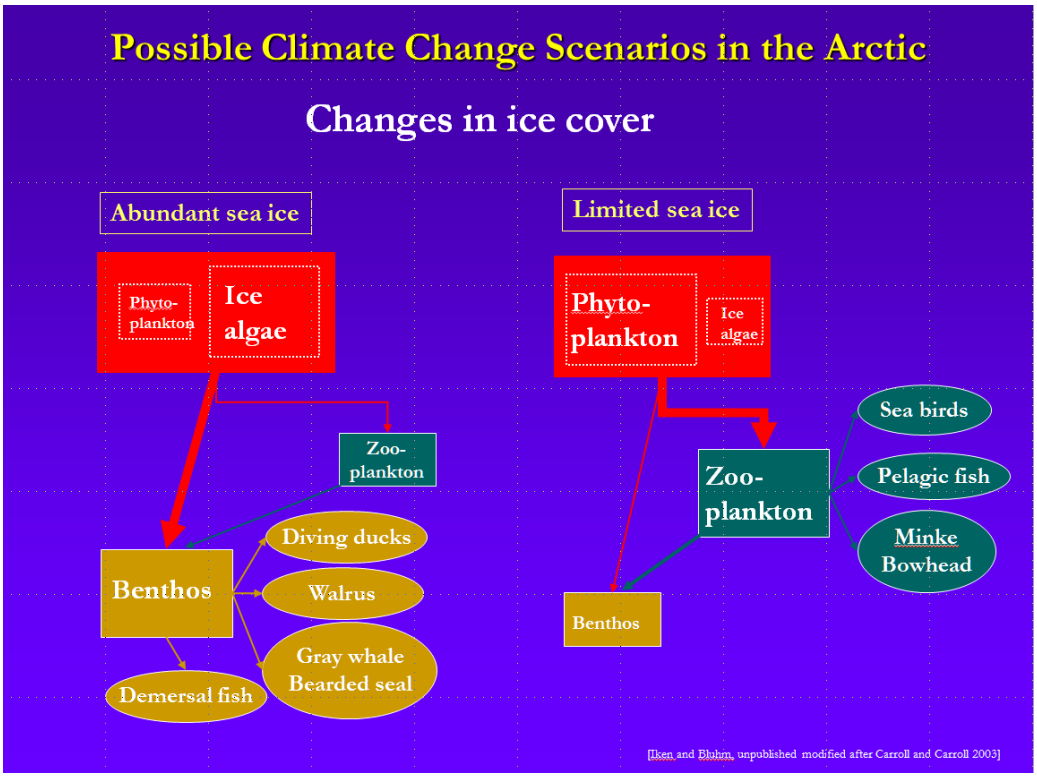

Figure 11 – Current Sea Ice connected Food Web and Possible Change with limited Sea Ice

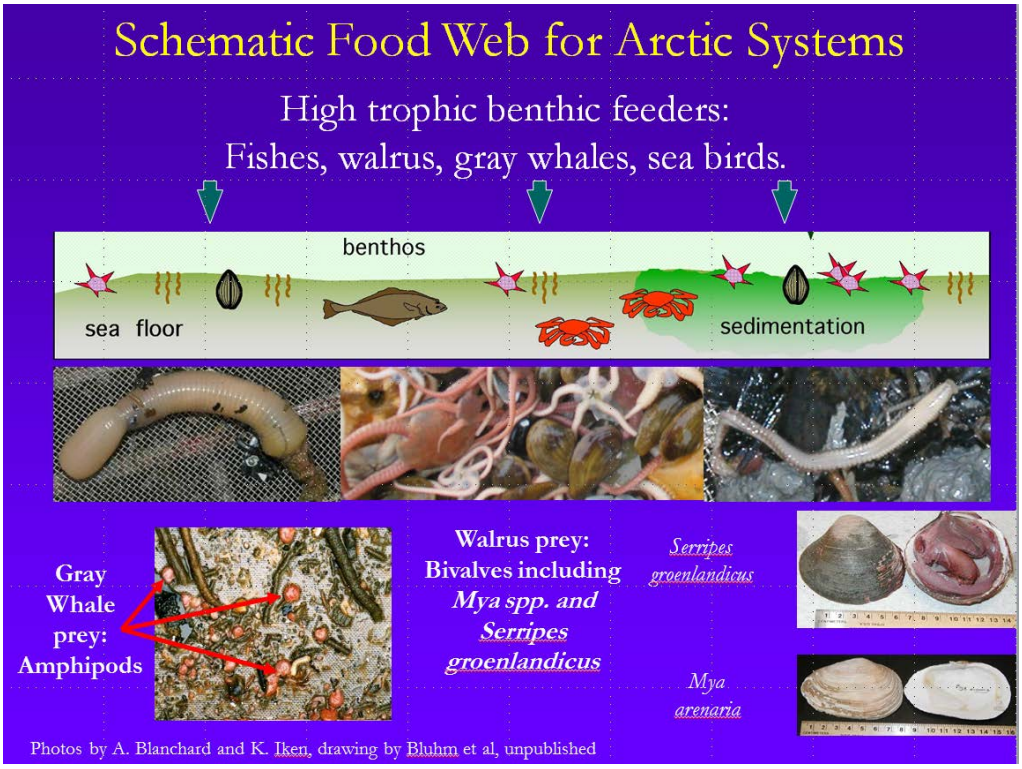

Figure 12 – Schematic of Existing Food Web

3. Oil and Gas Development

Significant effects for all resources are discussed in the 2007 Chukchi Sea Planning Area Environmental Impact Statement Volume 1 (MMS, 2007). The following summary of cumulative impacts is taken directly from the referenced document from page V-13 and V-14.

