ConocoPhillips

STUDY PLANS FOR THE ENVIRONMENTAL STUDIES PROGRAM IN THE CHUKCHI SEA, 2009

ConocoPhillips Alaska, Inc.

P.O. Box 100360

Anchorage, AK 99510–0360

August 2009

This page left intentionally blank.

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

In February 2008, ConocoPhillips Alaska, Inc. (CPAI) obtained 98 lease blocks in federal waters of the Chukchi Sea as part of the Minerals Management Service's (MMS) Lease Sale 193. Lease blocks are concentrated within two main prospect areas: the Klondike prospect and the Burger prospect (see Figure Intro-1). Prior to exploratory drilling and development of these lease blocks, CPAI conducted a 3 ¬dimensional seismic survey in 2006, a shallow hazard, or site-clearance survey in 2008 and a coring program in 2009. This document contains information on the integrated ecosystem program operated by CPAI on behalf of itself and Shell Exploration & Production (Shell E&P). The key objective of this program is to gather baseline, or pre-exploration and development data. The environmental studies will be conducted during the summer/fall of 2009. Although not gathered in 2008, the program has added a fisheries ecology component to the program in 2009.

The environmental studies program for 2009 covers numerous facets of the marine ecosystem including physical oceanography, plankton ecology, benthic ecology (infaunal and epibenthic communities) seabird ecology, marine mamma ecology, pelagic and demersal fisheries, and the hydroacoustic environment. The data collected will be used in permit applications for exploration and development within a National Environmental Policy Act (NEPA) document. The data will provide information on the environmental baseline conditions that can be ultimately be used for comparison with post-development conditions. It is anticipated that future studies in the lease areas will involve additional collaborators such as Minerals Management Service (MMS), the North Pacific Research Board (NPRB), the National Marine Fisheries Service (NMFS), United States Fish and Wildlife Service (USFWS), United States Geological Survey (USGS), Alaska Beluga Whale Committee (ABWC), Ice Seal Commission, and Alaska Eskimo Walrus Commission.

The Studies Plan is outlined as follows:

- •Section I: Physical Oceanography
- •Section II: Planktonic Communities
- •Section III: Benthic Communities
- •Section IV: Fisheries
- •Section V: Seabirds
- •Section VI: Marine Mammals
- •Section VII: Passive Acoustic Monitoring

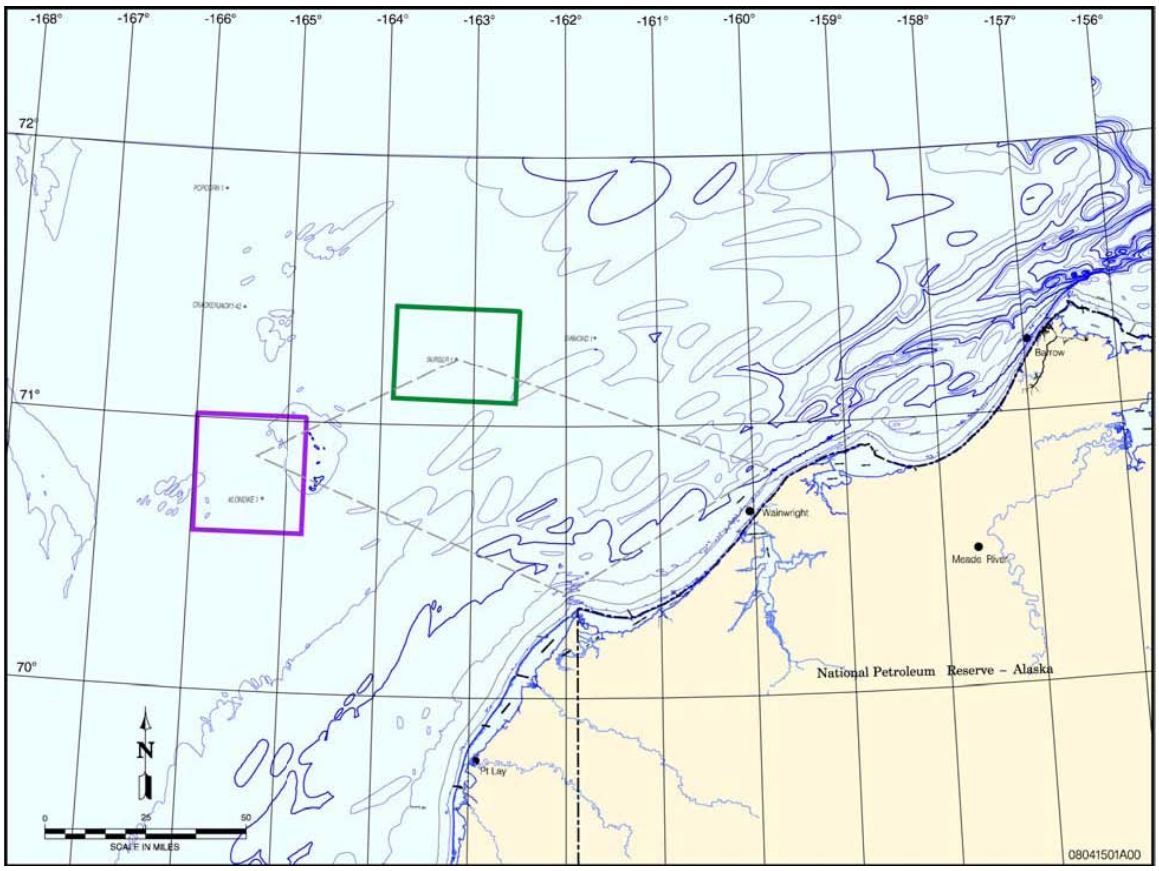

Figure Intro - 1. Map of study areas with the Klondike site outlined in purple and the Burger site outlined in green.

SECTION I
PHYSICAL OCEANOGRAPHY

PRINCIPAL INVESTIGATOR
TOM WEINGARTNER
UNIVERSITY OF ALASKA FAIRBANKS

1.0 Introduction

The Chukchi Sea is intimately linked, atmospherically and oceanographically, to the Pacific Ocean. The atmospheric connection is primarily via the Aleutian Low, whose varying position and strength and interactions with polar air masses affects the regional meteorology. The oceanographic connection is solely through Bering Strait, where the mean northward flow transports waters and organisms from the Bering Sea shelf and basin. This Pacific connection profoundly influences the wind and wave regimes, the seasonal distribution of sea ice, the regional hydrologic cycle, and the water masses and circulation characteristics of the Chukchi Sea

The shallow (~50 m) Chukchi Sea shelf extends ~800 km northward from Bering Strait to the shelf-break at about the 200-m isobath. The mean flow over much of the shelf is northward due to the Pacific–Arctic oceanic pressure gradient and opposes the prevailing northeasterly winds. The Bering Strait influx of heat, nutrients, carbon, and organisms bestows the Chukchi shelf with physical and ecological characteristics that are unique among arctic shelves.

Much of our understanding of the Chukchi shelf derives from the early syntheses of Coachman et al. (1975) and Walsh et al. (1989) and, more recently (since 1985), in the papers by Aagaard et al. (1985), Aagaard and Roach (1989), Weingartner et al. (1998), Weingartner et al. (1999), Münchow and Carmack (1997), Münchow et al. (1999), Münchow et al.(2000), Weingartner et al. (2005), and Woodgate et al. (2005). The physical oceanographic summary of the Chukchi shelf is drawn primarily from these papers.

1.1 Mean Circulation

The Bering Strait through-flow crosses the Chukchi Sea along three principal pathways associated with distinct bathymetric features (Figure I-1). A western branch flows northwestward from the strait and exits the shelf through Herald Valley. While most of this outflow probably descends through Herald Valley, some of it spreads eastward across the central shelf. A second branch flows northward across the central channel shelf and then probably splits; with some water continuing eastward toward the Alaska coast while the remainder flows northeastward toward the continental slope. The third branch flows northeastwards along the Alaska coast towards Barrow Canyon, which lies at the junction of the Chukchi and Beaufort shelves. In summer, this flow includes the northward extension of the Alaska Coastal Current (ACC) that originates south of Bering Strait. Within the canyon, the ACC is joined by waters flowing eastward from the central shelf; the merged flow then moves down-canyon toward the shelf-break. Mean current speeds within the Herald and Barrow canyons are swift (~25 cm s-1), are more moderate in the central channel (~10 cm s-1),

but generally are ≤5 cm s-1 elsewhere on the shelf. Long-term transport estimates for these three pathways are only approximate but suggest that the flow across the central Chukchi shelf is ~200,000 m3 s-1 while the branches in both Herald Valley and Barrow

Canyon carry ~300,000 m3 s-1. In summer and fall, the influence of the warm Bering Sea inflow along these pathways is manifested in the form of “melt-back embayments” indenting the ice edge (Paquette and Bourke 1981). Finally, there is also a small fraction of the strait through-flow that flows westward through Long Strait into the East Siberian Sea and appears to be an important nutrient source to this shelf (Codispoti and Richards 1968; Codispoti et al. 1991).

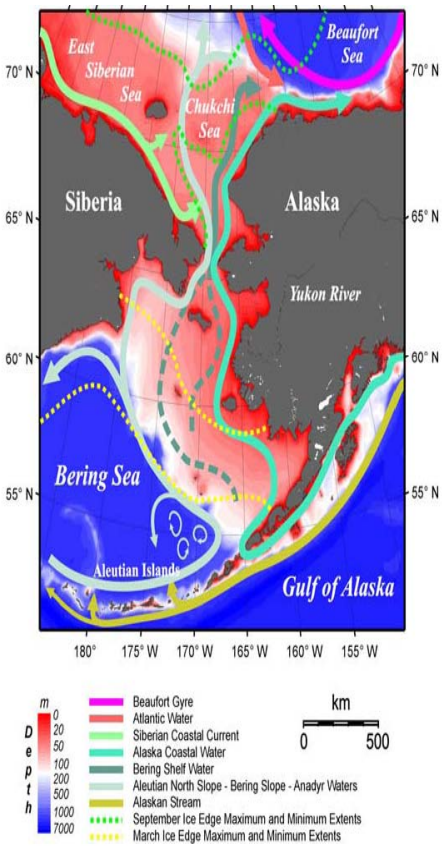

Figure I-1. Schematic circulation map of the Bering-Chukchi-Beaufort Seas ecosystem.

The nutrient and carbon loads carried along these branches differ (Walsh et al. 1989, Hansell et al. 1993; Cooper et al. 1997). The Herald Valley outflow is saltier, colder, and richer in nutrients and marine-derived carbon than the waters transported in the Alaska Coastal Current, whereas waters crossing the central shelf have intermediate properties. In winter, shelf waters decrease to the freezing point and salinities increase due to salt rejection from growing sea ice. These seasonal changes in shelf salinities have important implications on the fate of the nutrients and carbon in the Chukchi shelf waters that enter the basin. Low-density summer waters are confined to the upper 75 m of the shelf-break and slope, whereas denser winter waters descend to 100–150 m depth.

There are two other aspects of the Chukchi shelf circulation of importance. The first is the buoyancy-influenced Siberian Coastal Current (SCC) that originates in the East Siberian Sea and flows southeastward along the Siberian coast into the Chukchi Sea. The SCC carries cold, low-salinity, nutrient-poor ice-melt, and river waters that enter the East Siberian and Laptev seas. The SCC is confined to within ~60 km of the Chukotka coast and is bounded on its offshore side by an unstable front, which appears to be an important bowhead whale foraging zone (Moore et al. 1995). Nearing Bering Strait, the

SCC narrows and turns offshore to mix with waters exiting the strait. Most of the resulting mix is most likely transported through Herald Valley and across the central shelf. It also appears likely that surface waters over the outer shelf and slope are flowing westward on average (Muench et al. 1991), bringing sea ice and cold, low-salinity waters of the polar mixed layer over the outer shelf and slope.

The mean circulation results from the large scale pressure field between the Pacific and Arctic oceans and opposes the mean winds, which are from the northeast. The winds are, however, the principal cause of flow variability. Wind forcing varies seasonally with both wind magnitude and variability being largest in fall-winter and smallest in summer. In particular, in fall and winter, the winds can frequently reverse the shelf flow field or re-distribute the flow from one branch to another (Weingartner et al. 1998). As a consequence of this seasonality, transit times along the three flow pathways across the Chukchi shelf are 3–6 months in spring and summer but are longer in fall and winter.

In general, wind-forced current fluctuations are coherent over much of the shelf, although, for reasons not known, the correlation is substantially weaker over the western shelf than for the eastern shelf (Woodgate et al. 2005b). Westward winds induce upwelling at the continental slope, which could be an important nutrient source at the shelf-break. While no measurements have been made of this phenomenon along the Chukchi slope, data from Barrow Canyon indicate that wind-forced upwelling carries waters from ~250 m depth or more toward the head of the canyon, which lies ~150 km from the canyon mouth (Aagaard and Roach 1990; Weingartner et al. 1998). Winds also appear to be important in the dynamics of the SCC. For example, in some years, the winds along the Chukotka coast are persistently upwelling and prevent the SCC from entering the Chukchi Sea (Münchow et al. 1999; Weingartner et al. 1999). The consequences of this variability are unknown, but if the SCC front is an important foraging zone for bowhead whales, its absence in some years could affect whale foraging behavior.

The other major sources of current variability are associated with mesoscale (10–50 km) instabilities associated with large cross-frontal density gradients. Mesoscale flows can be vigorous (>20 cm/s) and uncorrelated with winds. The instabilities initially appear as meanders along the front but can rapidly grow in strength and/or detach into eddies that move across the axis of the front. Eddies and meanders are very prominent within the SCC front and promote cross-shore mixing between SCC and Bering Strait waters flowing northward through the Hope Sea Valley. Eddies and cross-shore mixing result from frontal instabilities along the edge of polynyas due to the large salinity differences between high salinity polynya waters and less saline offshore waters (Gawarkiewicz and Chapman 1995). Finally, fronts associated with melting along the ice-edge often include vigorous three-dimensional mesoscale motions (Liu et al. 1994; Muench et al. 1991) that often lead to enhanced biological production at the ice edge. Moreover, the mixing and circulation fields associated with the mesoscale motions associated with the SCC and ice edge may also be important in establishing biologically-rich mesoscale patches.

1.2 Measurement History

Prior to the 1970s, several hydrographic expeditions were collected throughout the Chukchi Sea and summarized by Coachman et al. (1975). In the 1970s and 1980s, several year-round moored measurement programs were conducted in the United States Exclusive Economic Zone

(US EEZ) and supported by the Outer Continental Shelf Environmental Assessment Program (OCSEAP), as summarized by Aagaard (1988). Beginning in 1990, National Science Foundation (NSF), Office of Naval Research (ONR), and MMS supported a number of physical-oceanographic programs, the results of which were summarized above. Most recently, these included the NSF-ONR sponsored Shelf–Basin Interaction (SBI), which recently completed a three-year field program (2001–2004). The SBI program focused primarily upon biogeochemical processes over the outer shelf and shelf-break, and the data from this program are still undergoing analysis.

1.3 Purpose of Study and Rationale

Before any exploration, development, or production activities are conducted in the Chukchi Sea lease blocks, MMS requires the collection of specific baseline information in order to discern between the potential effects to the marine environment from oil and gas activities from natural variation. Circulation characteristics and physical-oceanographic influences on biological oceanography and production form one aspect of these baseline studies. The physical oceanography may influence ultimate development design considerations, and it may affect spatial and temporal patterns of biological production and the distribution and abundance of organisms.

1.4 Objectives of Study

The primary objective of the physical oceanography program is to describe spatial and seasonal characteristics of the water masses and circulation in the two study areas. The main objective of the 2009 oceanographic data will be to combine the physical-oceanographic data with the various biological measurements. This will help determine the spatial and temporal patterns of biological production and the distribution and abundance of organisms in this region. [Note that CPAI will pursue collaboration with other entities such as the MMS to obtain data representative of the regional scale recommendation of University of Alaska Fairbanks (UAF)].

2.0 STUDY AREA

2.1 Location

As part of the post-leasing process, CPAI will oversee a second year of scientific data collection in 2009 around two areas, termed Klondike and Burger. Both study areas consist of a 30 by 30 nm area that encompasses potential exploratory drilling locations.

2.2 Period of Study

The study's program is anticipated to consist of approximately three 20-day cruises occurring between August and October. The exact length of the cruises will depend on access to the study sites (i.e. ice coverage). The first half of each cruise is proposed to collect data in the Klondike study area, and the second half would collect data in the Burger study area. To

establish seasonality and increase the statistical confidence of observations, the pelagic biological-oceanography surveys will be conducted concurrently with physical-oceanographic observations during all cruises.

3.0 METHODS AND PROCEDURES

3.1 Sampling or Survey Design and Technical Rationale

The study design from 2008 will be repeated in 2009, covering a 30 X 30 nm survey block, with a grid of 5 x 5 stations, at ~7.5 nm spacing, within each study site, on all three cruises. Each cruise will consist of 20 to 24 sampling days, depending on weather. The physical oceanography data to be collected include conductivity-temperature-depth (CTD) stations at the same sites at which samples are collected for zooplankton, fisheries, benthos, nutrients, and chlorophyll. The CTD includes a fluorometer (as an index of chlorophyll biomass) and a transmissometer (as index of water-column turbidity). In addition, surface temperature, salinity, and fluorescence (SSTSF) data will be captured as the vessel transits. Finally, using a vessel-mounted ADCP will allow for the collection of current data to provide an estimate of the water-column current structure and its spatial and temporal variability.

3.2 Field Team Size and Composition

Marine technicians with Aldrich Offshore, Inc. will conduct the field work in 2009, responsible for deploying, recovering, and collecting the various physical-oceanographic data sets. This team has extensive experience and will have ultimate technical oversight by Dr. T. Weingartner.

3.3 Data-Collection Procedures

CTD data will be collected with a Seabird system with a descent rate of no more than 30 meters/minute. The surface temperature, salinity, and fluorescence (SSTSF) system will also include a flow monitor in the intake system, and the data stream will be blended with the ship's navigation system so that global positioning system (GPS) time and position are recorded. At each CTD cast, the marine technician will record the time of CTD deployment and position. The technician will also record the temperature and salinity values of the SSTSF system once the CTD is ready to descend through the water column. (This will allow us to compare the underway system values with the CTD data; which is usually more accurate than the underway system.) Vessel-mounted acoustic Doppler current profiler (ADCP) (VM-ADCP) data will be collected from a 150-kHz Teledyne RDI system. The instrument should be run in bottom-track and broadband modes with a 2-m bin size and 2-second ensemble rate. Both raw (single¬ ping) and 10-minute averaged data should be stored (with duplicate copies). The ADCP data stream must also include the GPS position and time.

We also propose to collect and process remotely sensed imagery during the field season. This will include thermal infrared for sea surface temperature, ocean color (chlorophyll or suspended sediment) and sea ice distributions. Imagery will be processed and made available at least bi-weekly, depending upon atmospheric conditions

3.4 Analytical Procedures

All of the processing procedures used are routine and are based on common physical-oceanographic standard practices used at the Institute of Marine Sciences and most other oceanographic institutions. Hydrographic processing of the CTD data will include application of calibration values and our standard quality-control routines used in processing CTD data sets. Standard procedures are be used for assessing the SSSTF and remotely-sensed images, which are all geo-referenced. Our analyses will include

describing the seasonally (and, if possible, shorter-period) variations in fronts, water masses, geostrophic current

fields, and stratification. ADCP data processing may be time-consuming (see below). We have allocated a month to this task and will attempt to provide summary statistics on the ocean currents for each cruise. At the very least, the analyses will provide CPAI with an estimate of data quality and simplified analyses of the circulation within the boxes (e.g., means and variances). Time permitting we will examine shorter period variations in the currents.

3.5 Data-storage Procedures

Data files collected during cruises will be backed up after each cast by the onboard Data Manager. Data will be transmitted to UAF at the conclusion of each cruise.

3.6 Quality-control Procedures

We require the manufacturer's pre- and post-calibration values for the CTD data. The underway sensors should also be calibrated prior to and after the cruise by the manufacturer. We will examine for systematic offsets between the CTD surface values and the underway system (usually in temperature). ADCP data-processing procedures include an exhaustive screening procedure based on ship accelerations, backscatter intensity, error values, etc. Bias and misalignment errors of the ADCP will be corrected for, following Joyce et al. (1989).

4.0 COORDINATION

4.1 Current Studies in the Region

Recent and ongoing studies have been described in Section 1.1. Weingartner is a PI in the NSF and National Oceanic and Atmospheric Administration (NOAA)-funded Russian-American Long-term Census of the Arctic (RUSALCA) program that began in 2004 and that involves year-round current meter sampling in both the US and Russian EEZs of Bering Strait.

5.0 REFERENCES

Aagaard, K. 1988. Current, CTD, and pressure measurements in possible dispersal regions of the Chukchi Sea. Outer Continental Shelf Environmental Research Program, Final Reports f Principal Investigators 57: 255–333.

Aagaard, K., and Roach. 1990. Arctic ocean-shelf exchange: measurements in Barrow Canyon, Journal of Geophysical Research 95: 18163–18175.

Aagaard, K., C. H. Pease, A. T. Roach, and S. A. Salo. 1989. Beaufort Sea Mesoscale Circulation Study—Final Report. NOAA Technical Memorandum ERL PMEL-90. 114 pp.

Aagaard, K., J. H. Swift, and E. C. Carmack. 1985. Thermohaline circulation in the Arctic mediterranean seas. Journal of Geophysical Research 90: 4833–4846.

AMAP (Arctic Monitoring and Assessment Programme). 2003. AMAP Arctic Pollution 2002: Persistent organic pollutants, heavy metals, radioactivity, Human health, changing pathways. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway. 112 pp.

Carmack, E. C. 1986. Circulation and mixing in ice-covered waters. In N. Unstersteiner (Ed.). The geophysics of sea ice. Plenum Press, New York, NY. Pp. 641–712.

Carmack, E. C., and D. C. Chapman. 2003. Wind-driven shelf/basin exchange on an Arctic shelf: the joint roles of ice cover extent shelf-break bathymetry. Geophysical Research Letters 30 (14): 1778. [available at: doi: 10.1029/203GL017526]

Coachman, L. K., K. Aagaard, and R. B. Tripp. 1975. Bering Strait: the regional physical oceanography. University of Washington Press, Seattle, Washington, Seattle, WA. 172 pp.

Codispoti, L., G. E. Friederich, C. M. Sakamoto, and L. I. Gordon. 1991. Nutrient cycling and primary production in the marine systems of the Arctic and Antarctic. Journal of Marine Systems 2: 359–384.

Codispoti, L., and F. A. Richards. 1968. Micronutrient distributions in the East Siberian and Laptev seas during summer 1963. Arctic 21: 67–83.

Cooper, L. W., J. Grebmeier, T. Whitledge, and T. Weingartner. 1997. The nutrient, salinity, and stable oxygen isotope composition of Bering and Chukchi sea waters in and near Bering Strait. Journal of Geophysical Research 102: 12563–12578.

Gawarkiewicz, G., and D. C. Chapman. 1995. A numerical study of dense water formation and transport on a shallow, sloping continental shelf. Journal of Geophysical Research 100: 4489–4508.

Joyce, T. 1989. On in situ “calibration” of shipboard ADCPs. 1989. Journal of Atmospheric and Oceanographic Technology 6: 169–172.

Hansell, D., T. E. Whitledge, and J. J. Goering. 1993. Patterns of nitrate utilization and new production over the Bering-Chukchi shelf. Continental Shelf Research 13: 601–627.

Liu, A. K., C. Y. Peng, and T. J. Weingartner. 1994. Ocean–ice interaction in the marginal ice zone using SAR. Journal of Geophysical Research 99: 22391–22400.

Muench, R. D., C. H. Pease, and S.A. Salo. 1991. Oceanographic and meteorological effects on autumn sea-ice distribution in the western Arctic. Annals of Glaciology 15: 171–177.

Münchow, A., E. C. Carmack, and D. A. Huntley. 2000. Synoptic density and velocity observations of slope waters in the Chukchi and East Siberian Seas. Journal of Geophysical Research 105: 14103–14119.

Münchow, A., T. Weingartner, and L. Cooper. 1999. The summer hydrography and surface circulation of the East Siberian Shelf Sea. Journal of Physical Oceanography 29: 2167– 2182.

Münchow, A., and E. C. Carmack. 1997. Synoptic flow and density observations near an Arctic shelfbreak. Journal of Physical Oceanography 6: 461–470.

Paquette, R. G., and R. H. Bourke. 1981. Ocean circulation and fronts as related to ice melt-back in the Chukchi Sea. Journal of Geophysical Research 86: 4215–4230.

Walsh, J. J., C. P. McRoy, L. K. Coachman, J. J. Goering, J. J. Nihoul, T. E. Whitledge, T. H. Blackburn, P. L. Parker, C. D. Wirick, P. G. Shuert, J. M. Grebmeier, A. M.

Springer, R. D. Tripp, D. A. Hansell, S. Djenedi, E. Deleersnijder, K. Henriksen, B. A. Lund, P. Andersen, F. E. Müller-Karger, and K. Dean. 1989. Carbon and nitrogen cycling within the Bering/Chukchi seas: source regions for organic matter affecting AOU demands of the Arctic Ocean. Progress in Oceanography 22: 277–359.

Walsh, J. J., D. A. Dieterle, F. E. Muller-Karger, K. Aagaard, A. T. Roach, T. E. Whitledge, and D. Stockwell. 1997. CO2 cycling in the coastal ocean. II: Seasonal organic loading of the Arctic Ocean from source waters in the Bering Sea. Continental Shelf Research 17: 1–36.

Weingartner, T., K. Aagaard, R. Woodgate, S. Danielson, Y. Sasaki, and D. Cavalieri, Circulation on the north-central Chukchi Sea shelf. 2005b. Deep-Sea Research (II) 52: 3150–3174.

Weingartner, T. J., S. R. Okkonen, and S. L. Danielson. 2005c. Circulation and water-property variations in the nearshore Alaskan Beaufort Sea. Final Report, OCS Study No. MMS 2005 028. 103 pp.

Weingartner, T. J., S. Danielson, Y. Sasaki, V. Pavlov, and M. Kulakov. 1999. The Siberian Coastal Current: a wind- and buoyancy-forced arctic coast current. Journal of Geophysical Research 104: 26697–29713.

Weingartner, T. J., D. J. Cavalieri, K. Aagaard, and Y. Sasaki. 1998. Circulation, dense water formation, and outflow on the northeast Chukchi shelf. Journal of Geophysical Research 103: 7647–7661.

Woodgate, R. A., K. Aagaard, and T. J. Weingartner. In press. Changes in the Bering Strait fluxes of volume, heat and freshwater between 1991 and 2004. Geophysical Research Letters.

Woodgate, R. A., and K. Aagaard. 2005. Revising the Bering Strait freshwater flux into the Arctic Ocean. Geophysical Research Letters 32: L02602. [available at doi:10.1029/2004GL021747]

Woodgate, R. A., K. Aagaard, and T. Weingartner. 2005. Monthly temperature, salinity, and transport variability for the Bering Strait throughflow. Geophysical Research Letters 32: L04601. [available at doi:10.1029/2004GL021880]

Woodgate, R. A., K. Aagaard, and T. Weingartner. 2005. A year in the physical oceanography of the Chukchi Sea: moored measurements from autumn 1990–91. Deep-Sea Research (II) 52: 3116–3149.

SECTION II
PLANKTONIC COMMUNITIES

PRINCIPAL INVESTIGATOR
RUSS HOPCROFT
UNIVERSITY OF ALASKA FAIRBANKS

1.0 INTRODUCTION

1.1 Brief History of Planktonic Biological Oceanography in the Chukchi Sea

The Chukchi Sea represents a complex gateway into the Arctic, where variation in climate may have profound impacts due to the complex interplay of several distinct water masses of Pacific origin with those of the central Arctic Ocean and its marginal seas. Large quantities of Pacific nutrients, phytoplankton, and zooplankton enter the region through the Bering Strait in a complicated mixture of water masses (i.e., Alaska Coastal, Bering Shelf, and Anadyr Water), each with unique assemblages and quantities of zooplankton (Springer et al. 1989; Coyle et al. 1996). This inflow is diluted by Coastal Arctic waters carried along by the East Siberian Current and water carried in from the deeper waters of the Canada Basin or Chukchi Plateau (Grebmeier et al. 1995). The influx of the "rich" Pacific water determines the reproductive success of both the imported and resident zooplankton communities (Plourde et al. 2005). Both interannual and long-term variation in climate will affect the relative transport of these various water masses and, hence, the composition, distribution, standing stock, and production of zooplankton and their predators within the Chukchi Sea.

Much of what is known about zooplankton of the Western Arctic and Northern Bering Sea comes from sporadic, spatially-restricted, and non-repeated surveys that often undertake incomplete analysis of their samples. Consequently, much of what has been done does not appear in the primary scientific literature but remains buried in the "gray literature." Although physical-oceanographic measurements typically have earlier histories, the first scientific records of planktonic work in the Bering Strait and Chukchi Sea appear to be those of Johnson (1934), Stepanova (1937), Bogorov (1939), and Jaschnov (1940), all of whom noted the significant influence of Pacific fauna in the Chukchi Sea.

Further work resumed after World War II, with the results of the early Russian sampling reported in Brodsky (1950, 1957), the English translation of which still remains a primary reference source for the region. Work more specific to this region appeared in Virketis (1952). North American work in the region initially maintained a quantitative and taxonomic dimension (Johnson 1953, 1956, 1958), but then interest waned. The results of the 1959 and 1960 Brown Bear cruises were never published as more than displacemnt volumes (English 1966) and, although the United States Coast Guard (USCG) Cutter Northwind appears to have sampled zooplankton in the Bering Strait and Chukchi Sea during the 1960s, the data are either unpublished or buried in the gray literature. Chukchi Sea collections by the USCG Glacier in 1970 as part of WEBSEC were reported quantitatively (Wing 1974), while samples collected in the Northern Bering and Chukchi seas (Cooney 1977) by the Alaskan OCSEAP (OCSEAP; 1960–1981) were never published as more than presence–absence data (although raw data still exist at UAF). Only limited additional quantitative zooplankton sampling occurred in the Chukchi Sea under the OCSEAP program (English and Horner 1977), as most effort became

focused on the nearby waters of the Beaufort Sea (ibid; Redburn 1974; Horner 1981; Horner and Schrader 1984) and the southeastern Bering Sea (Cooney 1977; followed by PROBES, FOCI). It was the mid-1980s before quantitative sampling resumed in Bering Strait and the Chukchi Sea with the Inner Shelf Transfer and Recycling (ISHTAR) program (see below). Russian research in this region has undoubtedly continued since the 1950s, but the results are often buried in their own gray literature and are generally unavailable to the international community (see Herman 1989). No doubt, the relative paucity of information north of Bering Strait is a consequence of limited commercial harvesting there in comparison with the Bering Sea.

From the North American perspective, post OCSEAP science begins with the ISHTAR program in 1985 and 1986 (Springer et al. 1989) and, more peripherally, the 1994 Trans-arctic Section (Thibault et al. 1999) and the SHEBA drift across the Chukchi Plateau in 1997–1998 (Ashjian et al. 2003). In the past decade, our knowledge of plankton in the Chukchi Sea and Western Arctic has improved considerably due to ongoing efforts such as NSF's SBI program (2002–2004) on the Beaufort and Chukchi shelves (e.g., Plourde et al. 2005; Llinas 2007; Lane et al. 2008), plus cross-sea cruises by NOAA's RUSALCA Program (e.g., Lee et al. 2007; Hopcroft and Kosobokova, in review), and the Northward extension of the Bering–Aleutian Salmon International Survey (BASIS) into the Chukchi Sea beginning in 2006. More limited sampling in the Chukchi has occurred during northward transit of Canadian ice breakers during the past decade, and the Japanese ship Oshoro Maru began last year extending its annual cruise into northward into the Chukchi Sea. A notable exception to the political boundaries imposed on most post-WWII sampling in the Bering and Chukchi seas has been the Joint US-USSR BERPAC program. Five such cruises were executed between 1977 and 1993 (Tsyban 1999). BERPAC 1988 is particularly relevant to this proposal because it encompassed stations from the southern Bering Sea to the mid-Chukchi Sea (Kulikov 1992). The RUSALCA program, which begun sampling in 2004 and will re-sample in 2008 and 2012, continues this bi-national sampling effort.

A regional and basin-wide review of Arctic zooplankton, their composition, seasonal life cycles, and trophic interactions was completed nearly two decades ago (Smith and Schnack-Schiel 1990). The review emphasizes the larger copepods in the genus Calanus. A more recent effort emphasizing the Russian literature for just the Bering Sea has also been completed (Coyle et al. 1996). One common shortcoming of all this initial work is that sampling techniques were not standardized; in particular, the use of only a single net of 303 to ~600 µm mesh as employed in these studies missed the majority of the zooplankton community numerically and missed a substantial proportion of the community biomass and diversity. For the most part, Arctic studies have now standardized on 150-µm mesh nets (e.g., Kosobokova and Hirche 2000; Ashjian et al. 2003; SBI and OE program) that more completely sample the numerically-dominant copepods in the genera Oithona, Oncaea, Microcalanus, and Pseudocalanus (ibid; Auel and Hagen 2002; Hopcroft et al. 2005).

Within the Chukchi Sea, there is considerable diversity of both small and large jellyfishes, hydromedusae, and ctenophores that are often overlooked: more than a dozen species were encountered in RUSALCA 2004 (Hopcroft and Kosobokova, in review), and more are reported from the nearby deep basins (Raskoff et al. 2005, in review). There were also considerable populations of larvaceans, particularly the large arctic Oikopleura vanhoeffeni throughout the sampling area. Larvaceans are increasingly implicated as key players in polar systems (e.g., Acuna et al. 1999; Hopcroft et al. 2005; Deibel et al. 2005) due to their high grazing and growth rates. At times, the biomass of

larvaceans in 2004 rivaled that of the copepods, particularly at the ice-edge stations in Herald Valley, where some of the highest recorded densities for Oikopleura vanhoeffeni were observed. Shifts from copepod-dominated communities to larvacean-dominated can have large consequences on the export of phytoplankton to the benthos (Gorsky and Feanaux 1998; Alldredge 2005). As in many ecosystems, chaetognaths remain an important and neglected predatory group (Ashjian et al. 2003; Hopcroft et al. 2005; Lane et al. 2008; Hopcroft and Kosobokova, in review), The meroplanktonic larvae of benthic organisms were also exceptionally common throughout the sampling region in 2004, and better knowledge of their abundance and distribution is of high relevance to understanding recruitment to the rich benthic communities in this region. To a large extent, the spatial distribution of these zooplankton communities is tied to the different water masses present in this region (Hopcroft and Kosobokova, in review).

In terms of mechanisms, planktonic communities of the Chukchi Sea could undergo climate-related changes either through shifts in the absolute transport rate, and thus penetration, of Pacific species into the Arctic, or by environmental changes that ultimately affect their survival. It has been estimated that 1.8 million metric tons of Bering Sea zooplankton are carried into the Chukchi Sea annually (Springer et al. 1989) and that this, along with the entrained phytoplankton communities, are responsible for the high productivity of the Chukchi Sea in comparison with adjoining regions of the Arctic Ocean (e.g., Plourde et al. 2005). In the summer of 2004, one would characterize the southern Chukchi zooplankton fauna as primarily Pacific in character, and there were clear signs that Pacific species were carried northward as far as the eastern side of Wrangel Island and Harold Canyon (Hopcroft and Kosobokova, in review), while in the northeastern Chukchi transitions to fully Arctic communities did not occur until the shelf break (Lane et al. 2008). Future increases in transport could carry even more Pacific zooplankton through Bering Strait, with even further penetration into the Arctic. In contrast, a reduction in transport of Bering Sea water would not only decrease the overall productivity of the Chukchi Sea but would give it a more Arctic Ocean faunal character. Thus, changes in the transport rates ultimately affect the species-composition of this region as well as the absolute zooplankton biomass, and such shifts may result in changes in the size-structure of zooplankton communities. Since most higher trophic levels select their prey based on size, the consequences of size-structure shifts could be more important than changes in zooplankton biomass.

1.2 Purpose of Study and Rationale

The Chukchi Lease Sale 193 occurred in February 2008. Prior to any exploration, development, or production activities being conducted in a lease block, MMS requires specific baseline information to be collected. Multiple years of data will be necessary to prepare a defensible NEPA document to support exploratory drilling and future development. Pelagic biological oceanography forms one aspect of these baseline studies because

the productivity of the water column determines the flux of energy to the seafloor and to productivity transferred through zooplankton to higher trophic levels such as fishes, seabirds, and marine mammals. Alterations to water-column productivity as a result of development activities, or long-term climate change, could therefore have direct impact on the ecosystem, including the more visible vertebrates. Long-term studies with direct observations of community composition and biomass are the only means to compare temporal variation in biological communities with environmental change.

1.3 Objectives of Study

The primary objective is to describe spatial and seasonal characteristics of the plankton (phytoplankton and zooplankton) communities with specific detail in the two study areas. In future years, it will be essential to survey the surrounding region to provide oceanographic context, because the study area is near the historical transition between Alaska Coastal waters and Bering Shelf waters, both of which have unique assemblages of zooplankton. It will therefore become critical to assess typical communities in both these water masses, concurrent with physical and chemical (i.e., nutrients) oceanographic measurements to ensure that appropriate baselines are available for both water masses, regardless of which occupies the study areas during future assessments. Secondarily, we will obtain opportunistic samples of zooplankton where bowhead whales are observed feeding to determine both the type of prey as well as the concentration that elicits bowhead feeding activity.

2.0 STUDY AREA

2.1 Location

As part of the post-leasing process, CPAI is continuing a multi-year scientific field program in 2009 for two study areas, termed Klondike and Burger (Figure Intro-1). Both study areas consist of a smaller area measuring 12 x 12 nm, s within a larger block that is ~30 by 30 nm.

2.2 Period of Study

The studies program is anticipated to be multi-year, but this plan is specific to the 2009 season. The current schedule consists of three 20-day cruises occurring between August and October. The first half of each cruise will collect data in the Klondike study area, and the second half will collect data in the Burger study area. To establish seasonality, and increase the statistical confidence on our observations, the pelagic biological-oceanography surveys will be conducted concurrent with physical oceanographic observations described in Section I.

3.0 METHODS AND PROCEDURES

3.1 Sampling or Survey Design and Technical Rationale

A 30 X 30 nm box will be sampled , with a grid of 5 X 5 stations, at ~7.5-nm spacing, within each study site on all cruises (see Figure II-1). Both phytoplankton (as chlorophyll) and zooplankton will be sampled because the phytoplankton is the major prey for the zooplankton and for the benthos once it settles. Together, nutrients, phytoplankton, and zooplankton form effective biological tracers of the waters masses present in this region. In general, re-sampling of fixed sampling locations over time along transects/grids (a model-based rather than a probability-based design) will provide the highest power for statistical comparisons between years (but limit inferences) and will result in spatially and temporally correlated data. Thus, statistical methodologies considered will include methods for analyzing data in the presence of correlated error structures (e.g., linear models through SAS Proc Mixed, SAS Institute, Cary, NC, or geostatistical methods) and multivariate procedures. Additional sets of collections will be conducted in any area where bowhead whales are observed to feed, with a pair of collections taken inside the feeding area and a pair taken outside for reference.

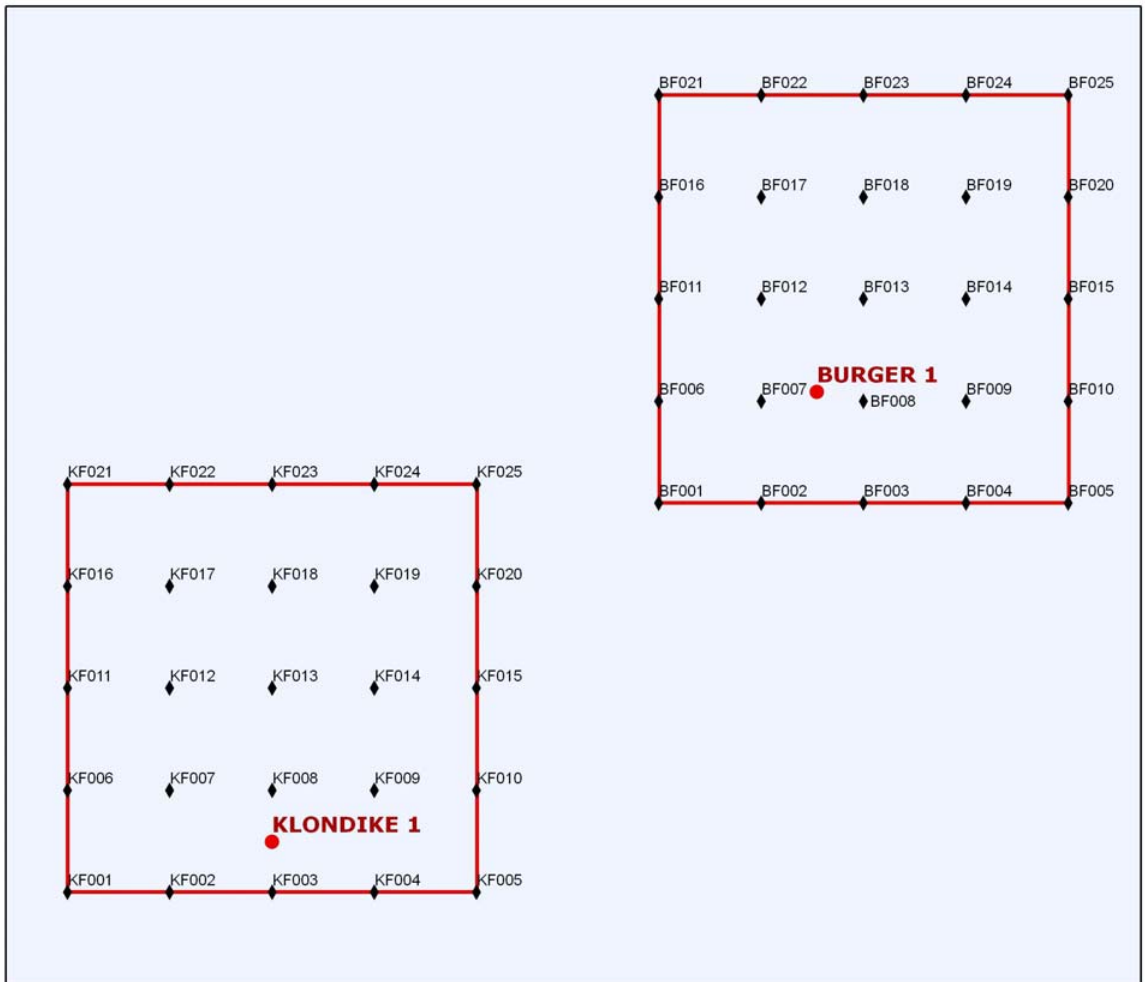

Figure II-1. 30 nm grids and fixed sampling stations.

3.2 Field Team Size and Composition

The field team will consist of two graduate students from the University of Alaska Fairbanks, assisted by marine technicians from Aldrich Offshore, Inc.