> The MMS does not expect any significant cumulative impacts to result from any of the planned activities associated with the exploration and development of North Slope and Beaufort Sea oil and gas fields. Significance thresholds and significant impacts are discussed in Section IV.A.1. In the event of a large offshore oil spill, some significant adverse impacts could occur to spectacled eiders, long-tailed ducks, common eiders, polar bears, subsistence resources, sociocultural systems, and environmental justice. However, the probability of such an event combined with the seasonal nature of the resources inhabiting the area make it less likely that an oil spill would contact these resources. Spectacled eiders, long-tailed ducks, and common eiders are present on the North Slope for as long as 8 months out of the year. A resource may be present in the area but may not necessarily be contacted by the oil. An oil spill could affect the availability of bowhead whales, or the resource might be considered tainted and unusable as a food source. The potential for adverse effects to some key resources (bowhead whales, subsistence, polar bears, and caribou) is of primary concern and warrants continued close attention. Effective mitigation practices (winter construction, an advanced leak-detection system, thick-walled pipeline designs, etc.) also should be considered in future projects. (V13 – V14).

A conceptual model showing some potential ecosystem exposure routes for spilled oil is shown in Figure 13 (NOAA, 2015b).

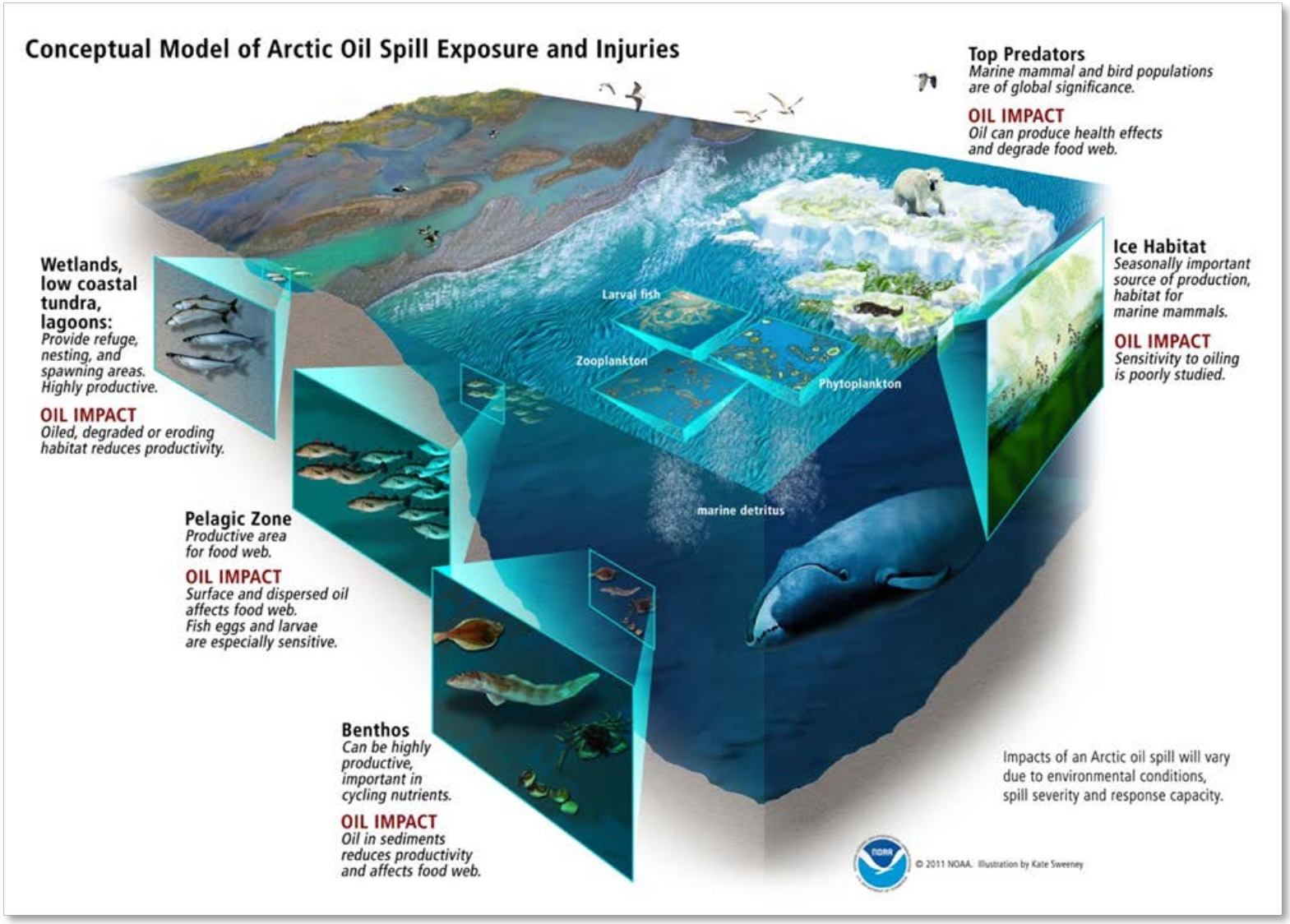

Figure 13 – NOAA Conceptual Model of Arctic Oil Spill Exposure and Injuries

4. Selected Chukchi Sea Environment On-Line Resources

1). Arctic Marine Synthesis: Atlas of the Chukchi and Beaufort Seas
http://ak.audubon.org/arctic-marine-synthesis-atlas-chukchi-and-beaufort-seas

2). EEMA: Arctic / Chukchi Sea Ecosystem Assessment
http://www.afsc.noaa.gov/ABL/EMA/EMA_Chukchi.php

3). NOAA'S RESPONSE AND RESTORATION BLOG
How Would Chemical Dispersants Work on an Arctic Oil Spill?
https://usresponserestoration.wordpress.com/2012/07/09/how-would-chemical-dispersants-work-on-an-arctic-oil-spill/

4). Hopcroft, Russ, Bodil Bluhm and Rolf Gradinger (eds). 2008. Arctic Ocean Synthesis: Analysis of Climate Change Impacts in the Chukchi and Beaufort Seas with Strategies for Future Research. Institute of Marine Sciences, University of Alaska-Fairbanks and North Pacific Research Board.
http://www.arcodiv.org/news/NPRB_report2_final.pdf