3.3 Data-collection Procedures

Routine methods are similar to those employed during the 2004 and 2008 RUSALCA expeditions and on the 2006 and 2007 BASIS cruises. Phytoplankton will be assessed as Chlorophyll a concentration from samples collected with a CTD rosette on upcasts at ~5 depths/station. Samples will be filtered under low pressure onto a Whatman GFF filters, with extracted Chlorophyll a being determined fluorometrically on board ship or post-cruise from frozen samples (Parsons et al. 1984). Measurements will be used to calibrate the in vivo fluorescence profiles measured at all stations. Nutrient samples will be taken from the same bottles as chlorophyll, frozen immediately, and measured post-cruise using an Alpkem Rapid Flow Analyzer (Whitledge et al. 1981); analyses will conform to WOCE standards (Gordon et al. 1993).

Zooplankton will be collected routinely by a pair of 150-µm mesh Bongo nets of 60-cm diameter hauled vertically from within 3 m of the bottom; the volume of water filtered will be measured by GO flow meters in each net that are rigged not to spin during descent.

To target larger, more mobile zooplankton, a set of 60-cm-diameter 505-µm Bongo nets will be deployed in a double-oblique tow while the ship is moving at 2 knots.

Opportunistic samples of zooplankton collected where bowhead whales are observed feeding will employ only the 505-µm net because they exploit only larger prey items. These samples will be collected after the mammals have left the area. Upon retrieval, one sample of each mesh size will be preserved in 10% formalin, and the other in 100% non-denatured ethanol (required for molecular identification). A quantitative subsample of fresh material from the sample to be preserved in ethanol will be made available to the contaminants team upon request.

3.4 Analytical Procedures

Formalin-preserved samples will be processed for quantitative determination of species ¬composition and biomass (predicted). During taxonomic processing, all larger organisms (primarily shrimp and jellyfishes) will be removed, enumerated, and weighed; then, the sample will be Folsom split until the smallest subsample contains about 100 specimens of the most abundant taxa. The most abundant taxa will be identified, copepodites will be classified to stage, and will be enumerated and measured (Roff and Hopcroft 1986). Each larger subsample will be examined to identify, measure, enumerate, and weigh the larger, less-abundant taxa. The three lead zooplankton technicians at UAF each have been working in Alaska waters from 8–20 years. When needed, specimens will be compared with the voucher set housed at UAF or will be sent to an appropriate taxonomic expert.

To estimate biomass, blotted wet weights of larger animals will be weighed directly, whereas the weight of smaller animals will be predicted from measurements of length using species-specific relationships. Wet-weight measurements are generally taken to ±1 µg (or where needed to ±0.1 µm) on a Cahn Electrobalance. Measured weights will be periodically compared to those predicted from length-weight equations to compare the two methods. The data will be uploaded to an Excel and/or Microsoft Access database for sorting and analysis. At present, multidimensional scaling of similarity or dissimilarities between samples has proven an effective method of revealing distributional patterns (Coyle and Pinchuk 2003, 2005; Hopcroft and Kosobokova, in review) and will be coducted with the Primer software package.

Ethanol samples will be scanned for representatives of the species and contribute to a growing international “molecular bar-coding” effort by the Census of Marine Zooplankton (CMarZ) at the

University of Connecticut for determination of the Cytochrome Oxidase I sequence. This sequence has been identified for the universal molecular “bar-coding” of eucaryotic organisms (Hebert et al. 2003) and is currently being employed for global analysis of zooplankton (e.g., Bucklin et al. 2003, in preparation). Initially, these sequences will simply serve to catalogue the species encountered, but they ultimately will become the preferred method of ensuring taxonomic consistency of identification within long-term studies.

3.5 Data-storage Procedures

Data files collected during cruises will be backed up periodically, and multiple copies will be transported back to UAF. At UAF, data are backed up routinely onto departmental servers.

3.6 Quality-control Procedures

In the field, samples are always collected in duplicate, so any discrepancy in the flowmeter readings become readily apparent. Replicate samples are not routinely analyzed but serve as insurance in the event that one sample is compromised. Periodically, the same subsamples are processed by several technicians to ensure taxonomic consistency. As indicated previously, the three lead zooplankton technicians at UAF each have been working in Alaska waters from 8 to 20 years. When questions arise, specimens will be compared with the voucher set housed at UAF, will be sent to an appropriate taxonomic expert, or will be identified through emerging molecular-identification libraries.

4.0 COORDINATION

4.1 CPAI

The PI will attend all proposed meeting and interacts regularly as needed with CPAI.

4.2 Other Studies in the Chukchi Sea Program

The PI regularly interacts with other PIs currently at UAF and has a long collaborative relationship with Weingartner, in particular, through the GLOBEC and NPRB Seward Line time-series. Hopcroft oversaw a recent multidisciplinary synthesis of studies from the Chukchi and Beaufort region, which has connected him to investigators in many other disciplines.

4.3 Current Studies in the Region

Recent and ongoing studies have been described in Section 1.1. Hopcroft is a PI within the NOAA-funded RUSALCA program begun in 2004, which will be a re-sampling over a broad domain of the Chukchi Sea in September 2008. Hopcroft and his students are actively involved with the BASIS sampling program in the Chukchi Sea (which has stopped at 70°N), as well as in the deep Canada Basin. Hopcroft is also a lead PI in the ongoing Arctic Ocean Biodiversity project (www.arcodiv.org), which, among other goals, is compiling biological data from the Chukchi Sea, in conjunction with colleagues and ongoing efforts by NOAA-NMFS, ArcOD has digital access to much of the zooplankton data from OCSEAP, ISHTAR, WEBSEC, SBI, Ocean Exploration cruises. Recently, several of these datasets have been made available on-line at http://ak.aoos.org/op/data.php?region=AK&name=obis or http://www.st.nmfs.gov/plankton/content/area_bering/index.html. Thus far, we have been unsuccessful in locating all BERPAC data, but such efforts and others are ongoing.

5.0 REFERENCES

Acuna, J. L., D. Deibel, A. B. Bochdansky, and E. Hatfield, E. 1999. In situ ingestion rates of appendicularian tunicates in the Northeast Water Polynya (NE Greenland). Marine Ecology Progress Series 186: 149–160.

Alldredge, A. 2005. The contribution of discarded appendicularian houses to the flux of particulate organic carbon form oceanic surface waters. In G. Gorsky, M. J. Youngbluth, and

D. Deibel (Eds.). Response of marine ecosystems to global change: ecological impact of appendicularians. Gordon and Breach, Paris, France. Pp. 309–326.

Ashjian, C. J., R. G. Campbell, H. E. Welch, M. Butler, and D. V. Keuren. 2003. Annual cycle in abundance, distribution, and size in relation to hydrography of important copepod species in the western Arctic Ocean. Deep-Sea Research (I) 50: 1235–1261.

Auel, H., and W. Hagen. 2002. Mesozooplankton community structure, abundance and biomass in the central Arctic Ocean. Marine Biology 140: 1013–1021.

Bogorov, V. G. 1939. The characteristics of seasonal phenomena in the plankton of the Arctic seas and their significance for ice forecastings. Zoologicheskii Zhurnal 18 (5): XXX–XXX. [in Russian].

Brodsky, K. A., 1950. Copepods (Calanoida) of the far-eastern seas of the USSR and the polar basin. Zoological Institute of the Academy of Sciences of the USSR, Leningrad.

Brodsky, K. A., 1957. The copepod fauna (Calanoida) and zoogeographic zonation of the North Pacific and adjacent waters. Akademiya Nauk SSSR, Leningrad.

Bucklin, A., B. W. Frost, J. Bradford-Grieve, L. D. Allen, and N. J. Copley. 2003. Molecular systematic and phylogenetic assessment of 34 calanoid copepod species of the Calanidae and Clausocalanidae. Marine Biology 142: 333–343.

Bucklin, A., R. R. Hopcroft, K. N. Kosobokova, and K. A. Raskoff. In preparation. Molecular sequencing of marine zooplankton communities: COI sequences of the western Arctic.

Conover, R. J., and M. Huntley. 1991. Copepods in ice-covered seas—distribution, adaptations to seasonally limited food, metabolism, growth patterns, and life-cycle strategies in polar seas. Journal of Marine Systematics 2: 1–41.

Cooney, R. T. 1977. Zooplankton and micronekton studies in the Bering-Chukchi/Beaufort seas. NOAA OCSEAP Annual Reports 10: 275–363.

Coyle, K. O., V. G. Chavtur, and A. I. Pinchuk. 1996. Zooplankton of the Bering Sea: a review of Russian-language literature. In A. O. Mathisen and K. O. Coyle (Eds.). Ecology of the Bering Sea: a review of the Russian literature. Alaska SeaGrant College Program, University of Alaska, Fairbanks, AK. Pp. 97–133.

Coyle, K. O., and A. I. Pinchuk. 2003. Annual cycle of zooplankton abundance, biomass and production on the northern Gulf of Alaska shelf, October 1997 through October 2000. Fisheries Oceanography 12: 227–251.

Coyle, K. O., and A. I. Pinchuk. 2005. Cross-shelf distribution of zooplankton relative to water masses on the northern Gulf of Alaska shelf. Deep-Sea Research (II) 52: 217–245.

Deibel, D., P. A. Saunders, J. L. Acuna, A. B. Bochdansky, N. Shiga, and R. B. Rivkin. 2005. The role of appendicularian tunicates in the biogenic carbon cycle of three Arctic polynyas.

In G. Gorsky, M. J. Youngbluth, and D. Deibel (Eds.). Response of marine ecosystems to global change: ecological impact of appendicularians. Gordon and Breach, Paris, France. Pp. 327–356.

English, T. S. 1966. Net plankton volumes in the Chukchi Sea. In N. J. Wilimovsky, and J. N. Wolfe (Eds.). Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission, Washington, DC. Pp. 809–915.

English, T. S., and R. Horner. 1977. Beaufort Sea plankton studies. NOAA OCSEAP Annual Reports 9: 275–627.

Gordon, C., A. A. Jennings, and J. M. Krest. 1993. A suggested protocol for continuous flow automated analysis of seawater nutrients (phosphate, nitrate, nitrite, and silicic acid) in the WOCE Hydrographic Program and the Joint Global Ocean Fluxes Study. Oregon State University, Corvallis, OR. P. 51.

Gorsky, G., and R. Fenaux. 1998. The role of Appendicularia in marine food chains. In Q. Bone (Ed.). The biology of pelagic tunicates. Oxford University Press, New York, NY. Pp. 161– 169.

Grebmeier, J. M., W. O. Smith, Jr., and R. J. Conover. 1995. Biological processes on Arctic continental shelves: ice-ocean-biotic interactions. In W. O. Smith, Jr., and J. M. Grebmeier (Eds.). Arctic oceanography: marginal ice zones and continental shelves. American Geophysical Union, Washington, DC. Pp. 231–261.

Grice, G. D. 1962. Copepods collected by the nuclear submarine Seadragon on a cruise to and from the North Pole, with remarks on their geographic distribution. Journal of Marine Research 20: 97–109.

Hebert, P. D. N., A. Cywinska, S. L. Ball, and J. R. deWaard. 2003. Biological identifications through DNA barcodes. Proceedings of the Royal Society of London (B) 270: 313–321.

Hopcroft, R. R., C. Clarke, R. J. Nelson, and K. A. Raskoff 2005. Zooplankton communities of the Arctic's Canada Basin: the contribution by smaller taxa. Polar Biology 28: 197–206.

Hopcroft, R. R., and K. N. Kosobokova. In review. Distribution and production of Pseudocalanus species in the Chukchi Sea. Deep-Sea Research (II).

Hopcroft, R. R., and K. N. Kosobokova. In review. Zonation of zooplankton communities in the Chukchi Sea. Deep-Sea Research (II).

Horner, R. 1981. Beaufort Sea plankton studies. NOAA OCSEAP Final Reports 13: 65–314.

Horner, R. 1984. Analysis of Harrison Bay zooplankton samples. NOAA OCSEAP Final Reports 25: 65–314.

Huntley, M. E., 1996. Temperature and copepod production in the sea: a reply. American Naturalist 148: 407–420.

Jaschnov, V. 1940. Plankton productivity of the northern seas of the USSR. Moscovskoe Obshestvo Ispytatelei Prirody Press, Moscow, Russia.

Johnson, M. W. 1934. The production and distribution of zooplankton in the surface waters of the Bering Sea and Bering Strait, Part II. Report of the oceanographic cruise U.S. Coast Guard Cutter Chelan—1934. Pp. 45–82.

Johnson, M. W., 1953. Studies on the plankton of the Bering and Chukchi Seas and adjacent areas. Proceedings 7th Pacific Science Congress (1949), Vol. 4, 'Zoology'. Pp. 480–500.

Johnson, M. W., 1956. The plankton of the Beaufort and Chukchi Sea areas of the Arctic and its relation to hydrography. Arctic Institute of North America, Montreal, Canada.

Johnson, M. W. 1958. Observations on inshore plankton collected during the summer 1957 at Point Barrow, Alaska. Journal of Marine Research 17: 272–281.

Kosobokova, K., and H.-J. Hirche. 2000. Zooplankton distribution across the Lomonosov Ridge, Arctic Ocean: species inventory, biomass and vertical structure. Deep-Sea Research (I) 47: 2029–2060.

Kulikov, A. S. 1992. Characteristics of zooplankton communities. In P. A. Nagel (Ed.). Results of the third Joint US–USSR Bering and Chukchi seas expedition (BERPAC), summer 1988.

U.S. Fish and Wildlife Service, Washington, DC. Pp. 161–XXX.

Lane, P. V. Z., L. Llinás, S. L. Smith, and D. Pilz. 2008. Zooplankton distribution in the western Arctic during summer 2002: hydrographic habitats and implications for food chain dynamics. Journal of Marine Research 70: 97–133.

Lee, S. H., T. E. Whitledge, and S.-H. Kang. 2007. Recent carbon and nitrogen uptake rates of phytoplankton in Bering Strait and the Chukchi Sea. Continental Shelf Research 27: 2231– 2249.

Llinás, L. 2007. Distribution, reproduction, and transport of zooplankton in the western Arctic, University of Miami, Coral Gables, FL.

Parsons, T. R., Y. Maita, and C. M. Lalli. 1984. A manual for chemical and biological methods in seawater. Pergamon Press, Toronto, Canada.

Plourde, S., R. G. Campbell, C. J. Ashjian, and D. A. Stockwell,. 2005. Seasonal and regional patterns in egg production of Calanus glacialis/marshallae in the Chukchi and Beaufort seas during spring and summer, 2002. Deep-Sea Research (II) 52: 3411–3426.

Raskoff, K. A., R. R. Hopcroft, K. N. Kosobokova, M. J. Youngbluth, and J. E. Purcell. In review. Jellies under ice: ROV observations from the Arctic 2005 Hidden Ocean Expedition. Deep-Sea Research (II).

Raskoff, K. A., J. E. Purcell, and R. R. Hopcroft. 2005. Gelatinous zooplankton of the Arctic Ocean: in situ observations under the ice. Polar Biology 28: 207–217.

Redburn, D. R. 1974. The ecology of the inshore marine zooplankton of the Chukchi Sea near Point Barrow, Alaska. M.S. thesis, University of Alaska, Fairbanks, AK.

Roff, J. C., and R. R. Hopcroft. 1986. High precision microcomputer based measuring system for ecological research. Canadian Journal of Fisheries and Aquatic Sciences 43: 2044– 2048.

Sirenko, B. I. 2001. List of species of free-living invertebrates of Eurasian arctic seas and adjacent deep waters. Russian Academy of Sciences, St. Petersburg, Russia.

Smith, S. L. 1990. Egg production and feeding by copepods prior to the spring bloom of phytoplankton in Fram Strait, Greenland Sea. Marine Biology 106: 59–69.

Springer, A. M., C. P. McRoy, and K. R. Turco. 1989. The paradox of pelagic food webs in the northern Bering Sea. II: Zooplankton communities. Continental Shelf Research 9: 359–386.

Stepanova, V. S. 1937. Biological indicators of currents in the northern Bering and southern Chukchi Seas. Issled. Morei SSSR 25: 175–216 [in Russian].

Thibault, D., E. J. H. Head, and P. A. Wheeler. 1999. Mesozooplankton in the Arctic Ocean in summer. Deep-Sea Research (I) 46: 1391–1415.

Tsyban, A. V. 1999. The BERPAC pProject: development and overview of ecological investigations in the Bering and Chukchi seas. In T. R. Loughlin and K. Ohtani (Eds.). Dynamics of the Bering Sea. Alaska SeaGrant College Program, University of Alaska, Fairbanks, AK. Pp. 713–731.

Virketis, M. 1952. Zooplankton of the Chukchi Sea and Bering Strait. In K. A. Brodsky (Ed.). The extreme north-east of the USSR. 2. Fauna and flora of the Chukchi Sea. Akademiya Nauk SSSR, Moscow, USSR. XXX pp. [in Russian].

Whitledge, T. E., S. C. Malloy, C. J. Patton, and C. D. Wirick,. 1981. Automated nutrient analyses in seawater. Brookhaven National Laboratory, Upton, NY. 216 pp.

Wing, B. L. 1972. Preliminary report on the zooplankton collected on WEBSEC-70. In M. C. Ingham, B. A. Rutland, P. W. Barnes, G. E. Watson, G. J. Divoky, A. S. Naidu, G. D. Sharma, B. L. Wing, and J. C. Quast (Eds.). An ecological survey in the eastern Chukchi Sea. U.S. Government, Washington, DC.

SECTION III
BENTHIC COMMUNITIES OF THE KLONDIKE AND BURGER PROSPECT REGIONS OF THE CHUKCHI SEA

PRINCIPAL INVESTIGATOR
ARNY L. BLANCHARD
UNIVERSITY OF ALASKA FAIRBANKS

1.0 INTRODUCTION

1.1 Brief History of Subject Research in Chukchi Sea

The last 30 years have seen tremendous development and resource use in the North Slope of Alaska. Development and extraction of petroleum reserves and associated industrial and urban growth has increased the potential for adverse anthropogenic effects on the environment (Naidu et al. 1997). In the Chukchi Sea, cultural and subsistence resources of interest mainly include marine mammals and seabirds, some of which feed on sediment-dwelling (benthic) organisms (e.g., Lovvorn et al. 2003; Grebmeier et al. 2006). Disturbance to the short food chains in the arctic has the potential for large effects on higher trophic levels, making assessment of benthic community species-composition and structure important components for monitoring.

The first investigation of infaunal community structure in the northeast Chukchi Sea was performed in 1971 to 1974 by Stoker (1978). This study was followed in 1985 and 1986 by investigations of the benthos/environmental interactions by Feder et al. (1994b) and of pelagic/benthic coupling by Grebmeier et al. (1988). A rich epifaunal community is also known for the area, including mollusks, crabs, and echinoderms (e.g., Feder et al. 1994a; Ambrose et al. 2001). These studies provided insights into the benthic fauna present and factors structuring infaunal communities. The benthic biomass of the region is high in spite of the seasonal ice cover due to the tight coupling of pelagic and ice-edge primary production and benthic community structure and production (Grebmeier et al. 2006). Current investigations in the region include the Shelf-Basin interaction study (SBI; see http://sbi.utk.edu) and the Russian-American Long-term Census of the Arctic (RUSALCA) investigating ecosystem dynamics, food-webs, and benthic ecology; however, long-term studies in the region are lacking.

The northeastern Chukchi Sea is a productive shallow sea influenced by advective processes (Grebmeier et al. 2006). Water advected into the region includes Bering Shelf (BSW) and Alaska Coastal water (ACW; Coachman 1987). The BSW has high nutrient concentrations (derived in part from water from the Gulf of Anadyr off Russia) that enhance benthic biomass, whereas the ACW along the Alaska coast is comparatively nutrient poor (Feder et al. 1994b; Codispoti et al. 2005; Grebmeier et al. 2006). The differences in nutrient concentrations in water masses lead to substantial differences in primary production, and thus, benthic community structure (Feder et al. 1994b) and benthic food web structure (Iken et al., in review). Factors influencing benthic community structure of the Chukchi Sea include sediment granulometry and sediment organic carbon to nitrogen ratios (C/N ratio) and have been identified as important predictors of community structure (Feder et al. 1994b). Sediment granulometry (e.g., percent gravel, sand, or mud) reflects a number of environmental processes, including hydrodynamics (strong currents, storms, ice gouging, etc.), sediment deposition, and proximity to sediment sources. The C/N ratio in sediments reflects the availability of particulate

organic carbon to benthic animals, which is of particularly high nutrient value when derived from phytoplankton as opposed to terrigenous carbon.

The benthic community in the Chukchi Sea and northern Bering Sea is an important feeding ground for higher-trophic-level organisms such as walruses and gray whales (e.g., Oliver et al. 1983; Moore et al. 2003; Highsmith et al. 2006; Bluhm et al. 2007). Traditional feeding hot spots are located south of St. Lawrence Island and the Chirikov Basin (both in the Bering Sea) and the south-central Chukchi Sea, but recent marine-mammal observations have shown that these hotspots may be changing because of changes in both sea ice as resting platforms for walruses and seals between feeding bouts and in the benthic community structure. While the ConocoPhillips Burger and Klondike prospect areas currently are not known feeding grounds for gray whales or other higher trophic levels, monitoring effects need to include the possibility that these areas may become feeding grounds in the future. Therefore, the benthic studies suggested here will be an opportunity to provide valuable baseline information, should these areas become more important for marine mammals and seabirds in the future.

1.2 Purpose of Study and Rationale

This program constitutes the second year of a multi-year program to collect benthic macrofaunal invertebrates within the Burger and Klondike prospects, determine community structure, and assess historical environmental data from the Chukchi Sea. This is one component of a larger ConocoPhillips Chukchi Science Program for 2009. This work will provide background information for environmental impact statements (EIS) and future monitoring efforts. Results of the first year of this study will assist with planning of future sampling efforts, designing a long-term monitoring program, and contributing data to an EIS.

Long-term studies provide the means to compare temporal variation in biological communities to environmental change and assess community readjustment. Gray and Christie (1983) suggest that effects of direct anthropogenic disturbance can be observed as a difference in changes over time between a location experiencing the disturbance and a location unaffected by that disturbance. This approach helps to distinguish between anthropogenic disturbance (which shows time differences between test and control sites) and other exogenous disturbance (which is more likely to affect all sites at the same time). For example, an Alaska environmental study program assessing the effects of treated ballast-water effluents on fauna has investigated the marine environment in Port Valdez since 1971 (Hood 1973; Colonell 1980; Shaw and Hameedi 1988). Comprehensive investigations of Port Valdez in 1971 to 1980 comprised a nearly complete ecological and oceanographic assessment of the fjord (Hood et al. 1973; Colonell 1980). The current environmental studies in Port Valdez are now focused on monitoring sediments in the fjord for increases in sediment hydrocarbons and associations with changes in benthic biota (Blanchard et al. 2002, 2003, 2007). The project has been very successful at detecting small increases in sediment hydrocarbons and associated adverse responses by fauna (Blanchard et al. 2002, 2003). Similarly, long-term monitoring in the Chukchi Sea is a necessary step in understanding and protecting the environment where human impacts are planned to provide an early detection to prevent undesirable ecosystem-level effects.

Invertebrate community data from soft sediments are widely used to survey marine environments for anthropogenic effects. Infauna are excellent indicators of environmental conditions because they are not highly mobile and move small distances compared with the scale of anthropogenic stressors (Clarke 1999). Measurement of

change in infaunal communities is particularly useful when assessing effects from the point-source dispersal of pollutants and sources with defined spatial limits. Investigations of infauna in the North Sea have demonstrated long-term changes in fauna in association with contaminants (drilling mud and associated contaminants including hydrocarbons) and climatic variability include increases in the abundance of the small, opportunistic polychaete families (Olsgard and Gray 1995; Pearson and Mannvik 1998; see also May and Pearson 1995). The primary source of disturbance in North Sea oil and gas platforms has been drill cuttings (particularly oil-based drilling cuttings) discharged into the sea (Olsgard and Gray 1995).

1.3 Objectives

The objective of this study will be to describe the spatial trends in macrobenthic infaunal communities. This addresses the benthic ecology component of the 2009 environmental studies program in the Chukchi Sea for CPAI. Specific objectives of the proposed work are to:

Task 1: Assessment of historical data.

- Search for and acquire historical databases of benthic fauna and relevant environmental data from the Chukchi Sea; and
- Summarize and synthesize the relevant historical databases with respect to macrofaunal community structure.

Task 2: Benthic ecology.

- Sample the benthos within the Chukchi Sea to describe benthic macrofaunal community structure;
- Sample the benthos where gray whales are observed feeding in the area; and
- Assess species-composition, abundance, and biomass of macrobenthic communities within the study area.

2.0 STUDY AREA

2.1 Location

The study area is located in the northeastern Chukchi Sea. Work is proposed for benthic sampling in the CPAI Klondike and Burger prospects (Introduction Figure Intro-1)

3.0 METHODS AND PROCEDURES

3.1 Sampling or Survey Design and Technical Rationale

Benthic sampling will focus on sites within the Burger and Klondike prospects. Opportunistic samples will be collected in locations where gray whales are observed feeding by the marine-mammal team, but this should be, at most, a small number since the prospects are not known as feeding areas for gray whales (Highsmith et al. 2006). Thus, benthic sampling will include:

- sampling at fixed stations within the prospect sites (40 locations at each site); and
- opportunistic sampling where marine mammal scientists observe gray whales and/or walruses feeding.

We propose to sample a grid of stations from a 30 X 30-nm grid within each study site during the mid-August cruise. There will be 25 sampling points on each grid. Benthic

sampling for infauna and contaminants will sample 13 of these systematic grid points and 13 randomly-selected points from the grid. (see Figure III-1). Additionally, benthic sampling will occur at the two old drill sites located in the prospects. Sampling points surrounding the drill sites will consist of a radial design with 4 transects located at 90° to each other and sampling points located at 1 km and 3 km from each drill site, for a total of 8 sampling points/grid. Additionally, it is estimated that 6 subjectively-chosen sites will be located within each grid.

These subjectively-chosen sites will be opportunistic sites sampled due to marine-mammal feeding activities or for other aspects of interest. In general, re-sampling of fixed sampling locations over time along transects/grids (a model-based rather than a probability-based design) will provide the highest power for statistical comparisons between years (but will limit inferences) and will result in spatially- and temporally-correlated data. Thus, statistical methodologies considered will include methods for analyzing data in the presence of correlated error structures (e.g., linear models through SAS Proc Mixed, SAS Institute, Cary, NC, or geostatistical methods) and multivariate procedures. In terms of benthic studies, the sampling of the fixed design allows for a direct association with physical oceanography and zooplankton sampling (for which the fixed-grid design is more appropriate). Together, nutrients, phytoplankton, and zooplankton form effective biological tracers of the waters masses present in this region, and sampling the water column and benthos will allow assessment of the connections between the two. The strength of design-based sampling is that inferences are applicable to the whole of a study area. Thus, the combination of sampling approaches allows both for connections to the other oceanographic studies and inferences appropriate for the scale of the study area.

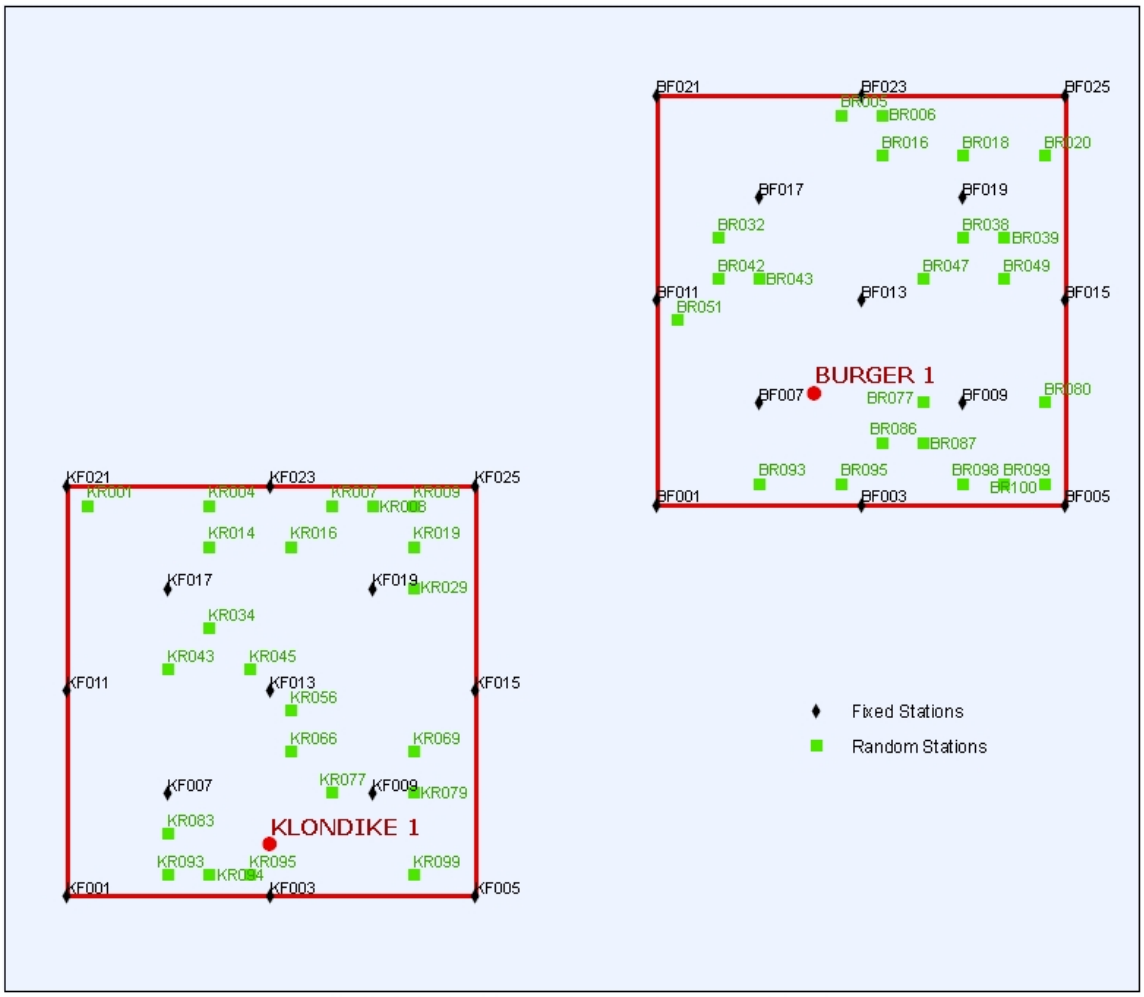

Figure III-1. Benthic/Contaminant Sampling Stations

Figure III-1. Benthic/Contaminant Sampling Stations

3.2 Field Team Size and Composition

The benthic-ecology field team will consist of two personnel. The team will consist of a research technician trained in field sampling and a Ph.D. graduate student.

3.3 Data-collection Procedures

Benthic fauna will be sampled at two prospect sites in the summer of 2008. Infaunal benthic invertebrates will be sampled with a 0.1-m2 double van Veen grab sampler (with ~30 kg of extra weight to increase penetration of the sediments) at a series of benthic stations. Three replicate samples will be collected at each station, although five replicates may be collected at some sites to help address small-scale variability. Samples will be washed through a 1.0-mm-mesh stainless-steel screen until all that is left is biological material and larger sediments. Samples will be preserved in 10% buffered formalin. Identifications of each organism will be made to the lowest practical taxon (likely family level with dominants identified to species for the first year), counted and weighed (blotted wet weight). Average faunal abundance (individuals m-2) and

biomass (g m-2) will be estimated for each site. Information from the ship's bridge collected at the time of sampling includes sampling depth and GPS coordinates. This information will be recorded for every grab sample taken. Preserved specimens will be kept aboard the vessel until the vessel returns to Seward and will be shipped to Fairbanks from there. Sediments for grain-size analyses will be collected from the first grab at each station. Surface sediments will also be collected for percent organic carbon and nitrogen determinations and separately for chlorophyll and phaeopigment concentrations. These sediment samples will be frozen until delivery to UAF.

A double van Veen grab will be used to sample sediments. Benthic samples will be taken from the grab, with each team using one of the single grabs.

Biological samples will be sieved through a 1.0-mm screen, and the remains will be placed into a plastic jar with spoons and forceps. Once all animals and sediments are removed, a UAF sample tag from the sample log book (for in-lab identification only—not fort chain of custody) will be completed and placed inside the jar. The jar then will be filled with 10% buffered formalin. The sample will be listed on a chain of custody (COC) form, and an identification number written or bar-code label will be placed on the outside of the jar. The COC number will be written in the UAF sample log book as well. (Estimated total of 300 samples.)

The sample will be placed into a marine cooler or other similar packing crate. The cooler should be lined with a heavy-duty 55 gallon garbage bag. The bottom of the bag will be covered with vermiculite in which the sample shall be placed. Vermiculite will be used to fill in the spaces around samples and should cover all samples when the cooler is filled. The full bag should be closed with a cable tie. A full cooler will be wrapped with duct tape to ensure that it stays closed. This system serves as Hazmat-certifiable packaging for shipment.

A single sediment sample will be taken from one van Veen grab at each station. This sample will consist of a large tablespoon scoop of surface sediment from the top of the grab that is placed into a plastic whirl-pak bag. A UAF sample tag from the sample book will be placed in the sample bag with the sediments. The COC number will be written or the bar-code will be placed on the outside of the bag. The sample can then be double-bagged and placed into the freezer. (Estimated total of 80 samples)

Single samples for chlorophyll and isotope analysis will be collected at each station. A clean scoop will be used to scrape surface sediments and place them in a pre-cleaned vial. The COC form will be completed, and the COC information/bar-code will be placed on the vial; then, the contents ill be frozen. Tissue samples for isotope analysis, collected opportunistically from the grabs not sampled for biology, will also be placed in vials and handled accordingly. Station and replicate information will be written on the outside of each sample. (Estimated total of 200 samples.)

Sediment, isotope, and chlorophyll samples are not classified as hazardous material.

3.4 Analytical Procedures

3.4.1 Historical data assessment

Historical infaunal benthic data for the Chukchi Sea will be synthesized to understand better the ecological context of the study area and potential anthropogenic effects. Investigations of infaunal community structure include Stoker (1978), Feder et al. (1994), Grebmeier et al. (2006), the Shelf-Basin interaction study (SBI; http://sbi.utk.edu), and

the (RUSALCA; http://www.arctic.noaa.gov/aro/russian-american/cruise2-objectives.htm). Other investigations of importance in the Chukchi Sea include physical oceanography (e.g., Weingartner et al. 2005), nutrient transport (e.g., Codispoti et al. 2002), distributions of epifaunal mollusk (Feder et al. 1994a), contributions of ophiuroids to benthic remineralization (Ambrose et al. 2001), and distributions of fishes (Barber et al. 1997) as well as ongoing work on infauna, epifauna, and ecosystem processes (SBI and RUSALCA). The benthic data from Stoker (1978) and Feder et al. (1994) are available from the IMS benthic data archive (A. L. Blanchard). Other data are available from IMS investigators, the SBI website (http://sbi.utk.edu), the Ocean Biogeographic Information System (www.iobis.org), the Global Biodiversity Information Facility (www.gbif.org), and the Arctic Ocean Diversity Census of Marine Life database (www.aoos.org). Available data will be integrated and synthesized as appropriate to understand spatial and temporal variability in fauna and community structure. With the addition of the proposed sampling in 2008 to the infaunal database, faunal variability will be better known, helping to guide planning of further investigations in the Chukchi Sea and assist with the required EIS. Statistical methods used may include regression, analysis of variance, correlation testing, geostatistical analyses, and multivariate methods such as cluster analysis, nonmetric multidimensional scaling, and principal components analysis. The methods applied will be determined by the data quality, but an emphasis will be placed on linear models (regression and ANOVA) whenever possible.

3.4.2 Benthic Sampling

The number and location of sampling locations is estimated as more than 300 individual samples, with potentially as many as 400 collected for processing. Thus, it is expected that many benthic samples will not be completed in time for the draft report and possibly by 1 May 2009. To ensure that a spatially-dispersed collection of samples are available for the draft report, the samples will be sorted according to established priorities. Samples will be sorted according to the following priority structure:

- First-priority samples: the first three replicates at sites from the outer edges of the prospects, every other site within the prospect, and sites of any observed gray whale feeding sites.
- Second priority: The first three replicates for each of the remaining grid point sites will be worked up.
- Third priority: the remaining replicates from the first and second priority sites.
- Fourth priority: additional random samples collected to describe smaller-scale variability.

Processing time for the any samples not completed by 31 May 2009 would be included in the next funding period, and the full data reported in a Final Report of May 2010. The priority structure above will allow for completion of a suite of stations and replicates to provide

preliminary information on macrofaunal community structure. Identification of organisms to the family level for the first year will make more data available within the short time frame for the CPAI study. Alternatively, large, sandy or gravelly samples can be subsampled, an approach successfully used by Jewett et al. (1999) in describing effects from the Exxon Valdez oil spill.

3.4.3 Benthic Community Analyses

Benthic community data will be analyzed with appropriate and available statistical techniques. Descriptive measures, average abundance (individuals m-2), biomass (g wet weight m-2), number of taxa, and diversity measures are useful for summarizing benthic-infaunal information. Transformations of data are often required to meet assumptions of normality when using parametric statistical methods and will be considered. Expected transformations include the ln(x+1) transformation for abundance data and the ln(x) transform for biomass data. Data will be analyzed as appropriate with a range of methods including analysis of variance, linear regression, cluster analysis, and multidimensional scaling; geostatistical methods may also apply. The emphasis in these analyses will be to describe community structure of the benthic communities and to determine their spatial variability. Depending on availability of results from the other components of the CPAI Chukchi science team, such as contaminant concentrations, physical oceanography, and zooplankton ecology, other methods such as canonical correspondence analysis may be used to assess baseline associations between infaunal communities and environmental factors. Sediments for sediment-grain-size analyses will sub¬contracted to an established laboratory. Surface sediments will be analyzed for percent organic carbon and nitrogen by the University of Alaska's Stable Isotope Laboratory. Chlorophyll will be determined with the fluorometer purchased for zooplankton ecology, and phaeopigment concentrations will be determined by trained IMS personnel.

3.5 Data-storage Procedures

Data for this project will be entered and stored in computer systems at UAF. A benthic data-entry system has been in use for a number of years at IMS. This data system was created to eliminate transcription errors from hand-written data sheets and other data-entry mistakes. With its use, transcription and data entry errors decreased by over 95%. This data system will be used for this study as well. The resulting data are stored in a MS Access database, but hard copies are printed out and archived separately. The data-storage system is located on a secure computer not connected to the internet. For the UAF system, backups of all data maintained there will be conducted weekly. The data on the UAF computer system will be incorporated into MS Access databases and MS Excel spreadsheets. The resulting data sets will be archived at CPAI as one of the project deliverables. Ultimately, the data will be archived with the Arctic Ocean Diversity Census of Marine Life database (www.aoos.org). The data archive at IMS also includes the original work in the Chukchi Sea conducted by Dr. Howard Feder in 1986. These data are available and will be used for temporal comparisons.

Voucher collections will be maintained at the University of Alaska, Fairbanks. The voucher collection will include at least one representative specimen of each species identified in the study. Specimens will be evaluated by a taxonomic specialist to ensure correct identification as necessary. Remaining biological specimens will be stored at IMS. Sorted sediments, those with all biological material removed, will be stored for a short time to allow for validation of the sorting via quality-control procedures and then will be discarded.

3.6 Quality-control Procedures

The following quality-control procedures are followed in processing samples. The work of sorters is monitored throughout the project. At a minimum, 25% of samples sorted by student employees are checked, but more often up to 50% of the samples are checked.

Of the samples checked, the sorted material is examined to be certain that 100% of the organisms in each sample are removed. One-hundred percent of the work performed by junior taxonomists is checked and verified by a senior taxonomist. Work is verified to ensure that all counts are accurate and that all organisms are correctly identified. The verification of identifications by junior taxonomists tapers off as they approach the skill level expected for a senior taxonomist. A voucher collection is maintained at IMS and includes examples of organisms found throughout the thirty-year study period in Port Valdez. This collection is used to ensure that the identification of organisms is consistent from year to year. Sorted debris from each annual survey collection is archived in sealed containers for one year. Sorted debris will be kept for one year, and organisms identified in the samples will be archived at IMS and museum repositories.

4.0 COORDINATION

4.1 CPAI

Safety training will be provided by CPAI. Specific training on the safe use of benthic sampling equipment will be provided by Dr. Arny Blanchard.

4.2 Other Studies in the Chukchi Sea Program

Coordination and collaboration with scientists who are working on CPAI projects in the Chukchi Sea is expected through the coordination meetings and report preparation. It is anticipated that results from the other CPAI Chukchi Sea projects will be available for determining benthic community structure. These include sediment grain-size, trace metal, and contaminants concentrations, measures of water-column productivity, and oceanographic variables.

4.3 Current Studies in the Region

A number of projects will be sampling in the Chukchi Sea in the summer of 2008. These include the RUSALCA cruise and research sponsored by Shell. Drs. Bodil Bluhm and Katrin Iken are part of the RUSALCA project and will help coordinate information transfer between the studies. Dr. Jaqueline Grebmeier, a biological oceanographer specializing in the benthos, is also part of the RUSALCA project and is managing the Shell-funded studies in the Chukchi Sea. It is anticipated that this project can be coordinated in many ways with Dr. Grebmeier's work.

5.0 REFERENCES

Ambrose, W. G., L. M. Clough, P. R. Tilney, and L. Beer. 2001. Role of echinoderms in benthic remineralization in the Chukchi Sea. Marine Biology 139: 937–949.

Barber, W. E., R. L. Smith, M. Vallarino, and R. M. Meyer. 1997. Demersal fish assemblages of the northeastern Chukchi Sea, Alaska. Fishery Bulletin 95: 195–209.

Blanchard, A. L., H. M. Feder, and D. G. Shaw. 2002. Long-term investigation of benthic fauna and the influence of treated ballast water disposal in Port Valdez, Alaska. Marine Pollution Bulletin 44: 367–382.

Blanchard, A. L., H. M. Feder, and D. G. Shaw. 2003. Variations of benthic fauna underneath an effluent mixing zone at a marine oil terminal in Port Valdez, Alaska. Marine Pollution Bulletin 46: 1583–1589.

Bluhm, B. A., K. O. Coyle, B. Konar, B., and R. Highsmith. 2007. High gray whale relative abundances associated with an oceanographic front in the south-central Chukchi Sea. Deep-Sea Research (II) 54: 2919–2933.

Clarke, K. R. 1999. Nonmetric multivariate analysis in community-level ecotoxicology. Environmental Toxicology and Chemistry 18: 118–127.

Coachman, L. K. 1987. Advection and mixing on the Bering-Chukchi Shelves. Component A: Advection and mixing of coastal water on high latitude shelves. ISHTAR 1986 Progress Report, Vol. 1. Institute of Marine Science, University of Alaska, Fairbanks, AK. Pp 1–42.

Codispoti, L. A., C. Flagg, V. Kelly, and J. H. Swift. 2005 Hydrographic conditions during the 2002 SBI process experiments. Deep-Sea Research (II) 52: 3199–3226.

Colonell, J. M. (Ed.). 1980. Port Valdez, Alaska: environmental studies, 1976–1979. Institute of Marine Science, University of Alaska, Fairbanks, AK. XXX pp.

Feder, H. M., S. C. Jewett, and A. Blanchard. 2005. Southeastern Chukchi Sea (Alaska) epibenthos. Polar Biology 28: 402–421.

Feder H. M, S. C. Jewett, and A. L. Blanchard. 2007. Southeastern Chukchi Sea (Alaska) macrobenthos. Polar Biology 30: 261–275.