5). Chukchi Circulation webpage is by Tom Weingartner of the University of Alaska Institute of Marine Science
http://www.ims.uaf.edu/chukchi/

6). Chukchi Sea Environmental Studies Program (CSESP) webpage.
https://www.chukchiscience.com/

7). PacMARS Pacific Marine Arctic Regional Synthesis Data Archive
http://pacmars.eol.ucar.edu/

Figure 14 – Deploying Otter Trawl Doors off the Stern of the Norseman II

Chapter 3 - Chukchi Sea Coastal Survey Environmental Status Indices and Characterization

1. Background

AKMAP's Chukchi Sea coastal survey status report is based on ecological indices and component indicators for data sets obtained during the summers of 2010 and 2011. Ranking of good, fair, or poor are shown herein for comparison with Alaska Water Quality Standards (DEC, 2015) or other criteria within the sampled region or target population. Figure 1 delineates the sampled region containing the target population. The indices with their cutpoints used in this report are described below. These water quality indices descriptions are based in part on the methodology used in NCA IV report (EPA, 2012). For more details on AKMAP survey data analysis see *Alaska Monitoring and Assessment Program 2010 and 2011 Chukchi Sea Coastal Survey Statistical Summary* (DEC, 2015 – linked to DEC website).

The ranking for good, fair, or poor was based by interpolation of cumulative percent area of the target population meeting the cutpoints for nutrients, chlorophyll *a*, dissolved oxygen for Ledyard Bay, and sediment trace metals, total organic carbon and PAHs. Not included in the water quality and sediment indices respectively were dissolved oxygen for Peard Bay as only a small number of results were obtained due to equipment problems. Sediment for organochlorine contaminants, such as DDT and PCBs, due to previous finding of studies resulting in very low or non-detect levels, only a limited number of samples were analyzed. While there were a limited number of results no water or sediment quality indices cutpoints were exceeded in these samples.

2. Water Quality Index

The water quality index is based on measurements of the four component indicators: dissolved nitrate-nitrogen, dissolved phosphate as phosphorus, chlorophyll *a*, and dissolved oxygen. Table 2 and 3 provide information on cutpoints and ranking. It does not isolate a particular agent of degradation, nor does it consistently identify sites experiencing occasional or infrequent low dissolved oxygen conditions, nutrient enrichment, or decreased water clarity. Some nutrient inputs to coastal waters are necessary for a healthy estuarine ecosystem; however, when nutrients from various sources, such as sewage, are introduced, concentrations can increase above natural background levels. This increase in the rate of supply of organic matter is called eutrophication and may result in a host of undesirable water quality conditions.

The DEC does not have numeric water quality standards for nutrients or chlorophyll *a* in marine waters (DEC, 2015). A dataset representing pelagic Chukchi Sea nutrient and chlorophyll *a* concentrations were downloaded from the NOAA National Centers for Environmental Information World Ocean Database (NOAA, 2015c). A total of 237 dissolved nitrates, 241 dissolved phosphate, and 177 results were used to develop nutrient and chlorophyll *a* cutpoints. Cutpoints were based on upper confidence levels of 90% and 99%. The nutrient and chlorophyll *a* concentrations < 90% were selected to represent good, values between the good cutpoint and 99% UCL were ranked fair, and >99% was ranked poor. Pro-UCL was used to calculate the 90% and 99% nonparametric UCLs (EPA, 2010). Dissolved oxygen cutpoints were based on the numeric criteria for marine waters (DEC, 2015).

Table 2 – Description of Cutpoints for Nutrients, Chlorophyll *a*, and Dissolved Oxygen

Nutrients, Chlorophyll *a*, Dissolved Oxygen	Good	Fair	Poor
Nitrate Nitrogen as Nitrogen (NO_3-N mg/l)	≤ 0.08	> 0.08 - ≤0.12	> 0.12
Phosphate as Phosphorus (PO_4-P mg/l)	≤ 0.13	>0.13 - ≤ 0.23	> 0.23
Dissolved Oxygen (DO mg/l) Surface (1 m)	≥ 6 - ≤17	≥4 - < 6	< 4
Dissolved Oxygen (DO mg/l) Bottom	≥ 4 - ≤ 17	≥ 3 - < 4	< 3
Chlorophyll *a* (Chl *a* µg/l)	≤ 3.97	>3.97 - ≤ 6.39	> 6.39

Table 3 – Water Quality Index Regional Ranking

Ranking By Region
Good: Less than 10% of the coastal area is in poor condition and more than 50% of the coastal area is in good condition.
Fair: Between 10% and 20% of the coastal area is in poor condition or 50% or less of the coastal area is in good condition.
Poor: More than 20% of the coastal area is in poor condition.

A. Nutrients: Dissolved Nitrate and Phosphate

Nitrogen and phosphorus are necessary and natural nutrients required for the growth of phytoplankton, the primary producers that form the base of the food web in coastal waters. However, excessive levels of nitrogen and phosphorus can result in large, undesirable phytoplankton blooms. Dissolved nitrate-nitrogen can contribute to eutrophication in open estuarine and marine waters whereas dissolved phosphate may promote algal growth in the brackish parts of estuaries.

B. Dissolved Oxygen

Dissolved oxygen is necessary for all aquatic life. Often, low dissolved oxygen conditions occur as a result of large algal blooms that sink to the bottom where bacteria use oxygen as they degrade the algal mass. DEC water quality criteria state that for coastal waters, dissolved oxygen may not be reduced below 4 mg/l at any point beneath the surface, surface waters to one meter may not be below 6 mg/l, and no values may exceed 17 mg/l.

C. Chlorophyll *a*

One of the symptoms of degraded water quality condition is the increase of phytoplankton biomass as measured by the concentration of chlorophyll *a*. Chlorophyll *a* is a measure used to indicate the amount of microscopic algae or phytoplankton growing in a waterbody. High concentrations of chlorophyll *a* indicate the potential for problems related to the overproduction of algae. For this report, surface concentrations of chlorophyll *a* were determined from a filtered portion of water collected at each site.

3. Water Quality Rankings

The water quality index for the AKMAP Chukchi Sea survey region is rated good based on less than 10% of the region being in poor status and more than 50% of the region ranked as good. The index

is based on four component indicators assessed as follows: Nitrate as Nitrogen (NO_3-N), Phosphate as Phosphorus (PO_4-P), chlorophyll *a*, and dissolved oxygen (Figure 15).

The water quality was rated good over 96.8 % of the coastal area surveyed with 1.9 % as fair and 1.3 % as poor. Overall fair conditions were due to higher NO_3-N or PO_4-P values taken from the cumulative distribution function. As mentioned in the previous limitation, the ranking of good, fair or poor must be considered in light of the reference condition of the AKMAP survey area. Given the small human population density and no known significant anthropogenic sources of nutrients near the stations, the observed fair and poor values reflect natural conditions, rather than any direct human influences.

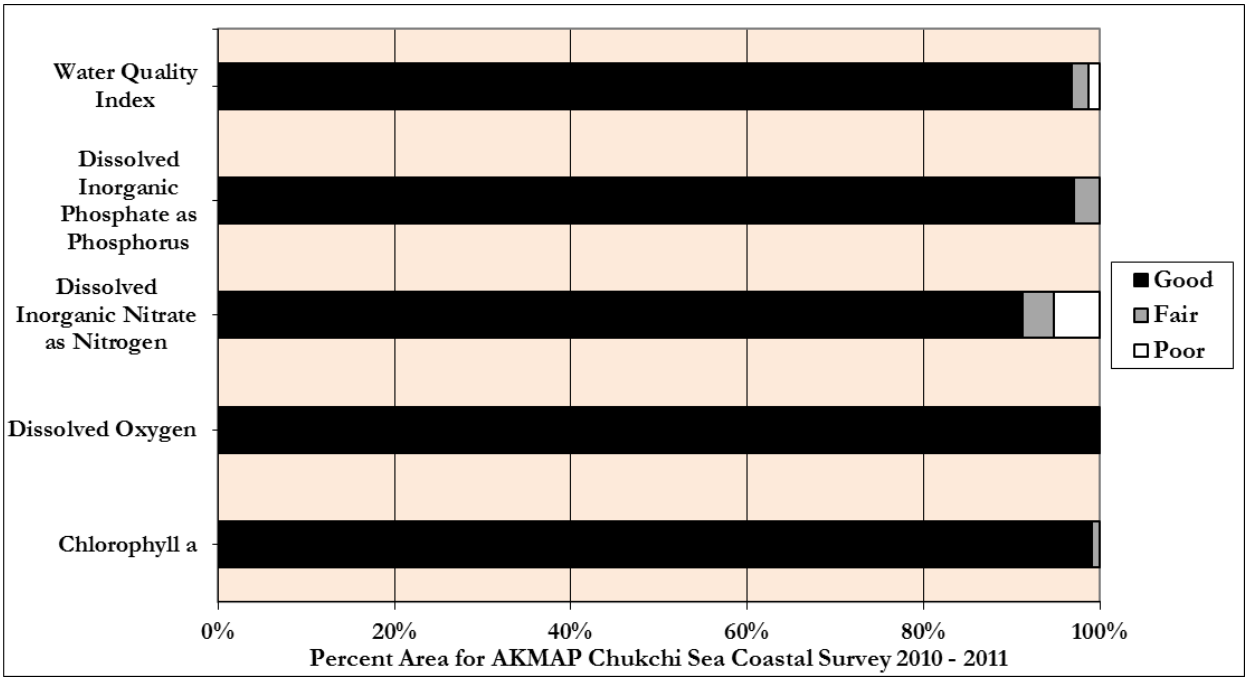

Figure 15 – Water Quality Index Status

A. Nutrients: Nitrate as Nitrogen and Phosphate as Phosphorus

Chukchi Sea coastal status is rated good for NO_3-N and PO_4-P with 91.3 % rated good, 3.6 % fair, and 5.1% poor for NO_3-N and 97 % good, 3 % fair, and 0 % poor for PO_4-P. Nutrients were evaluated based on cutpoints developed from results of previous historical sampling. Lack of any adjacent large domestic or industrial wastewater discharges or active resource development activities the AKMAP Chukchi Sea survey area suggests that the fair and poor rankings represent the upper range of background values and not industrial or anthropogenic influences.

B. Dissolved Oxygen

Dissolved oxygen concentration is rated good for the AKMAP Chukchi Sea coastal survey, with 100 % good. Surface and bottom waters sampled met Alaska Water Quality Standards criteria for all marine water uses, i.e. aquaculture, growth and propagation of fish, shellfish, and other aquatic life and wildlife, and harvesting mollusks or other raw aquatic life (DEC, 2015). The lowest inferred

value of dissolved oxygen was 4.9 mg/l in the 2010 Ledyard Bay stratum. The sampled waters were well mixed as evidenced by the stratification index measured at the sample stations. Results support reference condition and the DO levels observed were natural and not perturbed by human or industrial activities.

C. Chlorophyll *a*

Chlorophyll *a* status for the AKMAP survey is rated good with 99 % good, 1 % fair and 0 % poor. The Chlorophyll *a* levels were evaluated based on cutpoints developed from results of previous historical sampling. The 1 % fair ranking remains within the higher values seen in the background range and are not inferred to represent disruption by human activities.