Feder, H. M., N. R. Foster, S. C. Jewett, T. J. Weingartner, and R. Baxter. 1994a. Mollusks of the northeastern Chukchi Sea. Arctic 47: 145–163.

Feder, H. M., A. S. Naidu, S. C. Jewett, J. M. Hameedi, W. R. Johnson, and T. E. Whitledge. 1994b. The northeastern Chukchi Sea: benthos–environmental interactions. Marine Ecology Progress Series 111: 171–190.

Grebmeier, J. M., L. W. Cooper, H. M. Feder, and B. I. Sirenko. 2006. Ecosystem dynamics of the Pacific-influenced northern Bering and Chukchi seas in the Amerasian Arctic. Progress in Oceanography 71: 331–361.

Grebmeier, J. M., C. P. McRoy, and H. M. Feder. 1988. Pelagic–benthic coupling on the shelf of the northern Bering and Chukchi seas. I: Food supply source and benthic biomass. Marine Ecology Progress Series 48: 57–67.

Highsmith, R. C., K. O. Coyle, B. A. Bluhm, and B. Konar. 2006. Gray whales in the Bering and Chukchi seas. In J. Estes, D. P. DeMaster, D. F. Doak, T. M. Williams, and R. L. Brownell (Eds.). Whales, whaling and ocean ecosystems. University of California Press. Pp. 303–313.

Hood, D. W., W. E. Shiels, and E. J. Kelley (Eds.). 1973. Environmental studies of Port Valdez. Institute of Marine Science, University of Alaska, Fairbanks, AK. 495 pp.

Hopcroft, R., B. Bluhm, R. Gradinger, T. Whitledge, T. Weingartner, B. Norcross, and A. Springer. 2006. Arctic Ocean synthesis: analysis of climate change impacts in the Chukchi and Beaufort seas with strategies for future research. Final Report to North Pacific Research Board. 152 pp.

Iken, K., B. Bluhm, and K. Dunton. In review. Benthic food web structure serves as indicator of water mass properties in the southern Chukchi Sea. Deep-Sea Research.

Jewett, S. C., T. A. Dean, R. O. Smith, and A. Blanchard. 1999. The Exxon Valdez oil spill: impacts and recovery in the soft-bottom benthic community in and adjacent to eelgrass beds. Marine Ecology Progress Series 185: 59–83.

Lovvorn, J. R., S. E. Richman, J. M. Grebmeier, and L. W. Cooper. 2003. Diet and body condition of Spectacled Eiders wintering in pack ice of the Bering Sea. Polar Biology 26: 259–267.

Moore, S. E., J. M. Grebmeier, and J. R. Davies. 2003. Gray whale distribution relative to forage habitat in the northern Bering Sea: current conditions and retrospective summary. Canadian Journal of Zoology 81: 734–742.

Naidu, A. S., A. Blanchard, J. J. Kelley, J. J. Goering, J. M. Hameedi, and M. Baskaran. 1997. Heavy metals in Chukchi Sea sediments as compared to selected circumpolar shelves. Marine Pollution Bulletin 35: 260–269.

Oliver, J. S., P. N. Slattery, E. F. O'Connor, and L. F. Lowry. 1983. Walrus, Odobenus rosmarus, feeding in the Bering Sea: a benthic perspective. Fisheries Bulletin 81: 501–512.

RWJ Consulting. 2001. DeLong Mountain terminal 2000 environmental studies. Final Report to Cominco Alaska, Inc., 108 pp. + appendices.

Shaw, D. G., and M. J. Hameedi (Eds.). 1988. Environmental studies in Port Valdez, Alaska: a basis for management. Springer-Verlag, New York, NY. 423 pp.

Stoker, S. W. 1978. Benthic invertebrate macrofauna of the eastern continental shelf of the Bering and Chukchi seas. Ph.D. dissertation, University of Alaska, Fairbanks, AK. XXX pp.

Weingartner, T. J., K. Aagaard, R. Woodgate, S. Danielson, Y. Sasaki, and D. Cavalieri. 2005. Circulation on the north-central Chukchi Sea shelf. Deep Sea Research (II) 52: 3150–3174.

SECTION IV
FISHERIES ECOLOGY

PRINCIPAL INVESTIGATOR
BRENDA NORCROSS/BRENDA HOLLADAY
UNIVERSITY OF ALASKA FAIRBANKS

1.0 INTRODUCTION

1.1 Brief History of Subject Research in Chukchi Sea

Areas within the northeast Chukchi Sea from Point Hope to Barrow were recently offered for leasing by the Minerals Management Service (MMS) for oil and gas exploration and development. In support of these activities, there is interest in gaining an understanding of the current biological communities occupying this area. Fishes are the least-studied biological group in the western Arctic, if one considers the number of gear deployments that have taken place. There have been far more observations of lower trophic levels such as zooplankton and benthos, and higher trophic levels such as seals and whales, than of fishes in Arctic regions. Most of what is known about the ecology and life history of Alaskan Arctic marine fishes comes from work associated with marine mammals (Frost and Lowry 1981, 1983, 1984) and oil and gas exploration (Craig and McCart 1976; Craig et al. 1982, 1984). The general consensus seems to be that little is known about the ecosystem in general and Arctic marine fishes in particular (e.g., Johnson 1997, Power 1997, Mecklenburg et al. 2002, MMS 2006). The paucity of information on fish distribution and ecology is a critical gap in the understanding of this changing ecosystem.

Very little is known about arctic fish species that have no commercial or cultural significance (Power 1997). It is important to note that no commercial fisheries target fishes in the offshore Chukchi Sea, and that fishes utilized by subsistence users are nearly all nearshore (defined as within 20 miles of shore). Existing information published on fish distribution in the northeastern Chukchi Sea, including online sources, peer-reviewed and gray literature, is based entirely on catches of demersal fish trawls and ichthyoplankton collected 1959 – 1992, and the 2004 –2008 research in which we participated (Figures IV-1 and Figure IV-2). In the early 1990s, 72 fish species were thought to occupy the Chukchi Sea, and more recently FishBase (Froese and Pauly 2006) lists 80 species of fishes inhabiting the Chukchi Sea. The majority of these species are demersal (living on or near the bottom), many are benthopelagic (living or feeding near the bottom as well as in mid-water or near the surface), and far fewer are pelagic (at surface or mid-depths), bathydemersal (living below 200 m), or reef-associated. The dominant Arctic fish families are cods, eelpouts, snailfishes, sculpins, and salmonids. Arctic cod was the dominant species captured in all earlier surveys (Alverson and Wilimovsky 1966; Frost and Lowry 1983; Fechhelm et al. 1985; Barber et al. 1997). As it has the highest commercial importance, Arctic cod is also the best studied species (Hop et al. 1997). Recent distributional, biological, and ecological knowledge about fishes in the northern Chukchi Sea comes from cruises in 1990 – 91 (Barber et al. 1997), 1991 – 92 (Hokkaido University 1992, 1993), the RUSALCA 2004 expedition (Mecklenburg and Sheiko 2006; Mecklenburg et al. 2007; Norcross et al. submitted) and our unpublished collections from three cruises in the northeastern Chukchi Sea in July-September 2007 and 2008. The 15,061 fishes caught by bottom trawl during those three recent cruises were predominantly (>80% by number) sculpins,

pricklebacks, cods, and flatfishes. Other fishes such as eelpouts, ronquils, snailfishes, and poachers also were captured.

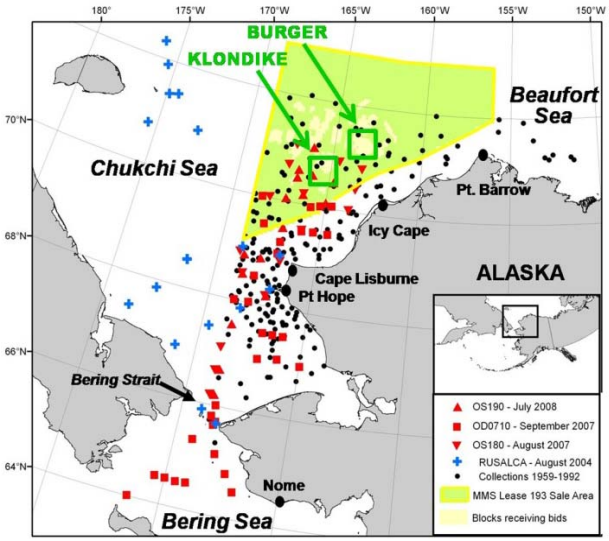

Figure IV-1. Demersal trawl sites from scientific cruises that entered the Chukchi Lease 193 area, historical through present day. Our 2004–2008 sites are shown in red and blue, and the proposed CPIA cruise areas are outlined in green.

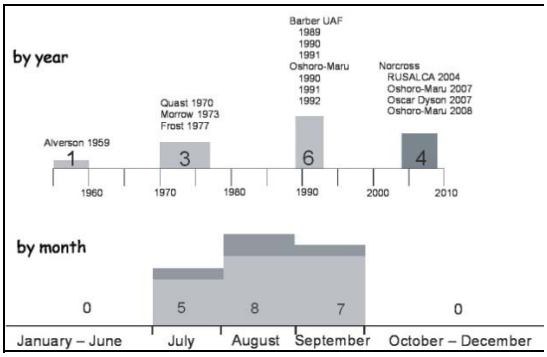

Figure IV-2. Number of cruises in the northeast Chukchi Sea (offshore) 1959 – 2008 by year and by month. Some cruises overlapped months and thus the true total number of cruises (14) appears inflated in the season.

Under separate funding from the Minerals Management Service through UAF's Coastal Marine Institute, Norcross and Holladay are currently establishing an electronic database of all scientific demersal trawl catches from cruises from inside and outside the Lease Sale 193 area. The database details demersal fishes caught during the 10 cruises that have sampled inside or near the lease area 1959 – 1992, and the four cruises in which we participated 2004 – 2008 (Figure IV-2). Temporal sampling of fish in the Chukchi Sea is limited to a few summer cruises with gaps of about 15 years. The paucity of fish collections within the lease area, especially near the Klondike and Burger prospects, is very clear (Figure IV-1).

From the early 1990s until recently, the Chukchi Sea has received very little attention, and the serious limitation of recent baseline data for fish species in the Chukchi Sea could be compounded by climate change. It will not be possible to detect changes or distinguish between anthropogenic and natural effects on fish composition, habitat use, or trophic ecology without additional documentation of the fish now existing in the Klondike and Burger areas and the remainder of the Lease Sale 193 area. Thus it is important to assess the distribution and abundance of fishes in the Chukchi Sea prior to oil exploration. Current and historic distribution and ecology of small demersal fishes in the Chukchi Sea is being examined by the senior scientists under separate funding (Norcross and Holladay, in prep.). Our collections in August and September 2007 and July 2008 added to the Russian-American Long-term Census of the Arctic (RUSALCA) that collected fishes further north, south, and west into Russian waters in 2004 (Figure

IV-1), and is planned to be repeated during September 2009. However, sampling of fishes in Lease Sale 193 area, and especially in the vicinity of the Burger and Klondike areas is lacking. There remains a paucity of data for demersal fishes in the lease area and published information for pelagic fishes is lacking entirely.

The Chukchi Sea has an extremely high biomass of benthic organisms for an Arctic area (Grebmeier and Dunton 2000). Until recently, the northern Bering Sea has been a benthic-dominated ecosystem, i.e., very similar to that of the Chukchi Sea. With Arctic warming (ACIA 2004, www.amap.no/acia), the composition of marine fish and benthic communities is expected to change. The northern Bering Sea is now shifting from a shallow, ice-dominated system in which bottom-dwelling fishes prevail to one more dominated by pelagic fishes (Grebmeier et al. 2006). It is possible that the Chukchi Sea may experience similar changes, but those changes cannot be detected without a baseline of the current state of ecosystem. Scientific collections in 2004 documented some species of demersal fishes in the Chukchi Sea north of where they had been observed in earlier years (Mecklenburg et al. 2007). This could be because of northward expansion of fishes or merely due to an increased northward effort of scientific sampling in the Chukchi Sea. Observed changes in distribution and abundance of walleye pollock (Theragra chalcogramma) and Arctic cod (Boreogadus saida), in response to changes in sea ice cover and subsurface temperatures, provide insight as to how Arctic climate change affects marine ecosystems (Wyllie-Echeverria and Wooster 1998). With the limited availability of information in the Chukchi Sea, we can only speculate what may be occurring in benthic and pelagic biological communities, and the proposed research will yield much needed baseline data necessary to describe and quantify potential changes in these communities.

Significant and interrelated changes have affected the atmosphere and the oceans of the Arctic, including reduced or absent sea ice cover (ACIA 2004) as seen in summers 2007 and 2008. Changes in global climate are most noticeable in high latitudes (Manabe and Stouffer 1994), but the changes cannot be recorded and quantified without a plan for scientific observations. Currently insufficient information is available to predict what ecosystem changes naturally may occur in the Chukchi Sea. Quantifying climate-related changes in the Arctic without baseline data will be complicated because: (1) there is not one clear cause of ecosystem change, (2) the effects will not be as abrupt, and (3) the area over which change occurs is massive. However, baseline data collected now will provide potential to separate impending changes into the relative effects of climate vs. anthropogenic sources. Therefore documenting the present distribution and abundance of fishes and trophically relating those fishes throughout the Chukchi Sea ecosystem is essential to document good stewardship by the oil and gas industry.

Understanding potential effects of climate change or oil and gas exploration in Klondike and Burger prospects will require collecting, identifying and quantifying fishes encompassing a range of species and life stages, as well as associating them with the biological and physical oceanographic conditions. Low diversity ecosystems, such as found in high latitudes, may be vulnerable to changes. While the Arctic may have a lower diversity of fishes than in lower latitudes, it includes fishes with a wide variety of life history mechanisms. Many Arctic fishes have pelagic eggs, e.g., Arctic cod, and could be affected by changes in water circulation or pollutants dispersed in the water column. Other species from within families that are abundant in the northeastern Chukchi Sea (e.g., sculpins, poachers, and pricklebacks) have demersal eggs, which could be affected by settled pollutants. However at this time no demersal fish eggs have been documented in the northeastern Chukchi Sea; as additional research is done in the area

and if more southern species move north, there is potential that demersal fish eggs may come into the picture. The larvae of Pacific herring (Clupea pallasii), a species with demersal eggs, experience morphometric deformities, genetic defects and low survival when exposed to oil inadvertently spilled in spawning season (Norcross et al. 1996). One of the most abundant fishes in the Chukchi Sea is the flatfish, Bering flounder (Hippoglossoides robustus). Flatfishes prefer specific sediment types (Moles and Norcross 1995) and do not relocate even when subjected to hydrocarbons, resulting in negative impacts on condition and survival (Moles et al. 1994). Demersal fishes would be affected by settling of pollutants, by direct disturbance of bottom substrates, or through food web transfer.

1.2 Purpose of Study and Rationale

As one component of the larger ConocoPhillips Chukchi Science Program for 2009, this proposal seeks funding for the first two years of fieldwork and additional laboratory analyses within a multi-year project to collect demersal fishes, epibenthic macroinvertebrates, and pelagic forage fishes within ConocoPhillips Burger and Klondike areas, from which community structure will be determined. The proposed work in these areas will provide baseline data of the abundance and distribution of fishes and background information for NEPA documents and future monitoring program design. Although the field collections of epibenthic macroinvertebrates are included in this project, the specimens and analysis of those animals will be examined within the scope of Dr. Arny Blanchard's assessment of benthic community structure. Results of the first year of this study will be used to adjust future sampling of fishes and epibenthos and epibenthos, to design a long-term monitoring program, and to provide data for NEPA documentation required for receipt of permits to drill an exploratory well (s).

The Fisheries Ecology project will assess seasonal and interannual fisheries ecology in the Klondike and Burger areas within the northeastern Chukchi Sea, thereby providing a high resolution assessment of fishes that will be enhanced by our 2004 – 2009 low resolution but broad spatial assessment of demersal fish distribution and abundance in the Chukchi Sea. Much of the data we will gather on Fisheries Ecology will provide a baseline for fish and epibenthic distributions that have not yet been documented. To date, there are insufficient collections to know which fishes inhabit the vicinity of the Klondike and Burger areas, or indeed the entire northern half of the Lease Sale 193 area (Figure IV-1). Information on biological aspects, i.e., maximum age of fishes, size at age, prey taxa composing the diet, the trophic level of those prey, and the trophic level of the fishes, that are known to differ seasonally and spatially for fishes in other areas are not or poorly known for fish species in these waters.

Despite limitation in spatial and temporal extent of studies, diets of the most abundant species of fish marine fishes in the Arctic waters of Alaska reveal fish feeding benthically and pelagically at all trophic levels. Arctic cod diet was examined from 1977 collections in the eastern Chukchi and western Beaufort Seas, where its predominant food was pelagic calanoid copepods, and (Lowry and Frost 1981.) In 1990 –1991 collections in the northeastern Chukchi Sea, Arctic cod consumed pelagic and epibenthic prey, saffron cod ate epibenthic and benthic prey, Arctic staghorn sculpin ate benthic polychaetes and mollusks, and Bering flounder ate fishes and epibenthic crustaceans (Coyle et al. 1997). In the Beaufort Sea in 1963 – 72 there seemed to be a division of prey resources and low interspecific competition (Atkinson and Percy 1992). Arctic alligatorfish, Arctic staghorn sculpin, and slender eelblenny consumed benthic and epibenthic animals, while the ribbed sculpin fed almost exclusively on zooplankton. Diet analysis for some

species of fishes collected in 2007 and 2008 south and west of Klondike and Burger prospects (Figure IV-1) may be conducted in a time frame to overlap the CPAI Chukchi Sea study. If that project is funded by MMS it will broaden the scope of the proposed study through examination of stomach contents and trophic analysis (stable isotopes) in locations upstream and adjacent to the Klondike and Burger prospects.

Earlier research has suggested that the spatial differences in diets of fishes in the northeastern Chukchi Sea may be related to origins and distributions of water masses in which they are feeding (Coyle et al. 1997). Because water mass distribution in the northeastern Chukchi Sea is likely linked to diets of both pelagic and demersal fishes, we hypothesize that these dietary differences may propagate into higher trophic levels. We intend to use stable isotopes as a tool to test this hypothesis.

Food webs are multi-species connections that describe trophic associations in ecosystems as well as reflect biodiversity, species interactions and ecosystem structure (Dunne et al. 2002). Stable nitrogen (□15N) and carbon isotope (□13C) analyses are established techniques to assess the structure of food webs, determine the food sources, and illustrate habitat usage when distinct changes in habitat occur during predator movements or migrations (Bentzen et al. 2008, Greenberg et al. 2007, Hobson and Welch 1992, Hobson et al. 1993, Hobson et al. 1996, Knoche et al. 2007). Stable nitrogen isotopes are integrated into consumer tissues with enrichment (higher level of □15N) occurring at each trophic step due to the preferential incorporation of the heavier isotope (15N) into tissues (Kelly 2000) .Food web length can be determined using nitrogen stable isotopes as a continuous integrative measure of trophic position or trophic level of species (Cabana and Rasmussen 1996). Most aquatic food webs are predicted to consist of no more than four trophic levels (Sterner et al. 1997, Pauly et al. 1998). Without prior knowledge of typical prey species consumed and their respective isotope ratios, only general statements can be made, e.g., if the diet is likely to be pelagic or benthic, and additional clarification on which taxonomic groups of prey are eaten (e.g., copepods, euphausiids, bivalves) is needed in order to understand how the fish species fits into the food web and make inferences about what impacts on the fish could come about as a result of changing pelagic and benthic communities. Isotopic mixing models have become powerful tools to evaluate proportional importance of prey with different isotopic signatures (Phillips and Koch 2002, Phillips and Gregg 2003, Phillips et al. 2005) and have been used successfully in the Arctic to describe polar bear diets (Bentzen et al. 2007).

Prey resource information is essentially lacking for the Chukchi Sea. Furthermore, because of impending climate change and offshore drilling, it is critical to establish pre-development conditions of forage fish resources. Knowledge of available prey resources is necessary to determine potential natural or anthropogenic effects that could ripple upward, affecting multiple trophic levels. A changing climate could have notable impacts on fish distribution, habitat, diet, the location and timing of spawning, and considerably more data are needed to establish a baseline to substantiate anticipated changes and to differentiate them from anthropogenic-induced changes.

Benthic sampling in the Klondike and Burger areas by Dr. Arny Blanchard during 2008 demonstrated a very abundant epibenthic community. Brittle stars, sea cucumbers, and crabs were abundant in clam dredge samples collected during the 2008 cruise (personal observations, H. Nichols and J. Hardin). The bottom trawl collections we propose would assess epibenthic macrofauna over a much larger sampling area than the point samples collected by dredge.

Long-term studies provide the means to compare temporal variation in biological communities to environmental change and assess community readjustment. Similarly, long-term monitoring in the Chukchi Sea is a necessary step in understanding and monitoring anthropogenic changes to the ecosystem. The proposed 2009 and 2010 ConocoPhillips cruises in the northeast Chukchi Sea will allow us to assess demersal and forage fish distributions and compare them with diet composition and benthic biota. Thus we will provide ConocoPhillips with an initial estimate of the distribution and importance of fisheries ecology prior to oil and gas development, as well as provide a basis for documenting changes caused by natural conditions such as climate change.