4. Sediment Quality Index

Another issue of major environmental concern in coastal waters is the contamination of sediments with toxic chemicals. A wide variety of metals and organic substances, such as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and pesticides, are discharged into coastal waters from urban, agricultural, and industrial sources in a watershed. These contaminants adsorb onto suspended particles and eventually accumulate in depositional basins where they may have adverse effects on the benthic community of invertebrates, shellfish, and crustaceans that live in or on the sediments. To the extent that the contaminants become concentrated in the organisms, they pose a risk to organisms throughout the food web including humans. However, benthic community attributes are included in this assessment of coastal condition as an independent variable rather than as a component of sediment quality.

The coastal watersheds along Alaska's coastline in this region and further south to the Aleutian Islands have no significant urban, agricultural, or industrial sources of contaminants. Contaminants, such as PCBs and other organochlorine pesticides, transported to the Chukchi Sea by atmosphere and ocean currents contribute low levels of contaminants. Vessels using the Bering Sea and those transiting through the Chukchi Sea contribute an unknown pollutant input to the region.

A. Sediment Contaminants

The *Alaska Monitoring and Assessment Program (AKMAP) 2010 – 2011 Chukchi Sea Coastal Survey Environmental Status Summary* utilized the NOAA SQUIRT guidelines to assess potential toxicity of the sediment polycyclic aromatic hydrocarbon concentrations to aquatic organisms (Buchman, 2008).

Five hydrocarbon groupings were be used in assessing sediment PAH toxicity status in accordance with the NOAA SQUIRT guidelines. These are total and individual polycyclic aromatic hydrocarbons (TPAH and PAH), TPAH low molecular weight (e.g., 2 to 3 ring group of PAHs such as naphthalenes, fluorenes, phenanthrenes, and anthracenes), TPAH high

Guidelines for Assessing Sediment Contamination (Long et al., 1995)

ERM (Effects Range Median)—Determined for each chemical as the 50th percentile (median) in a database of ascending concentrations associated with adverse biological effects.

ERL (Effects Range Low)—Determined values for each chemical as the 10th percentile in a database of ascending concentrations associated with adverse biological effects.

molecular weight (e.g., 4 to 7 ring from chrysenes to coronenes). The TPAH has been separated into two sub-groups: first is for TPAH guideline using 13 PAHs (Long et al., 1995) to determine Effects Range Low (ERL) and Effects Range Median (ERM) and second is the NOAA NS&T TPAH based on 24 individual PAHs in its core program to assess sediment toxicity. Table 4 shows the sediment ERL and ERM concentrations used. The cutpoint and ranking information is shown in Table 5.

Table 4 – Effects Range Low and Effects Range Median for Sediments

ERL and ERM Guidelines for Sediment (Long et al., 1995)[1]		
Trace Metal µg/g dw	**ERL**	**ERM**
Arsenic	**8.2**	**70**
Cadmium	**1.2**	**9.6**
Chromium	**81**	**370**
Copper	**34**	**270**
Lead	**46.7**	**218**
Mercury	**0.15**	**0.71**
Silver	**1**	**3.7**
Zinc	**150**	**410**
Polycyclic Aromatic Hydrocarbon (PAH) ng/g dw		
Acenaphthene	**16**	**500**
Acenapthylene	**44**	**640**
Anthracene	**85.3**	**1,100**
Flourene	**19**	**540**
2-Methylnapthalene	**70**	**670**
Napthalene	**160**	**2,100**
Phenanthrene	**240**	**1,500**
Benz(a)anthracene	**261**	**1,600**
Benzo(a)pyrene	**430**	**1,600**
Chrysene	**384**	**2,800**
Dibenzo(a,h)anthracene	**63.4**	**260**
Fluoranthene	**600**	**5,100**
Pyrene	**665**	**2,600**
Low molecular-weight PAH	**552**	**3,160**
High molecular-weight PAH	**1,700**	**9,600**
Total PAH	**4,022**	**44,792**

Table 5 – Sediment Quality Index Cutpoint and Regional Ranking

Sediment Contaminant Cutpoint	Ranking by Region
Good: No sediment contaminant concentrations exceed the ERM, and fewer than 5 contaminant concentrations exceed the ERL.	**Good:** Less than 5% of the coastal area is in poor condition.

[1] The ERM and ERL concentrations are normalized to dry weight, but not to sediment total organic carbon.

Fair: No contaminant concentrations exceed the ERM, and 5 or more contaminants exceed the ERL.	**Fair:** 5% to 15% of the coastal area is in poor condition.
Poor: At least one contaminant concentration exceeds the ERM.	**Poor:** More than 15% of the coastal area is in poor condition.

B. Sediment Total Organic Carbon (TOC)

Sediment contaminant availability or organic enrichment can be altered in areas where considerable deposition of organic matter occurs. Although TOC exists naturally in coastal sediments and is the result of the degradation of autochthonous and allochthonous organic materials, e.g., phytoplankton, leaves, twigs, dead organisms, anthropogenic sources, e.g., organic industrial wastes, untreated or only primary-treated sewage can elevate the level of TOC in sediments. TOC in coastal sediments is often a source of food for some benthic organisms. High levels of TOC in coastal sediments can result in significant changes in benthic community structure including dominance of pollution tolerant species (Pearson and Rosenberg, 1978).

Increased levels of sediment TOC can also reduce the general availability of organic contaminants, e.g., PAHs, PCBs, pesticides. However, increases in temperature or decreases in dissolved oxygen levels can sometimes result in the release of these TOC-bound and unavailable contaminants. Regions of high TOC content are also likely to be depositional sites for fine sediments. If there are pollution sources nearby, these depositional sites are likely to be hot spots for contaminated sediments. The cutpoints and ranking information for rating TOC are shown in Table 6.

Table 6 – Sediment Total Organic Carbon Cutpoint and Regional Ranking

Sediment TOC Cutpoint	Ranking by Region
Good: Sediment TOC concentration is less than 2%.	**Good:** Less than 20% of the coastal area is in poor condition.
Fair: Sediment TOC concentration is between 2% and 5%.	**Fair:** Between 20% and 30% of the coastal area is in poor condition.
Poor: Sediment TOC is greater than 5%.	**Poor:** More than 30% of the coastal area is in poor condition.