1.3 Objectives

This addresses the Fisheries Ecology component of the 2009 – 2010 environmental studies program in the Chukchi Sea for ConocoPhillips, Alaska Inc. (CPAI). The objective of this study is to better understand the ecology of fishes in the Klondike and Burger areas, thus collections will be in both locations and both years. Specific objectives of the proposed work are to assess:

Task 1: Fish ecology

- •Sample demersal and midwater fishes within the Chukchi Sea and document distribution, abundance and community structure in two locations for two seasons over two years

Task 2: Fish ages

- Use otoliths to age demersal and pelagic fishes to document maximum age of fishes, size at age, and age-related changes in diet

Task 3: Fish feeding ecology

- Examine stomach contents to assess the relative importance of prey taxa in demersal and pelagic fish diets
- Document the seasonal and interannual trophic level of demersal and pelagic fishes
- Assess the trophic level of demersal and pelagic fish prey

Task 4: Synthesize results

- Relate physical characteristics within the Chukchi Sea to distribution and community structure of demersal and pelagic fishes
- Assess linkages between demersal and pelagic fish communities
- Relate age and size of fishes to feeding ecology
- Associate the overall fish ecology and feeding ecology of fishes in the Klondike and Burger prospects to that of the broader Chukchi Sea area.

Task 1 is the sampling that will be conducted in 2009 and 2010. Tasks 2 and 3 will include fishes from both years of sampling, though processing the samples and analyzing the data will not be completed until the year following the collection. Task 4 will be included in the final report of 2012.

2.0 STUDY AREA

2.1 Location

The study area is located in the northeastern Chukchi Sea, in the vicinity of the CPAI Klondike and Shell Burger prospects. Specific sites are those that will be examined for benthic community structure by Blanchard.

2.2 Period of Study

Research will take place April 2009 through June 2012. We will participate in cruises 1 and 3 of the 2009 and 2010 ConocoPhillips cruises, thereby gathering both seasonal and interannual baseline data on fisheries ecology.

3.0 METHODS AND PROCEDURES

3.1 Sampling or Survey Design and Technical Rationale

The Fisheries Ecology project will collect fishes and epibenthos during cruises 1 and 3 of the 2009 and 2010 ConocoPhillips research. We will use a bottom trawl to collect demersal fishes and epibenthos, and a small midwater trawl to collect pelagic forage fishes and jellyfishes at 13 "fixed sites" in each prospect (26 sites per cruise; Figure IV-3). The 26 fishing sites also will be sampled for benthic infauna by Dr. Blanchard with a Van Veen grab during cruise 2 each year, and by Dr. Hopcroft with zooplankton nets during cruises 1, 2, and 3 each year. Coordinating with Blanchard's benthic community site design will maximize the amount of environmental and ecological data available for interpreting the fish, epibenthic, and infaunal communities.

We may elect to collect samples at additional fishing sites or redeploy nets at an already examined site if time is available and insufficient specimens have been captured for laboratory analyses. For example, if a particular species of sculpin was caught in low numbers, we may request to redeploy nets at the catch site or in similar habitat in order to supplement specimen quantities and allow for more complete laboratory analyses.

The 2009 sampling will further guide the 2010 fishing activities. Data gaps or areas of interest determined from 2009 may be targeted in 2010, changes in gear requirements may be addressed, or the sampling plan may be altered to address questions of interest. Thus the sampling plan for 2009-2010 is adaptive with a phased approach where each component of the benthic community is sampled over time.

3.2 Field Team Size and Composition

The Fisheries Ecology field team will consist of 3 personnel for sampling fish and epibenthic invertebrates via bottom and midwater trawling. Ms. Brenda Holladay, co-PI, is a research scientist with many years of expertise in diet of marine fishes and of fisheries and epibenthic sampling in the Chukchi Sea. Holladay will be aboard the first ConocoPhillips 2009 cruise and other cruises as her schedule permits. Ms. Christine Frazier is a graduate student studying fisheries oceanography, and she is expected to participate in each of the four proposed cruises. The third person will be a technician with epibenthic invertebrate identification expertise. We will coordinate with Dr. Blanchard to utilize his trained personnel in the field where possible, because the labor-intensive effort to sort demersal trawls is in separating and identifying the epibenthic invertebrate species, a task at which his team of invertebrate taxonomists is

experienced. Olgoonik/Fairweather and ConocoPhillips will provide additional persons to help process bottom trawl catches.

3.3 Data Collection Procedures

3.3.1 Fieldwork

At each Fisheries Ecology site (Figure IV-3), and at additional sites of opportunity, we will sample demersal taxa with a beam trawl and small pelagic taxa with an Isaacs-Kidd midwater trawl (IKMT). We estimate that our 3-person fishing crew, together with the additional persons provided by Olgoonik/Fairweather and ConocoPhillips (on first cruise) for bottom trawl processing, can complete 2 sites per night. Each of the two nets will be towed once per site, for a total of about 90 minutes of wire time and 2 – 4 hours of sample processing at each site (1 hr IKMT, 1 – 3 hr beam trawl). Catches can be processed while in transit. If the first deployment of a beam trawl is ineffective, i.e., the gear is damaged, twisted, "flying" above the seafloor, or full beyond the codend, we will know immediately before the ship has left the area and can quickly redeploy the net. To save time, we suggest deploying one of the nets while approaching a site, sorting its catch while the CTD and zooplankton net are deployed, and deploying the other net as the vessel begins to move toward the next site.

Both trawl nets are fished from a single towing cable and can be deployed using a vessel A-Frame. These features make the trawls, which are effective at targeting small demersal and midwater fishes, practical to deploy from vessels that are not traditional fishing trawler boats, an important consideration that reduces the logistical challenges of conducting long-term monitoring surveys in the Chukchi Sea. The weight of the IKMT plus catch is less than 200 pounds, and the maximum weight of the beam trawl gear plus a full codend is less than 700 pounds. A typical beam trawl catch contains less than 100 pounds in the codend. When the beam trawl is lifted to the surface by vessel equipment, the codend usually can be dragged aboard by 3 people without further mechanical assistance.

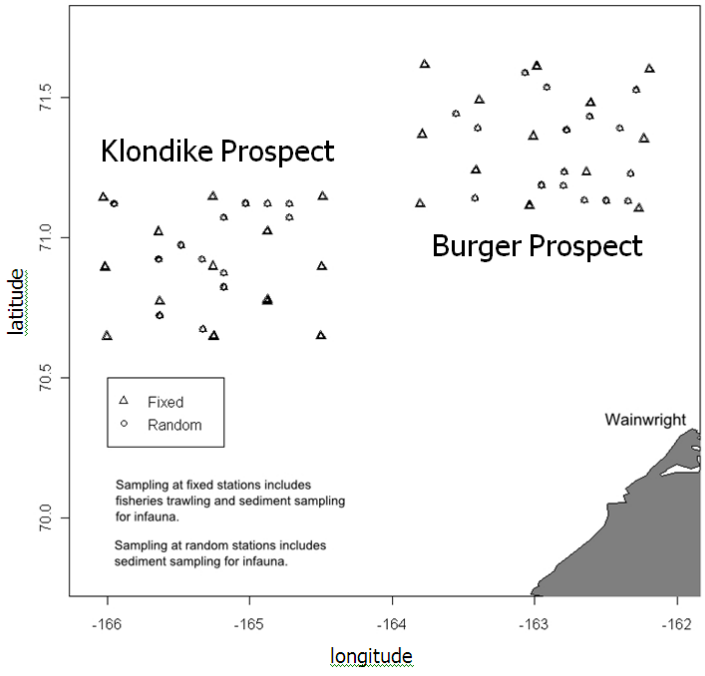

Figure VI-3. Trawl sites (n=13 fixed sites) in each of the Klondike and Burger prospects, northeastern Chukchi Sea.

3.3.1.1 Demersal collections

Demersal fishes for the Fisheries Ecology research and epibenthic invertebrates for Blanchard's research will be collected using a 3 m plumb-staff beam trawl with 7 mm mesh and 4 mm codend liner. This trawl is towed for 5 minutes on the sea floor while the vessel is moving at 1 – 1.5 kt; a typical tow is 300 – 500 m in distance, requiring approximately 60 minutes of wire time. A rigid 3 m pipe forward of the net holds the mouth open for an effective swath of 2.26 m, allowing for accurate quantifications of trawl effort by area swept or by time on bottom. The vertical opening of the net is approximately 1.2 m. We have used this net design successfully during several research cruises in the Chukchi Sea, Bering Sea and the Gulf of Alaska, and have found it to be particularly effective at capturing epibenthic invertebrates, juvenile and small adult demersal fishes in contact with and immediately above the sea floor.

The beam trawl is typically deployed off the stern, however due to the configuration of the Westward Wind vessel proposed for the 2009 program, the trawl will be deployed off the starboard???(plse fill in new methods). The beam will be raised several feet above the deck using the A-frame, and then pay the net out below the beam, codend first. The trawl is towed on the surface for a short distance to ensure proper tow configuration, and then the trawl warp is deployed at 30 m/min with a ratio of 3 – 5 m towing cable to 1 m water depth. The tow begins when the trawl warp is paid out and the vibration of the towing cable indicates the net is dragging on the seafloor. The vessel heading is maintained in a straight line during the five minute tow and the trawl warp is retrieved. The net is brought to the surface, and generally 2 – 3 people can drag the codend aboard without further mechanical assistance. Deploying the beam trawl net will require an indicator of amount of towing cable deployed, such as a meter wheel or the towing cable marked at 10-m intervals; additionally an approximately 4 oz temperature depth recorder (TDR) attached to the headrope provides post-tow verification that the net was fishing on the bottom. The recorded TDR data are examined after each tow. Because the net is relatively small and lightweight and a real-time depth sounder is sufficiently heavy and bulky that it would change the fishing effectiveness, the small TDR must be used. Time, depth, latitude, longitude, speed over ground, and course over ground will be recorded by bridge personnel at four points during trawling, when the mouth of the net is at the surface (in), trawl warp is paid out (at depth), trawl warp begins to be pulled back (haul back), and the mouth of the net is hauled above the surface (out).

The beam trawl will be brought aboard, the entire catch photographed, and fishes and epibenthos will be processed. Animals will be sorted on deck into taxonomic groups, counted and a weight recorded for each taxon. Fishes will be identified to species, measured to the nearest mm of total length and frozen for all subsequent laboratory examination; up to 100 fish of each species per site will be retained. Voucher samples of species having delicate tissues, e.g., snailfishes, will be retained in 10% buffered formalin. The precision of field identification of epibenthic invertebrates will depend on the expertise and available time of field staff; at minimum within general taxonomic groups such as bivalves, gastropods, crabs, and shrimps, we will count individuals, record a weight for the taxonomic group, and retain a few individuals for isotope sampling, stomach analysis where appropriate, and for archiving, and the rest of the invertebrates discarded. Invertebrate stomachs and samples to be archived will be preserved in 10% buffered formalin. Organisms or tissues from invertebrates kept for

isotope sampling will be frozen in pre-cleaned vials. When time permits, photographs will be taken of fresh fish and invertebrate specimens.

Additional fishes will be collected and shipped to the North Slope Borough's department of Wildlife Management for analysis of fatty acids. These data will be entered into a central database maintained by the Wildlife Department to catalogue potential prey sources for beluga whales.

3.3.1.2 Pelagic collections

Pelagic forage fishes will be targeted with an Isaac-Kidd midwater trawl (IKMT), which will also provide jellyfishes for Dr. Russ Hopcroft's study to evaluate biomass of the larger gelatinous zooplankton not collected by the smaller zooplankton nets his project will deploy. The IKMT mouth is approximately 1.5 m wide by 1.8 m high; a rigid diving vane keeps the mouth of the net open during towing and exerts a depressing force to vertically stabilize the net. A real-time depth sensor will be attached to the IKMT to continually monitor fishing depth. A sensor unit deployed over the stern of the boat will be read on the bridge so that depth of net can be adjusted. We will fish the IKMT with 3 mm codend mesh, at a speed of 4 kt, for double oblique tows examining the water column from the surface to 10 m above the seafloor. Fishing this net will require about 30 min/tow. The IKMT's large mouth and capacity for fast towing speeds enables it to capture a wider range of relatively large and more active organisms than smaller plankton nets. We anticipate catching fishes smaller than 7 cm with the IKMT. Pelagic fishes will be processed using the same method as demersal fishes, a sample of euphausiids will be kept for trophic analysis, jellyfishes will be pulled from the catch for examination by Hopcroft's personnel, and the remaining catch will be discarded.

Additional fishes will be collected and shipped to the North Slope Borough's department of Wildlife Management for analysis of fatty acids. These data will be entered into a central database maintained by the Wildlife Department to catalogue potential prey sources for beluga whales.

3.3.1.3 Collection Permits

UAF's Animal Care and Use Committee has approved our sampling protocol under permit IACUC -7-047; this protocol requires completion of an online training course by all persons who will handle live fishes. The National Marine Fisheries Service has provided a Letter of Acknowledgement for our scientific research plan (LOA 2009-05), and has forwarded that letter to the US Coast Guard.

3.3.2 Laboratory and statistical analyses

In the Fisheries Oceanography lab at UAF in Fairbanks, the age structure of fishes will be assessed using fish ear bones (otoliths). Annually, alternating opaque (summer) and translucent (winter) rings are deposited on the otolith, and these alternating rings can be counted to determine fish age. We will follow the break and burn method of aging otoliths that is typically used by the Alaska Fisheries Science Center (AFSC 2008), where the otolith is cut in half and then held over a flame until the protein contained in the otolith reacts with the heat by changing color, emphasizing the annuli that can then be examined under a dissecting microscope. Length frequency will be analyzed of each species based on field data collections, and within each apparent size class of a species, 60 otoliths will be aged. If size classes are not evident, then we will examine up to 20 individuals within each 10 mm increment of fish length. Prior to the 2010 cruise, we

will complete otolith aging of the most abundant fishes caught in 2009, thereby forming a baseline to assist the allocation of the aging effort on 2010 collections toward species and length ranges needing additional clarification. Over the course of the project, all fish species will be aged.

Analysis abundance, distribution and community composition of demersal and pelagic fishes is analogous to that planned for benthic communities; therefore statistical methods will generally follow those designed for benthic community analysis by Dr. Arny Blanchard. Statistical methods used may include regression, analysis of variance, correlation testing, geostatistical analyses, and multivariate methods such as cluster analysis, nonmetric multidimensional scaling and principal components analysis. The methods applied will be determined by the data quality but an emphasis will be placed on linear models (regression and ANOVA) wherever possible. Descriptive measures, average abundance (fish 1000 m-2), biomass (g wet weight 1000 m-2), and number of taxa, and diversity measures are useful for summarizing fish abundance and distribution. Transformations of data are often required to meet assumptions of normality when using parametric statistical methods and will be considered. Expected transformations include the ln(x+1) transformation for abundance data and the ln(x) transform for biomass data. Geostatistical methods may also apply. The emphasis in these analyses will be to document community composition of fishes and to determine their spatial and temporal variability. Depending on availability of results from the other components of the CPAI Chukchi science team, such as contaminant concentrations, physical oceanography and zooplankton ecology, other methods including principal component analysis, may be performed to assess baseline associations between fish communities and environmental factors, i.e., depth, temperature, salinity, sediment grain size.

The feeding ecology analysis will consist of a two-step approach, i.e., examination of stomach contents (diet) to assess the importance of prey taxa in fish diet, and documentation of the trophic level of prey taxa and predator fish. As our goal is to gain baseline understanding of the seasonal, interannual, and habitat-associated differences in feeding ecology, we have structured the laboratory sampling to examine a large number of fishes. Based on our 2004 – 2008 fish collections in the northeastern Chukchi Sea, we estimate collecting sufficient quantities of fishes to assess the diet and trophic level of 20 species of demersal fishes and 5 species of pelagic forage fishes (for a total of 25 species of fish for which we will examine stomach contents). Spatial and seasonal diet analysis will involve 10 individuals at 3 sites during 2 seasons in 2009 (25 x 10 x 3 x 2 = 1,500 individuals. We anticipate assessing interannual diet differences only for the most abundant species of fishes, i.e., approximately 10 species that should make up at least 80% of the fishes caught, 10 individuals at 3 sites during 2010 (10 species x 10 x 3 = 600 individuals). As with the aging analysis, development of the diet baseline from 2009 collections will guide the intensity and allocation of effort from 2010 collections, e.g., if ontogenetic prey switching is indicated or if it is unclear whether habitat or season is the driving factor for diets, we will stratify diet studies to include specimens throughout the fish size range and in appropriate habitats to assist in resolving these issues.

Diet analyses will assess the relative importance of prey taxa in the diet of each fish species. In the laboratory, a fish is thawed and then length, weight and proportional fullness of the stomach are recorded. The unpreserved prey are covered with water and separated into general groups, usually at the family level of taxonomic precision, which are assumed to be from the same life style, i.e., benthic infauna, epifauna, pelagic. A high-resolution dissecting microscope with a digital camera will be used for prey identification and documentation. Within the prey groups, animals with a large range of

sizes will be separated into categories of small and large individuals, e.g., small and large copepods, small and large euphausiids. The number of individuals within each category will be counted, and each category will be weighed. The most prevalent taxa of prey will be identified to the most specific level that is reasonable, usually the genus or species; taxa will not be counted or weighed at this specific level, but vouchers of each prey taxon will be photographed, preserved and stored in 50% isopropyl alcohol at the Fisheries Oceanography in Fairbanks.

Diet, i.e., stomach contents, will be described using established methodology that assigns an index of relative importance (IRI) provided by each prey taxon (e.g., Holladay and Norcross 1995, Pinkas et al. 1971). The IRI considers weight of prey, count of prey, and the proportion of predators that consumed the prey. We will group prey for the IRI at the general taxonomic level described above, e.g., usually to family level of precision. Diet of each fish species will be analyzed to detect differences among and between species, seasons, years, habitats, and fish sizes by pooling standardizing square-root transformed IRI values within each of the five variables. Differences within and between the pooled values will be analyzed by Principal Components Analysis, followed by cluster analysis (e.g., Ward 1963). Differences in diet diversity (i.e., Shannon˜Weiner diversity index, Smith 1986) and proportional gut fullness will be tested separately by one way analysis of variance (ANOVA) followed by Tukey Honest Significant Difference (Tukey HSD) if warranted. For each fish species, effects on diet diversity and proportional stomach fullness of the interaction between season, year, habitat, and fish size will be tested using a two-way ANOVA.

Stable isotope analysis will be performed to assess the seasonal and interannual trophic level of the demersal and pelagic fishes (predators) caught in the Klondike and Burger prospects, and to assess trophic level of their prey. When possible the stable isotope analysis will be conducted on same specimens of fish whose stomach contents were processed. To control for differences in isotopic compositions across the spatial extent of collections, we will process euphausiids as a measure of underlying baseline composition. We estimate assessing stable isotope from 520 individuals of fish and euphausiids over the two years of collections (25 species of fish + 1 euphausiid x 5 replicates (individuals) x 2 prospects x 2 seasons = 520). We expect to examine 520 samples of benthic and of pelagic prey, i.e., 40 taxa x 5 replicates x collected during cruise 1 in each of 2 years = 400; seasonal analysis of prey trophic level will be limited to pelagic taxa, because the animals and size of animals anticipated to be available in the water column is more likely to change than the benthic prey availability, i.e., 12 taxa per year x 5 replicates x 2 years = 120.

For stable isotope analysis replicate individuals of fishes and prey will be subsampled for muscle tissue, or pieces of body wall where muscle tissue cannot be distinguished. Prey will be examined at the taxonomic level used for the IRI. Whole prey organisms will be used if tissue subsampling does not yield sufficient mass, and several individuals will be pooled if individual organisms are too small to constitute a sample. Samples will be frozen, and subsequently freeze dried for a minimum of 24 hours. Tissues will be analyzed for $\delta^{15}N$ and $\delta^{13}C$ by the Alaska Stable Isotope Facility at UAF following the procedure described by Dehn et al. (2005).

3.4 Data Storage Procedures

Data will be entered, proofed, and stored within a MS Access database at the Fisheries Oceanography Laboratory at IMS. Handwritten data sheets will be kept at IMS for 5 years, and electronic data will be archived at CPAI as one of the project deliverables.

Ultimately, fish distribution data will be archived with the Arctic Ocean Diversity Census of Marine Life (ArcOD) and the Ocean Biogeographic Information System (OBIS) data portal. Voucher collections of fish and prey taxa will be archived in museums and other collections as detailed below (section 3.6).

3.5 Quality Control Procedures

The following quality control procedures will be followed during sample processing. Each taxon will be verified by expert taxonomists or by comparison with voucher specimens in museums or the collection held at the Fisheries Oceanography Laboratory at IMS. Specimens of each fish species will be verified by Catherine Mecklenburg, a taxonomist with considerable expertise with Arctic fishes, and author of "Fishes of Alaska," the most complete and current key for Alaskan fishes. Voucher specimens of each fish species caught will be archived in the University of Alaska Museum of the North (UAMN) and the Fisheries Oceanography Laboratory at IMS (FOL/IMS); specimens also will be made available for the growing collection of Arctic fishes held at the California Academy of Sciences. Muscle tissue from each fish species will be available for genetic examination by the Fish Barcode of Life Initiative, a global effort to develop a standardized reference sequence library including all fish species, thereby further substantiating the species identification. Voucher specimens of each prey species will be held at the Fisheries Oceanography Laboratory, IMS. Samples processed for stable isotopes will be subject to standard QA/QC measures of the Alaska Stable Isotope Facility at UAF. Otolith aging will be subject to the QA/QC measures of the AFSC (AFSC 2006), where a random subsample of 20% of otoliths will be aged by a second reader; the ages assigned by the two readers are compared and differences between reader findings are resolved between the readers. Identification of prey will be supervised by a senior taxonomist, and 5% of specimens will be verified to ensure that counts are accurate and organisms are correctly identified.

4.0 COORDINATION

4.1 CPAI

Logistical support will be provided directly by Fairweather Leasing. This includes purchase, transport, and loading of sampling gear on the vessel, providing travel arrangements and associated travel costs to PI meetings and for field crews to Wainwright. All travel will originate from Fairbanks, with the exception that Christine Frazier's travel to the Seattle safety meeting in July-09 will originate elsewhere. The senior staff (Norcross and Holladay) will attend meetings and interact as needed with CPAI and Fairweather Leasing.