5. Sediment Quality Rankings

The sediment quality index for the AKMAP Chukchi Sea coastal survey coastal waters is rated 100% good. Two component indicators - sediment contaminants and total organic carbon - were used to calculate the sediment quality index (Figure 16).

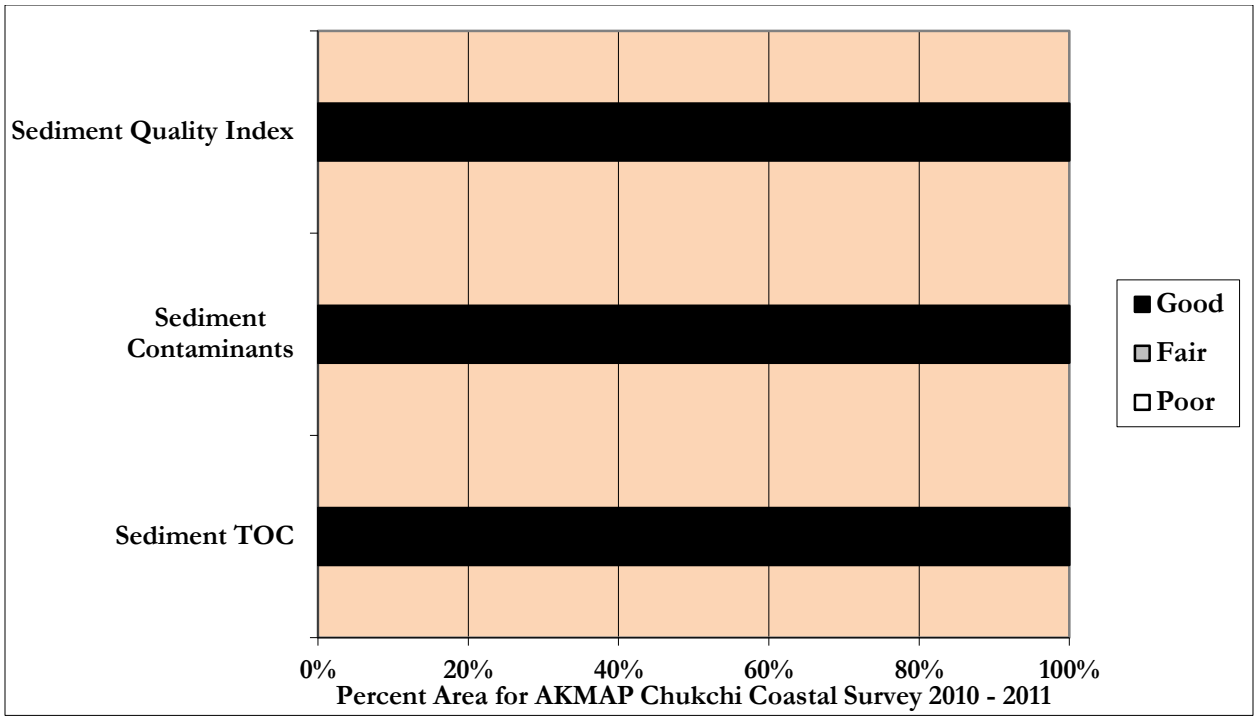

Figure 16 – Sediment Quality Index

A. Sediment Contaminants

AKMAP survey waters are rated good for sediment contaminant concentrations with 100% of the coastal area rated good for this component indicator. The AKMAP trace metal group was selected for comparison with an earlier 2008 Chukchi Sea environmental study (Neff et al., 2010). The trace metals Arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), mercury (Hg), manganese (Mn), lead (Pb), selenium (Se), silver (Ag), and zinc (Zn) were sampled because of potential concerns with toxicity and the association of these trace metals with oil and gas activities. For the trace metals sampled with ERL and ERM values, e.g. As, Cd, Cr, Cu, Pb, Hg, Ag, and Zn only As exceeded the ERL of 8.2 µg/g dry weight (dw) but not the ERM of 70 µg/g dw. Arsenic ranged from 12.1 to 29.7µg/g dw with a mean sediment concentration of 13.4±3.8 µg/g dw in the AKMAP Chukchi Sea coastal survey area. In a 2008 study of the sediments within the Federal Lease Sale 193 area, the mean sediment As concentration was 13.5± 5.0 µg/g dw, with a range from 7.4 to 37.5 µg/g dw (Neff et al, 2010). As concentration in many marine types of sediment may naturally exceed the ERL because of As input from sea water and from regional crustal geology though additional study is needed to support this hypothesis (Maher and Butler, 1988).

For the organic contaminants in sediments, polycyclic aromatic hydrocarbons (PAHs), Total DDT and 4,4'-DDE, and Total PCBs, only 2-Mehylnapthalene, a PAH, exceeded the ERL of 70 ng/g dw but not the ERM of 670 ng/g dw. Six of 55 sediment samples exceeded the 2-Mehylnaptahelene sediment ERL, with a maximum concentration of 217 ng/g dw.

B. Sediment Total Organic Carbon

AKMAP Chukchi Sea Coastal Survey waters are rated good for sediment total organic carbon (TOC) component indicator with 100% good.

6. Benthic Habitat Status

The AKMAP survey assessed and compared the invertebrate communities throughout the Chukchi Sea area shown in Figure 1. Alaska Water Quality Standards have not adopted indices of benthic community condition that can be used for ranking (DEC, 2015). However, studies in Port Valdez and Norton Sound provide a basis for interpreting benthic community characteristics for responses to anthropogenic stressors. For this survey the results were assessed using best professional judgment to rank the benthic habitat current condition. Based on historic macroinvertebrate data sets and results of the sediment chemistry for 2010 and 2011 little evidence exists to find that the benthic habitat is currently impacted by human activities (Blanchard et al, 2015, unpublished). Relative to the studies in Port Valdez and Norton Sound, there is no evidence of stress (e.g., increased proportions of stress tolerant species) in the AKMAP Chukchi Sea study area (Blanchard et al. 2002, 2003, 2010, 2011; Blanchard and Feder 2003; Jewett et al., 1999). Given the strong linkages and high similarity of fauna in the Chukchi Sea with those of Alaska's southern coastal waters (Blanchard, 2014), the results of the environmental studies elsewhere in Alaska are relevant and highly significant to inferences in the Chukchi Sea. The data sets gathered during the AKMAP survey provide further information that can help with future development of benthic indices for the various marine ecosystems in Alaska. Benthic habitat index for the AKMAP Survey coastal waters was rated good based on best professional judgment of species abundance and diversity.

7. Benthic Ranking

Benthic macrofauna, communities of worms, crustaceans, amphipods, and other animals living in or on the sediments are sensitive to physical and chemical changes to the sediment. Because of this sensitivity these macrofauna can be good indicators of impacts from human activities.

The Benthic index for the AKMAP survey was rated good based on best professional judgment. Since the AKMAP survey area does not contain nor is adjacent to any industrial wastewater discharges or domestic wastewater inputs and, thus, has no significant source of anthropogenic pollution, with the exception of atmospheric transport of certain pollutants, provides a reference condition. Comparisons with historical studies also suggest that there has been little change in macrofauna over the past 30 years (Blanchard et al., 2014, unpublished).

8. Fish Tissue Evaluation

Due to the lack of comprehensive ecological thresholds for contaminant concentrations in fish, the U.S. EPA risk-based advisory guidance values (Table 7) for recreational fishers were used to assess the fish health (EPA, 2012). The differences in fish species collected and limited number analyzed did not provide for regional rankings.

Table 7 – EPA Advisory Guidance Used in Assessing Fish Health

Contaminant	EPA Advisory Guidance Range (µg/g wet weight)[a]	Health Endpoint Used
Trace Metals		
Arsenic (Inorganic)[b]	0.35 - 0.70	non-cancer
Cadmium	0.35 - 0.70	non-cancer
Mercury (Methylmercury)[c]	0.012 - 0.23	non-cancer
Selenium	5.9 - 12.0	non-cancer
Organochlorine Pesticides, PAH & PCBs		
Chlordane	0.59 -1.2	non-cancer
Total DDT	0.059 - 0.12	non-cancer
Dieldrin	0.059 - 0.12	non-cancer
Endosulfan II	7.0 - 14.0	non-cancer
Endrin	0.35 - 0.70	non-cancer
Heptachlor Epoxide	0.015 - 0.031	non-cancer
Lindane	0.35 - 0.70	non-cancer
Mirex	0.23 - 0.47	non-cancer
PCBs	0.023 - 0.047	non-cancer
PAH		
Benzo(a)pyrene	0.023 - 0.047	cancer[d]

a) Range of concentrations associated with non-cancer and cancer health endpoint risk for consumption of four 8-ounce fish meals a week (U.S. EPA, 2012).
b) Inorganic arsenic concentrations were estimated to be 2% of the measured total arsenic concentrations (U.S. EPA, 2000)
c) The conservative assumption was made that all mercury is present as methylmercury.
d) A non-cancer concentration range for PAHs does not exist (U.S. EPA, 2012).

A. Fish Tissue Assessment

The AKMAP survey had planned to catch and provide subsistence-size fishes to the DEC Fish Monitoring Program. In 2010, the AKMAP Survey attempted to catch such fishes by hook and line, but had no success. Instead small demersal fish living on or near the bottom were collected by beam and otter bottom trawls in 2010 and 2011.

As demersal fishes live in close contact with the sediments, they are considered good indicators of contaminants in the sediments. The AKMAP survey selected six species of small fishes in 2011 for trace metals, hydrocarbons and other contaminant analyses. Arctic Staghorn Sculpin *Gymnocanthus tricuspis*, Capelin *Mallotus villosus*, Pacific Sand Lance *Ammodytes hexapterus*, Arctic Cod *Boreogadus saida*, Shorthorn Sculpin *Myoxocephalus scorpius*, and Slender Eelblenny *Lumpenus fabricii* comprised the fish sampled. The sampled fishes represent an important component in the Chukchi Sea food web for marine mammals (e.g. seals) and sea birds. Therefore, their tissue contaminant concentrations were evaluated against criteria used in the EPA National Coastal Condition Assessment IV (U.S. EPA,

2012) deemed to be protective of wildlife health. None of the fishes exceeded the criteria, and thus, fish tissue suggests good condition.

B. Demersal Fish Abundance and Biomass

Demersal fish catches were analyzed by area fished at a total of 30 stations in Ledyard Bay 2010 stratum and 28 stations in Peard Bay 2011 stratum. Capture gear was a plumb staff beam trawl with a 3.05 m beam spreader bar, 7 mm mesh, 4 mm codend liner mesh, and a double tickler chain. Abundance was reported as individuals per square kilometer and biomass was reported as kilograms per square kilometer.

Three species composed >85% of total abundance and biomass across both strata. These were the Arctic Staghorn Sculpin (49% abundance, 42% biomass), Shorthorn Sculpin (18% abundance, 24% biomass), and Slender Eelblenny (20% abundance, 18% biomass). The Arctic Cod, which is one of the most abundant fishes offshore in the Chukchi Sea (Norcross et al. 2010, 2013), accounted for only 1% of total abundance and total biomass in this study's nearshore strata.

Abundance and biomass of demersal fishes were greater in Peard Bay than in Ledyard Bay (Figure 7). Mean abundance of demersal fishes in Peard Bay was significantly greater than in Ledyard Bay (2.8 million ± 3.1 million fish/km^2 vs. 1.6 million ±1.5 million fish/km^2, $p < 0.05$). Mean biomass was also greater in Peard Bay than in Ledyard Bay (5587 ± 5219 kg/km^2 vs. 3427 ± 2787 kg/km^2 , $p = 0.5$). The large standard deviations indicate the ecologically patchy nature of areas within these strata.