Safety training for the field crew will be provided by CPAI and/or Fairweather Leasing. Specific training on the safe use of fish trawling equipment and catch processing will be provided by Brenda Holladay. An opportunity to tour the contracted vessel, discuss sampling procedures, and test the depth sounder for use with the IKMT in advance of the cruise is requested.

4.2 Other Studies in the Chukchi Sea Program

The proposed research is strongly relevant to the other research aboard the CPAI Chukchi Sea cruises. This multidisciplinary CPIA effort provides a rare opportunity to obtain sufficient concurrent fisheries, benthic, zooplankton and oceanographic information to examine fisheries ecology in the Chukchi Sea. We will work closely with

Weingartner (physical), Hopcroft (zooplankton and stable isotopes), Blanchard (benthic infauna and epifauna and stable isotopes), Day (birds) and Brown (contaminants) to produce an integrated collection of studies.

Our sample collection is equally integrated. We provide midwater jellyfish samples from the IKMT to Hopcroft (zooplankton). We will provide epibenthic samples from the bottom trawls to Blanchard (epibenthos). The epibenthos samples gathered by the Fisheries Ecology project are an integral part of Blanchard's assessment of benthic community structure, and funds are requested within the Fisheries Ecology budget for field personnel to provide epibenthic data and specimens for Blanchard's project. Likewise, Blanchard's research will provide details of the benthic community that will help us to interpret diet selectivity. If required, we will collect fishes and provide them for contaminant assessment.

Coordination and collaboration with scientists who are working on CPAI projects in the Chukchi Sea is expected through the coordination meetings and report preparation. It is anticipated that results from the other CPAI Chukchi Sea projects will be available for determining fish community structure. We request that a vertical record of temperature, salinity, and depth (CTD cast) be taken at each of our fishing sites. It is also anticipated that Fisheries Ecology results will be available to our CPAI colleagues, including fish identification, distribution and abundance data.

5.0 DELIVERABLES

5.1 Field Data

A description of the fishing activities, including location, date, time, depth, and comments about each tow will be provided 30 days after the final cruise each year together with a preliminary list of fishes present during the cruise. The list of fishes cannot be considered final until the draft report, because further examination of fishes by taxonomic (this project) or genetics (separate project) analysis may lead to changed identifications.

5.2 Draft Report

The Draft Report will be submitted to CPAI in electronic format (MS Word text; PDF figures and tables). It will summarize field collections from 2009 and 2010 and laboratory analyses of specimens. It will also describe background information on fishes in the northeastern Chukchi Sea, and our methods of collection and analysis. Results will include the topics of fish ecology, fish ages, and fish feeding ecology. Discussion will synthesize those results.

5.3 Final Report

The Final Report for the Fisheries Ecology project will be submitted in electronic format (Word text, Excel tables, PDF figures, entire report submitted as one PDF document). Additionally, the data upon which the report is based will be provided in an MS Access database. Additional deliverables required by CPAI are Sheyna, please advise.

6.0 SCHEDULE WITH MILESTONES

6.1 Field Studies

- Complete 2009 cruise 1 about 25-Aug-2009

- Complete 2009 cruise 3 about 16-Oct-2009; field data due 30 days later
- Complete 2010 cruise 1 about 25-Aug-2010
- Complete 2010 cruise 3 about 16-Oct-2010; field data due 30 days later

6.2 Deliverables

- Draft Study Plan on 3-June-2009
- Final Study Plan by approximately #date#
- 2009 Field Data Report by approximately 15-Nov-2009
- 2010 Field Data Report by approximately 15-Nov-2010
- Draft Report will be submitted electronically by 30-Apr-2012 (60 days before project end)
- Final Report will be submitted in electronic format (PDF and Word versions) by 30-Jun-2012, or within 60 days after receipt of comments, whichever is later. We require 60 days to finalize the report after reviewer comments because of anticipated travel and schedule conflicts of the PIs.
- Submission of data and photo deliverables by 30-Jun-2012
- Archiving and completion of project by 30-Jun-2012

7.0 REFERENCES

ACIA (Arctic Climate Impact Assessment) (2004) Impacts of a warming Arctic. www.amap.no/acia. Cambridge University Press.

AFSC (Alaska Fisheries Science Center, National Marine Fisheries Service – NOAA Fisheries) (2006) Age and Growth Program: Procedure for otolith examination – break and burn preparation. http://www.afsc.noaa.gov/refm/age/procedures.htm Webpage created 12-July-2006, accessed 22-Jan-2009.

Alverson DL, Wilimovsky NJ (1966) Chapter 31. Fishery investigations of the southeastern Chukchi Sea. In: Wilimovsky NJ and Wolfe JN (eds.) Environment of the Cape Thompson region, Alaska. U.S. Atomic Energy Commission, Washington D.C., pp 843-860.

Atkinson EG, Percy JA (1992) Diet comparison among demersal marine fish from the Canadian Arctic. Polar Biology 11:567-573.

Barber WE, Smith RL, Vallarino M, Meyer RM (1997) Demersal fish assemblages of the northeastern Chukchi Sea, Alaska. Fishery Bulletin 95: 195-209.

Bentzen TW, Follmann EH, Amstrup SC, York GS, Wooller MJ, Muir DCG and O'Hara TM (2008) Dietary biomagnification of organochlorine contaminants in Alaskan polar bears. Canadian Journal Of Zoology-Revue Canadienne De Zoologie 86: 177-191.

Bentzen TW, Follmann EH, Amstrup SC, York GS, Wooler MJ and O'Hara TM (2007) Variation in winter diet of southern Beaufort Sea polar bears inferred from stable isotope analysis. Canadian Journal of Zoology 85: 596-608.

Cabana G, Rasmussen JB (1996) Comparison of aquatic food chains using nitrogen isotopes. Proceedings of the National Academy of Sciences, USA 93: 10844-10847.

Coyle KO, Gillispie JA., Smith RL, Barber WE (1997) Food habits of four demersal Chukchi Sea fishes. American Fisheries Society Symposium 19: 310-318.

Craig PC, Griffiths WB, Haldorson L, McElderry H (1982) Ecological studies of Arctic cod (Boreogadus saida) in Beaufort Sea coastal water. Canadian Journal of Fisheries and Aquatic Sciences 39: 395-406.

Craig PC, Griffiths WB, Johnson SR, Schell DM (1984) Trophic dynamics in an Arctic lagoon. In: Barnes PW, Schell DM, Reimnitz E (eds) The Alaskan Beaufort Sea: ecosystems and environments. Academic Press, New York, pp 347-380.

Craig PC, McCart P (1976) Fish use of nearshore coastal waters in the western arctic: emphasis on anadromous species. In: Hood DW, Burrell DC (eds) Assessment of the arctic marine environment: selected topics. Institute of Marine Science, University of Alaska, Fairbanks, pp 361-388.

Dehn L-A, Sheffield GG, Follmann EH, Duffy LK, Thomas DL, Bratton GR, Taylor RJ, O'Hara TM (2005) Trace elements in tissues of phocid seals harvested in the Alaskan and Canadian Arctic – Influence of age and feeding ecology. Canadian Journal of Zoology 83: 726-746.

Dunne JA, Williams RJ, Martinez ND (2002) Network structure and biodiversity loss in food webs: robustness increases with connectance. Ecological Letters 5: 558-567.

Fechelm P, Craig C, Baker JS, Gallaway BJ (1985) Fish distribution and use of near shore waters in the northeastern Chukchi Sea. USDOC NOAA OCSEAP Final Report 32, pp. 121-297.

Froese R, Pauly D (eds) (2006) FishBase. World Wide Web electronic publication. www.fishbase.org, version (05/2006).

Frost KJ, Lowry LF (1981) Trophic importance of some marine gadids in northern Alaska and their body-otolith size relationships. Fish Bull 79: 187-192.

Frost KJ, Lowry LF (1983) Demersal fishes and invertebrates trawled in the northeastern Chukchi and western Beaufort Seas, 1976-77. NOAA Tech Rep NMFS SSRF-764, 22 pp.

Frost KJ, Lowry LF (1984) Trophic relationships of vertebrate consumers in the Alaskan Beaufort Sea. In: Barnes PW, Schell DM, Reimnitz (eds) The Alaskan Beaufort Sea: ecosystems and environments. Academic Press, New York, pp 381-401.

Grebmeier JM, Dunton KH (2000) Benthic processes in the northern Bering/Chukchi Seas: status and global change. In: Impacts of changes in sea ice and other environmental parameters in the Arctic, Rept. Marine Mammal Commission Workshop, 15-17 Feb 2000, Girdwood, AK, Available: Marine Mammal Commission, Bethesda, MD.

Grebmeier JM, Cooper LW, Feder HM, Sirenko BI (2006) Ecosystem dynamics of the Pacific-influenced Northern Bering and Chukchi Seas in the Amerasian Arctic. Progress in Oceanography 71: 331–361.

Greenberg R, Marra PP, Wooller M (2007) Stable-isotope (C, N, H) analyses help locate the winter range of the coastal plain swamp sparrow (Melospiza georgiana nigrescens). In "Auk," pp. 1137-1148.

Hobson KA, Alisauskas RT, Clark RG (1993) Stable-Nitrogen isotope enrichment in avian-tissues due to fasting and nutritional stress - implications for isotopic analyses of diet. Condor 95: 388-394.

Hobson KA, Welch HE (1992) Determination of trophic relationships within a high Arctic marine food web using delta-C-13 and delta-N-15 analysis. Marine Ecology-Progress Series 84: 9-18.

Hobson KA, Schell DM, Renouf D, Noseworthy E (1996) Stable carbon and nitrogen isotopic fractionation between diet and tissues of captive seals: implications for dietary reconstructions involving marine mammals. Canadian Journal of Fisheries and Aquatic Science 53: 528-533.

Hokkaido University (1992) The "Oshoro-Maru" cruise 38 to the northern North Pacific Ocean, the Bering Sea, the Chukchi Sea and the Gulf of Alaska in June-August 1991. In: Data record of oceanographic observations and exploratory fishing No. 35. Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan, pp. 73-204.

Hokkaido University (1993) The "Oshoro-Maru" cruise 44 to the northern North Pacific Ocean, the Bering Sea, the Chukchi Sea and the Gulf of Alaska in June-August 1992. In: Data record of oceanographic observations and exploratory fishing No. 36. Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido, Japan, pp. 73-188.

Holladay BA, Norcross BL (1995) August diet of age-0 Pacific halibut in nearshore waters of Kodiak Island, Alaska. Environmental Biology of Fishes 44: 403-416.

Hop H, Welch HE, Crawford RE (1997) Population structure and feeding ecology of Arctic cod schools in the Canadian high Arctic. In: Reynolds JB (ed) Fish ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda, Maryland, pp 68-80.

Johnson L (1997) Living with uncertainly. In: Reynolds JB (ed) Fish ecology in Arctic North America. American Fisheries Society Symp 19, Bethesda, Maryland, pp 340-345.

Kelly JF (2000) Stable isotopes of carbon and nitrogen in the study of avian and mammalian trophic ecology. Canadian Journal of Zoology 78: 1-27.

Knoche MJ, Powell AN, Quakenbush LT, Wooller MJ, Phillips LM (2007) Further evidence for site fidelity to wing molt locations by king eiders: Integrating stable isotope analyses and satellite telemetry. Waterbirds 30: 52-57.

Lowry LF, Frost KJ (1981) Distribution, growth and foods of Arctic cod (Boreogadus saida) in the Bering, Chukchi and Beaufort Seas. Canadian Field-Naturalist 95(2): 186-191.

Manabe S, Stouffer RJ (1994) Multiple-century response of a coupled ocean-atmosphere model to an increase of atmospheric carbon dioxide. Journal of Climatology 7: 5-23.

Mecklenburg CW, Mecklenburg TA, Thorsteinson LK (2002) Fishes of Alaska. American Fisheries Society, Bethesda, Maryland, xxxvii + 1,037 pp + 40 plates.

Mecklenburg CW, Stein DL, Sheiko BA, Chernova NV, Mecklenburg TA, Holladay BA (2007) Russian-American long-term census of the arctic: benthic fishes trawled in the Chukchi Sea and Bering Strait in August 2004. Northwest Naturalist 88: 168-187.

Mecklenburg CW, Sheiko BA (2006) RUSALCA 2004: Fishes of the Northern Bering Sea and Chukchi Sea Results Presented at Kotor, Serbia-Montenegro Postcruise

Workshop, 26 October 2005 and Recommendations for Future Research. http://www.arctic.noaa.gov/aro/russian-american/2004_2005/FishDiversity2Feb06.pdf Accessed 1-October-2008.

Minerals Management Service (2006) Alaska Annual Studies Plan, Final FY 2007, September 2007.

Moles A, Norcross BL (1995) Sediment preference in juvenile Pacific flatfishes. Netherlands Journal of Sea Research 34: 177-182.

Moles A, Rice S, Norcross BL (1994) Non-avoidance of hydrocarbon laden sediments by juvenile flatfishes. Netherlands Journal of Sea Research 32: 361-367.

Norcross BL, Holladay BA, Busby MS, Mier KL (Submitted) Frontal structure in the Chukchi Sea determines small demersal and larval fish communities. Deep-Sea Res. II.

Norcross BL, Hose JE, Frandsen M, Brown E (1996) Distribution, abundance, morphological condition and cytogenetic abnormalities of larval herring in Prince William Sound, Alaska, following the Exxon Valdez oil spill. Canadian Journal of Fisheries and Aquatic Science. 53: 2376-2387.

Pauly D, Trites AW, Capuli E, Christensen V (1998) Diet composition and trophic levels of marine mammals. ICES Journal of Marine Science 55: 467-481.

Phillips DL, Gregg JW (2003) Source partitioning using stable isotopes: coping with too many sources. Oecologia 136: 261-269.

Phillips DL, Koch PL (2002) Incorporating concentration dependence in stable isotope mixing models. Oecologia 130: 114-125.

Phillips DL, Newsome SD, Gregg JW (2005) Combining sources in stable isotope mixing models: alternative methods. Oecologia 144: 520-527.

Pinkas L, Oliphant MS, Iverson ILK (1971) Food habits of albacore, bluefin tuna, and bonito in California waters, 152. California Department of Fish and Game, Fisheries Bulletin, 105 pp.

Power G (1997) A review of fish ecology in Arctic North America. In: Reynolds JB (ed) Fish ecology in Arctic North America. American Fisheries Society Symposium 19, Bethesda, Maryland, pp 13-39.

Smith RL (1986) Elements of Ecology. Harper and Row Publishers, New York, NY.

Sterner RW, Bajpai A, Adams T (1997) The enigma of food chain length: absence of theoretical evidence for dynamic constraints. Ecology 78: 2258-2262.

Suthers IM, Frank KT (1991) Comparative persistence of marine fish larvae from pelagic versus demersal eggs off southwestern Nova Scotia, Canada. Marine Biology 108: 175-184.

Ward JH (1963) Hierarchial grouping to optimize an objective function. Journal of the American Statistical Association 58: 236.

Wyllie-Echeverria T, Wooster WS (1998) Year-to-year variations in Bering Sea ice cover and some consequences for fish distribution. Fisheries Oceanography 7: 159-170.

SECTION V
SEABIRD ECOLOGY

PRINCIPAL INVESTIGATOR
ROBERT H. DAY
ABR, INC. ENVIRONMENTAL RESEARCH & SERVICES

1.0 INTRODUCTION

1.1 Brief History of Subject Research in the Chukchi Sea

Data on the at-sea distribution and abundance of seabirds in the northeastern Chukchi Sea during the open-water season are limited. This limitation is caused by the area's inaccessibility and because most of the interest in seabirds in this area has concentrated on seabird colonies and on seabirds at sea in the vicinity of the Hope Basin, which is north of Bering Strait and in the southern Chukchi. The primary seabird colony to be studied is located at Cape Lisburne, which is part of the Alaska Maritime National Wildlife Refuge; a few years of data also have been collected at Cape Thompson, which is south of there. In addition, there has been some research on birds in the coastal-lagoon systems of the northeastern Chukchi Sea— probably as much as has been conducted on birds at sea in this area.

There are few historical at-sea data for this area. The first research was conducted by Jacques (1930), who surveyed birds in the Bering Sea and western Chukchi Sea in July–August 1928. Later, Swartz (1967) examined the at-sea distribution of seabirds in the southern and central Chukchi during the environmental studies at Cape Thompson for a short time in 1960.

The interest in oil development in arctic Alaska in the 1970s led to a burst of research on seabirds and other marine organisms. However, this area also has had little recent research, to a great extent because of its inaccessibility. The main research in recent years has been conducted by (1) Divoky (1970), who studied seabirds in this area from a USCG Icebreaker; (2) Divoky (1979), who described some aspects of the Chukchi Sea open-water avifauna; and (3) Divoky (1987), who studied seabirds at sea in the Chukchi Sea in the early 1980s as part of the OCSEAP. Unfortunately, the latter report was never released by OCSEAP as part of its "Environmental Assessment of the Alaskan Continental Shelf" publication series, so it is difficult to locate. The massive at-sea seabird database summarized by Gould et al. (1982) included no data from the Chukchi Sea. As part of OCSEAP studies, Johnson (1993) studied the importance of nearshore lagoons to migrating geese.

More recently, there has been some ship-of-opportunity sampling of seabirds in the Chukchi conducted primarily by the U.S. Fish and Wildlife Service and some aerial surveys for migrating and staging Spectacled and Steller's eiders, both of which are protected under the Endangered Species Act. The latter surveys have indicated that Ledyard Bay in particular is an important stopover area for migrating Spectacled Eiders in late summer and the fall (Balogh 1997). Finally, there has been extensive research conducted on seabird colonies in the eastern Chukchi Sea for many years by David Roseneau, primarily at the Alaska Maritime National Wildlife Refuge unit at Cape Lisburne; these studies have built on earlier work begun on nesting seabirds at Cape Thompson by Swartz (1966).

This lack of information on seabirds at sea in this area is discussed by the National Research Council (1994), which said:

"There are few published data on the at-sea distribution of marine birds in the Chukchi Sea during the open-water season, but unpublished reports of Divoky (1987) provides a useful overview and documents a moderately high number of shearwaters and alcids using the central and southern Chukchi sea. Studies by Piatt et al. (1992), Andrew and Haney (1993), and Schauer (1993) provide a useful overview of the pelagic distribution of birds in the Bering Strait and the southern Chukchi Sea, in which large concentrations of birds are to be expected between June and September. Data for the northern Chukchi Sea are inadequate to assess the potential effects of offshore oil development in that region, and data are lacking on the mechanisms and locations that might lead to predictable, large concentrations of foraging seabirds in the central and eastern Chukchi Sea."

1.2 Purpose of Study and Rationale

The overall purpose of the study is to provide to CPAI necessary baseline information about the marine environment in the CPAI lease areas that can be used in applications for permits, in an EIS, and in other documents and to help manage these resources. This information will be needed to inform applications for permits such as NPDES permits, and to provide information that can be used to help prepare an EIS that examines possible effects of this offshore drilling and oil production.

1.3 Objectives of Study

The specific objectives of the seabird component of this study are to:

- describe spatial and seasonal characteristics of the seabird community in the overall development area and the area covered by the EIS;
- describe community-level attributes such as species-richness and species-composition;
- provide detailed information on species that are of conservation concern (e.g., endangered, threatened, candidate species); and
- when possible, integrate the data on distribution and abundance of seabirds in this area with the data on physical and biological oceanography that are collected in 2009.

2.0 STUDY AREA

2.1 Location

The general study area is in the northeastern Chukchi Sea, where there are two prospects called "Klondike" and "Burger" (Figure Intro-1). These two areas are located ~60 nm offshore from the villages of Wainwright and Icy Cape, in ~40–60 m of water. This area is ice-covered during much of the year, being available for ship-based sampling only during the summer–fall months.

The field study will be concentrated in two study-area boxes called "Klondike" and "Burger." Each box consists of three lease-blocks within a core area and is 30 nm on a side when a buffer zone for marine mammals is included around the perimeter. (This buffer zone must be added because of the possible effects of noise on marine

mammals, especially cetaceans.) These two 900-nm2 (~3,367-km2) study-area boxes will be the focus of the seabird (and other oceanographic) sampling.

2.2 Period of Study

The field component of the seabird study will be conducted from early-August to late October 2009.

3.0 METHODS AND PROCEDURES

3.1 Sampling or Survey Design and Technical Rationale

We will survey seabirds (and other observers will survey marine mammals concurrently) along a series of parallel survey lines that run north–south through these 900-nm2 boxes. Lines will be spaced 2 nm apart, creating a set of 26 parallel survey lines each 30 nm long; hence, every fifth line will coincide with a line of oceanographic stations that will be sampled by other researchers on the bat (see Figure V-1). At a ship's speed of ~9–10 kt, each line can be surveyed in ~3 h, so several lines may be sampled in a day if weather and daylight permit. However, if inclement weather is limiting our ability to sample the entire area, the top priority on a cruise will be those lines that include the core parts of each study-area box. If possible, each study area will be surveyed at least once over a period of ~16 days on each of the three cruises. The same survey lines will be surveyed on each subsequent cruise, so that inter-cruise comparisons can be made.

An important aspect of the study design is the use of line-transect sampling within a zone ~300 m wide. The use of this sampling design allows the calculation of the bias in detectability of individual species (i.e., a small phalarope is much more difficult to detect than is a large albatross or a medium-sized gull), so that numbers of individuals seen can be corrected. Thus, the bias in detectability of individual species will be incorporated into the density estimates, increasing the accuracy of the estimates.

3.2 Field Team Size and Composition

The seabird team will consist of 8–10 observers total who will rotate though the three cruises planned for the summer, with each individual cruise team consisting of two observers who will trade off observation duties throughout the day.

4.0 References

Divoky, G. L. 1970. Pelagic bird and mammal observations in the eastern Chukchi Sea, early fall 1970. Pages 111–172 in WEBSEC–70: An ecological survey in the eastern Chukchi Sea, September–October 1970. U.S. Coast Guard Oceanographic Report No. 50 (CG 373– 50).