Abundance and biomass of demersal fishes in each strata were dominated by sculpins and pricklebacks (Figure 17). The proportional catches by family were similar between strata and for both abundance and biomass, with sculpins accounting for 68–70% of abundance and 61–75% of biomass. Pricklebacks accounted for 18–26% of abundance and 13–28% of biomass. Five families each provided 1–5% of total abundance or biomass, i.e., cods, eelpouts, poachers, righteye flounders, and snailfishes. Six families were rarely caught and each provided less than 1% of total abundance or biomass, i.e., eelpouts, greenlings, sailfin sculpins, sand lances, smelts, and wolf eels.

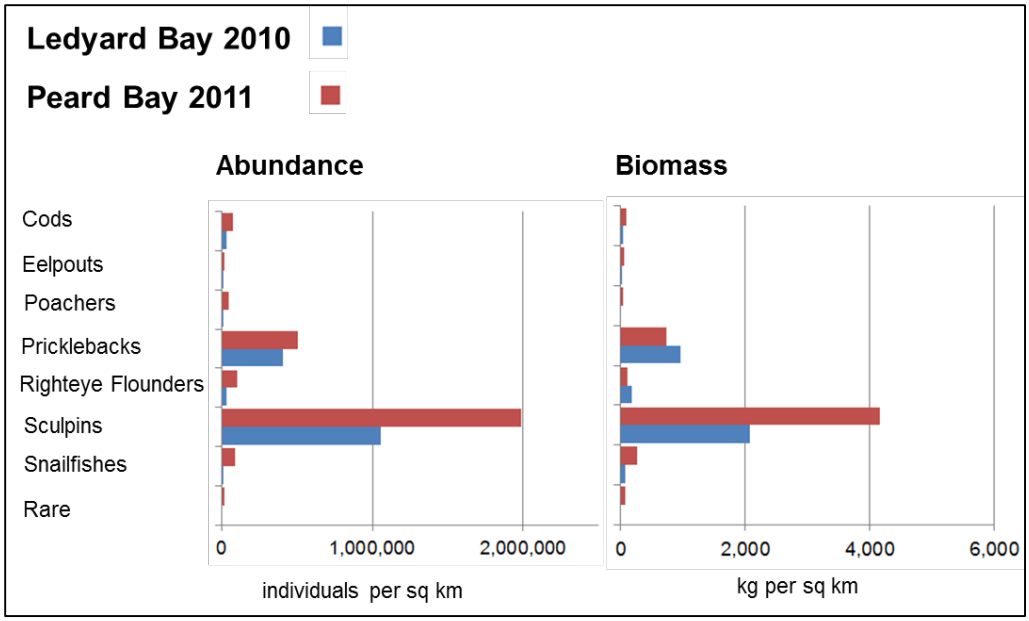

Figure 17. Abundance and biomass of demersal fishes in Ledyard Bay 2010 and Peard Bay 2011 strata reported from plumb staff beam trawl catches. Families that accounted for less than 1% of abundance are combined and reported as "Rare."

9. How the Overall Status is Summarized

Overall condition for the AKMAP Survey coastal near shore waters was calculated by summing the good, fair, and poor scores for the four indices and dividing by the number of available indices where good equals > 90%, fair is between 90% to 50%, and poor <50%. Ranking is shown in Table 8.

Table 8 - Overall Status Ranking Details

Ranking	Water Quality Index	Sediment Quality Index	Benthic Index	Overall Average
Good	96.8%	100%	100%	99%
Fair	1.9%			0.6%
Poor	1.3%			0.4%

Overall the regional environmental status in relation to the Alaska Water Quality Standardsand indices discussed is ranked as good (Figure 3). This status includes both numeric rankings and best professional judgment. The ranking does not address the potential for both positive and negative ecological changes occurring due to changing climate or oceanographic conditions. Numerous peer-reviewed publications and reported traditional ecological knowledge are documenting changes overtime in the Chukchi Sea. Trends or changes may become apparent if the AKMAP survey is repeated periodically.

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APPENDIX A

Presentations and Publications resulting from the AKMAP 2010-2011 Chukchi Sea Survey

Benthic Organisms and Plankton:

Blanchard AL, Dasher DH, Jewett SC. 2015. Oceanographic and Topographic Controls on Macrobenthic Distributions in the Chukchi Sea. Oral Presentation abstract, 3rd International Conference of Oceanography, Philadelphia, PA, June 2015. Blanchard Abstract Oceanography 2015.docx.

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Morgan T, Day RH, Jewett SC, Dasher DH. 2012. Monitoring marine birds in the nearshore Chukchi Sea: preliminary findings from the AKMAP Program in the coastal northeastern Chukchi Sea, 2010-2011. Poster, Alaska Marine Science Symposium, Anchorage, AK, January 2012. Morgan et al poster abstract AMSS12.pdf.

Morgan TC, Day RH, Gall AE. 2012. Monitoring Seabirds and Marine Mammals in the Nearshore Chukchi Sea as Part of the Alaska Monitoring and Assessment Program, 2010-2011. Final report for Institute of Marine Science University of Alaska Fairbanks. Prepared by ABR, Inc. – Environmental Research and Services. ABR_Chukchi_Nearshore_Seabird_and_Marine_Mammal_Study_July_2012_with disclaimer.pdf.

Fish:

Gray BP. 2014. Comparisons of Arctic Cod, Arctic Staghorn Sculpin, and Shorthorn Sculpin diets across the northeastern Chukchi and western Beaufort seas. MS thesis defense presentation, Fairbanks, Alaska, October 2014. Gray 2014 MS Thesis Defense.pdf.

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