Divoky, G. J., 1979. Sea ice as a factor in seabird distribution and ecology in the Beaufort, Chukchi, and Bering Seas. Pp. 9–17 in Conservation of marine birds of northern North America (J. C. Bartonek and D. N. Nettleship, Eds.). U.S. Fish and Wildlife Service, Wildlife Research Report No. 11.

Divoky, G. J. 1987. The distribution and abundance of birds in the eastern Chukchi Sea in late summer and early fall. Unpublished report prepared for National Oceanic and Atmospheric Administration/Outer Continental Shelf Environmental Assessment Program (NOAA/OCSEAP), Boulder, CO, by Arctic Environmental Information and Data Center, Anchorage, AK. 96 pp.

Gould, P. J., D. J. Forsell, and C. J. Lensink. 1982. Pelagic distribution and abundance of seabirds in the Gulf of Alaska and eastern Bering Sea. U.S. Fish and Wildlife Service, Biological Services Program, Report No. FWS/OBS-82/48. 294 pp.

Gould, P. J., and D. J. Forsell. 1989. Techniques for shipboard surveys of marine birds. U.S. Fish Wildlife Service Technical Report No. 25. 22 pp.

Johnson, S. R. 1993. An important early-autumn staging area for Pacific Flyway Brant: Kasegaluk Lagoon, Chukchi Sea. Journal of Field Ornithology 64: 539–548.

Magurran, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton, NJ. 179 pp.

National Research Council (Committee to Review Alaskan Outer Continental Shelf Environmental Information). 1994. Environmental information for outer continental shelf oil and gas decisions in Alaska. National Research Council, Washington, DC. 270 pp.

Swartz, L. G. 1966. Sea-cliff birds. Pp. 611–678 in Environment of the Cape Thompson Region (N. J. Wilimovsky and J. N. Wolfe, Eds.). U.S. Atomic Energy Commission, Oak Ridge, TN.

Swartz, L. G. 1967. Distribution and movement of birds in the Bering and Chukchi seas. Pacific Science 21: 332–347.

Tasker, M. L., P. H. Jones, T. J. Dixon, and B. F. Blake. 1984. Counting seabirds at sea from ships: a review of methods employed and a suggestion for a standardized approach. Auk 101: 567–577.

Thomas, L., J. L. Laake, S. Strindberg, F. F. C. Marques, S. T. Buckland, D. L. Borchers, D. R. Anderson, K. P. Burnham, S. L. Hedley, J. H. Pollard, J. R. B. Bishop, and T. A. Marques. 2006. DISTANCE 5.0 (Release 2). Research Unit for Wildlife Population Assessment, University of St. Andrews, United Kingdom. [available at: http://www.ruwpa.st-and.ac.uk/distance/]

SECTION VI
MARINE MAMMAL ECOLOGY

PRINCIPAL INVESTIGATOR

JAY BRUEGGEMAN

CANYON CREEK CONSULTING LLC

1.0 INTRODUCTION

1.1 Brief History of Subject Research in Chukchi Sea

Marine mammal research in the Chukchi Sea has been very limited in the last ten years. Recent research has included surveys of bearded and ringed seals by Bengtson et al. (2005), polar bear by Evans et al. (2003), and beluga whales by Suydam et al. (2005). In addition, CPAI and Shell have conducted marine-mammal monitoring programs in 2006 and 2007 for seismic operations. Except for these programs, marine-mammal research programs in the Chukchi Sea occurred over 15 years ago by Brueggeman, Moore, and Ljungblad. Consequently, research needs to be conducted to provide current information on the use of the Chukchi Sea by marine mammals for planning oil and gas exploration and development programs.

1.2 Purpose of Study and Rationale

The purpose of this study is to provide current information on marine-mammal use of the Chukchi Sea, specifically in areas proposed by CPAI for oil and gas exploration. The information will provide a baseline for planning oil and gas operations and future research programs.

1.3 Objectives of Study

The objectives of the study are to:

- Determine the species composition;
- Determine the seasonal abundance and distribution; and
- Identify important areas for marine mammals, including feeding areas based on distribution and behavior.

2.0 STUDY AREA

2.1 Location

The location of the study area is defined by CPAI as two rectangular areas (survey areas) west of Wainwright in the Chukchi Sea, named Burger and Klondike (see Figure Intro-1). Each area is 30 X 30 nm square and contains several potential oil and gas drilling sites. The location of the study area is provided in the RFP and is not repeated in this study plan.

2.2 Period of Study

The period of study will begin in early August and will end on about mid-October. There will be three vessel-based research cruises, each ~ 20 days long.

3.0 METHODS AND PROCEDURES

3.1 Sampling or Survey Design and Technical Rationale

Surveys will be conducted from the research vessel within each survey area. Trained observers will record marine mammals along north–south transect lines equidistantly spaced across each survey area. Each transect line will extend 30 nm and be spaced 2 nm apart, representing 16 transect lines. (see Figure VI-1). Each survey area may shift to ensure coverage 6 nm beyond the outer edge of any potential drilling site to capture the area affected by drilling sounds to a 160 dB level; this is the sound level that NMFS defines for potentially causing behavior disturbance to marine mammals. Transect lines will be surveyed sequentially from south to north or north to south to minimize fuel usage and maximize time.

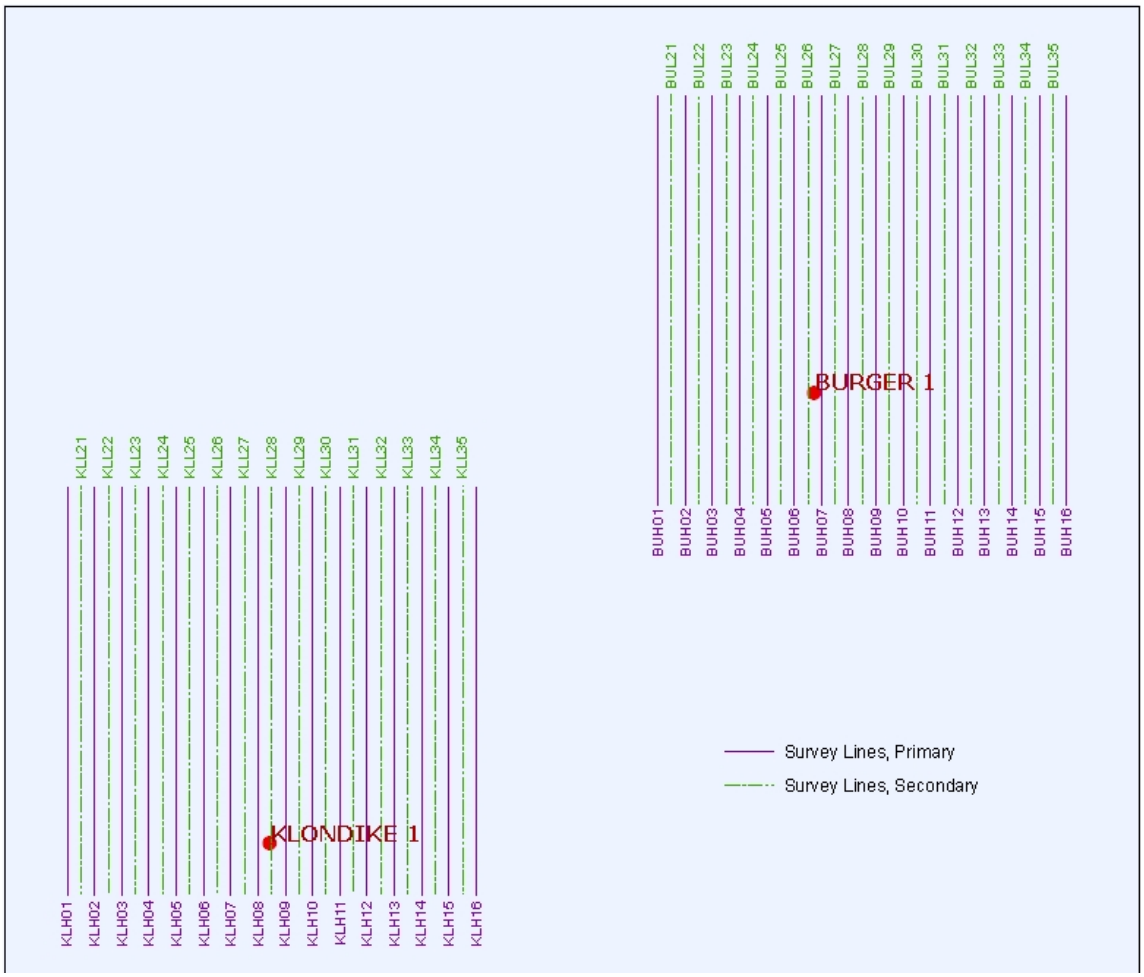

Figure VI-1. Marine Mammal Survey Lines

Each survey area will be surveyed at least once during each 32-day cruise, depending on the weather conditions. The order of the surveys will depend on the location of the ice and seismic activity, but it is anticipated that the first survey will begin at Klondike (southernmost area) and the last survey will begin at Burger (northernmost area). It is anticipated that a full survey will require a minimum of 5 days to complete/survey area or 10 days for both areas, assuming a cruising speed of 10 kt. Because of ice and/or bad

weather, it is likely that fully completing the surveys will require the entire time allocated per cruise. The number of north–south transect lines surveyed may be modified to accommodate changing weather conditions, particularly in the fall, to ensure that surveys cover the entire survey area for each cruise period.

3.2 Field Team Size and Composition

Two marine mammal observers will be on each cruise. Observers will be experienced and trained in vessel surveys.

3.3 Data-collection Procedures

Vessel based observer(s) will watch for marine mammals from the best available vantage point on the vessel, which is usually the bridge or flying bridge. The observer(s) will scan systematically with the naked eye and 7 X 50 reticle binoculars. Observer(s) will focus on the 180° area centered on the vessel's trackline, with occasional scans of the area behind the vessel. Marine-mammal observations will occur for up to 16 hours/day, depending on weather conditions and day length. Observers will alternate 4-hour watches, so each observer is on watch for no more than 8 hours/day. Observations will begin one hour before sunrise. Data will be recorded on field forms and transferred to an MS Excel spread sheet loaded into a laptop computer.

When a mammal sighting is made, the following information will be recorded:

- Species, group size, age/size/sex categories (if determinable), behavior, heading (if consistent), bearing and distance from vessel;
- Date, time, and location of the vessel, sea state, ice cover (10% increments), visibility, and sun glare; and
- The positions of any other vessel(s) in the vicinity of the research vessel.

The ship's position and water depth, sea state, ice cover, visibility, and sun glare will be recorded at the start and end of each observation watch and, during a watch, every 30 minutes and whenever there is a change in one or more of those variables. Location will be obtained from either a hand-held GPS or the navigation system on the ship.

Distances to nearby marine mammals will be estimated visually or with sighting aids (e.g., laser range-finder, fixed points, clinometer, reticule in binoculars). Observers will use sighting aids to test and improve their abilities for visually estimating distances to objects in the water. Surveys will generally not be conducted during sea states exceeding a Beaufort 5 because marine mammals become too difficult to detect in seas this high. (See Appendices 1–3 for data-collection codes and Appendix 4 for the field form).

3.4 Analytical Procedures

The analytical procedures will largely be determined by the sample sizes of the data collected on each marine-mammal species. However, standard approaches will be used, including Chi-square and regression analysis for spatial and temporal relationships and line-transect analysis for density estimates.

3.5 Data-storage Procedures

Field data will be recorded on an MS Excel spreadsheet stored on a laptop computer. The MS Excel spreadsheet will have all of the fields for data collected in the field. The data entered into the computer will be backed up onto CDs and USB keys. If possible,

data sheets will be photocopied daily during the field season. Data will be secured further by having data sheets and backup data CDs carried back to the MMOs' contractor office during crew-replacement rotations.

3.6 Quality-control Procedures

Observers on the vessel will record observations onto datasheets and then will enter them into an MS Excel file loaded on a laptop. During periods between watches and periods when operations are suspended, those data will be cross-checked by the observers. The accuracy of the data entry will be verified in the field by manually checking of the data sheets for completeness, accuracy, legibility, and logic. Additional checking will occur in the office after the field season.

4.0 COORDINATION

4.1 CPAI

Field studies, data analysis, and reporting will be closely coordinated with Caryn Rea of CPAI. Coordination will be in the form of emails and phone calls from Principal Investigator Jay Brueggeman and from meetings.

4.2 Other Studies in the Chukchi Sea Program

The marine-mammal study will be closely coordinated with the other studies in the program. This coordination will especially include the seabird program, whose observers will work closely with the MMOs on the vessel, sharing sighting information. The study will also be closely coordinated with the zooplankton studies for obtaining samples in areas of feeding marine mammals. Marine-mammal observations will also be closely coordinated with the acoustic study to assist in linking a species with recorded sounds of calling marine mammals. The overall coordination effort will be fully discussed between investigators of the studies at a meeting scheduled before the field program begins.

4.3 Current Studies in the Region

The MMS is funding a bowhead whale feeding study in the Beaufort Sea off Barrow, Alaska, which is referred to as BOWFEST (Bowhead Whale Feeding Ecology Study). This study includes aerial surveys of bowhead whales and corresponding vessel sampling of the physical and biological oceanography. In addition, there will be an acoustic study to determine spatial and temporal distribution of bowhead whales, and various characteristic of bowhead calls. The

marine mammal study that is the subject of this proposal to CPAI will closely coordinate with the BOWFEST lead, Dave Rugh, of the National Marine Mammal Laboratory.

5.0 REFERENCES

Bengston, J. L., L. M. Hiruki-Raring, M. A. Simpkins, and P. L. Boveng. 2005. Ringed and bearded seal densities in the eastern Chukchi Sea, 1999–2000. Polar Biology. 28: 833–845.

Brueggeman, J. J., R. A. Grotefendt, M. A. Smultea, G. A. Green, R. A. Rowlett, C. C. Swanson, D. P. Volsen, C. E. Bowlby, C. I. Malme, R. Mlawski, and J. J. Burns. 1992. 1991 Marine Mammal Monitoring Program, Walruses and Polar Bears,

Crackerjack and Diamond Prospects, Chukchi Sea. Shell Western E&P, Inc., and Chevron USA, Inc. 109 pp. + appendices.

Brueggeman, J. J., R. A. Grotefendt, M. A. Smultea, G. A. Green, R. A. Rowlett, C. C. Swanson, D. P. Volsen, C. E. Bowlby, C. I. Malme, R. Mlawski, and J. J. Burns. 1992. 1991 Marine Mammal Monitoring Program, Whales and Seals, Crackerjack and Diamond Prospects, Chukchi Sea. Shell Western E&P, Inc., and Chevron USA, Inc. 62 pp. + appendices.

Brueggeman, J. J., C. I. Malme, R. A. Grotefendt, D. P. Volsen, J. J. Burns, D. G. Chapman, D. K. Ljungblad, and G. A. Green. 1990. 1989 Walrus Monitoring Program, Klondike, Burger, and Popcorn Prospects in the Chukchi Sea. Shell Western E&P, Inc . 121 pp. + appendices.

Brueggeman, J. J., D. P. Volsen, R. A. Grotefendt, G. A. Green, J. J. Burns, and D. K. Ljungblad. 1991. 1990 Walrus Monitoring Program, Popcorn, Burger, and Crackerjack Prospects in the Chukchi Sea. Shell Western E&P. Inc. 53 pp. + appendices.

Evans, T. F., A. S. Fischbach, S. Schliebe, S. Kalxdorff, G. York, and B. Manly. 2003. Polar Bear Aerial Survey in the Eastern Chukchi Sea. Arctic 56: 359–366.

Ljungblad, D. K., S. E. Moore, and D. R. Van Schoik. 1984. Aerial surveys of endangered whales in the Beaufort, eastern Chukchi, and northern Bering seas, 1983: with a five year review, 1979–1983. Report from Naval Ocean Systems Center, San Diego, CA, for U.S. Minerals Management Service, Anchorage, AK. NOSC Technical Report No. 955. 356 pp. [NTIS AD-A146 373/6]

Ljungblad, D. K., S .E. Moore, and D. R. Van Schoik. 1986. Seasonal patterns of distribution, abundance, migration, and behavior of the Western Arctic stock of bowhead whales, Balaena mysticetus, in Alaskan seas. Reports of the International Whaling Commission, Special Issue 8: 177–205.

Ljungblad, D. K., S.E. Moore, J. T. Clarke, and J. C. Bennett. 1987. Distribution, abundance, behavior, and bioacoustics of endangered whales in the Alaskan Beaufort and eastern Chukchi seas, 1979–86. Report from Naval Ocean Systems Center, San Diego, CA, for U.S. Minerals Management Service, Anchorage, AK. NOSC Tech. Rep. 1177; OCS Study MMS 87-0039. 391 pp. [NTIS PB88-116470]

Ljungblad, D. K., B. Würsig, S. L. Swartz, and J. M. Keene. 1988. Observations on the behavioral responses of bowhead whales (Balaena mysticetus) to active geophysical vessels in the Alaskan Beaufort Sea. Arctic 41: 183–194.

Moore, S. E. 2000. Variability in cetacean distribution and habitat selection in the Alaskan Arctic, autumn 1982–91. Arctic 53: 448–460.

Moore, S. E., and R. R. Reeves. 1993. Distribution and movement. In J. J. Burns, J. J. Montague, and C. J. Cowles (Eds.). The bowhead whale. Society of Marine Mammalogy, Lawrence, KS. Special Publication No. 2. Pp. 313–386

Suydam, R. S., L. F. Lowry, and K. J. Frost. 2005. Distribution and movements of beluga whales from the eastern Chukchi Sea stock during summer and early autumn. Final Report, OCS Study No. MMS 2005-035. 48 pp.

6.0 APPENDICES

6.1 APPENDIX 1. FIELD CODES FOR VESSEL SURVEY DATA.

STUDY AREA

K = KLONDIKE

B = BURGER

O = OTHERT

DATE

Two number values (i.e., 01, not 1)

WATCH START–END

WS Watch Start WE Watch End

OBSERVER

Two letter initials of on-duty observer

LEG TYPE

S Systematic leg for survey along transect lines D Deadhead leg for survey between connecting transect lines T Transit leg for transiting between study areas or between land and study area

LEG NUMBER

Leg number sequentially ordered from east to west along transect lines; deadhead or transit legs are not numbered so leave blank

TIME

Two number values (i.e., 01, not 1)

POSITION

Two digit Degrees Two digits, two decimal minutes

SEA STATE

0 Glassy 1 Ripple 2 Small wavelets 3 Large wavelets, scattered white caps 4 Small waves, frequent white caps 5 Moderate waves, many white caps with chance of spray 6 Large waves, white foam crests with some spray

7–11 See handbook table

VISIBILITY (# KM)

0–10 km Or > < 3.5 if variable

GLARE AMOUNT

NO None
LI Little
MO Moderate
SE Severe

WATER DEPTH

In meters

SIGHTING ID

Consecutive # Use same number for repeat record of same group/individual

MARINE MAMMAL SPECIES

Whales/Porpoises

BW Bowhead Whale WW Beluga Whale GW Gray Whale HW Humpback Whale FW Fin Whale KW Killer Whale UD Unidentified Dolphin HP Harbor Porpoise

Pinnipeds

RS Ringed Seal BS Bearded Seal SS Spotted Seal RB Ribbon Seal SL Northern Sea Lion US Unidentified Seal PW Pacific Walrus UP Unidentified Pinniped

Bears

PB Polar Bear

MOVEMENT

AB Across Bow ST Swim Toward

SA Swim Away FL Flee SP Swim Parallel MI Mill NO No movement DE Dead UN Unknown

INDIVIDUAL OR GROUP BEHAVIOR

MA Mating DI Dive LO Look TR Travel BR Breach LT Lobtail SH Spyhop FS Flipper Slap FE Feeding FL Fluking BL Blow BO Bow Riding RE Resting MI Milling OT Other (describe) NO None (sign seen only) UN Unknown

ESTIMATE METHOD

R Range Finder E Estimate by eye F Relative to fixed point B Binocular reticules (0–16)

Where At/Where To

Numbers on a 12-hr clock

CLOSEST POINT OF APPROACH (CPA)

Nearest distance of individual/group (m)

6.2 APPENDIX 2. WIND SPEED, BEAUFORT WIND FORCE, AND SEA-STATE CODES

Sea State Code (Force)	Speed (10 m above ground)		Description	Specifications for use on land
	Miles per hour	knots		
0	0-1	0-1	**Calm**	Sea like a mirror
1	1-3	1-3	**Light air**	Ripple with the appearance of scales are formed, but without foam crests.
2	4-7	4-6	**Light Breeze**	Small wavelets, still short, but more pronounced. Crests have a glassy appearance and do not break.
3	8-12	7-10	**Gentle Breeze**	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white horses.
4	13-18	11 16	**Moderate Breeze**	Small waves, becoming larger; fairly frequent white horses.
5	19-24	17 21	**Fresh Breeze**	Moderate waves, taking a more pronounced long form; many white horses are formed. Chance of some spray.
6	25-31	2227	**Strong Breeze**	Large waves begin to form; the white foam crests are more extensive everywhere. Probably some spray.

6.3 APPENDIX 3. RETICLE-BINOCULAR DISTANCE SCALE (BASED ON FUJINON 7 X 50 BINOCULARS AND A DECK HEIGHT OF 6.1 M ABOVE THE WATER).

Reticle	Distance (m)
0.5	1623.9
1	967.1
1.5	690.9
2	537.9
2.5	440.5
3	373.0
3.5	323.5
4	285.6
4.5	255.7
5	231.4
6	194.5
7	167.8
8	147.6
9	131.7
10	118.9
11	108.4
12	99.6
13	92.1
14	85.7

SECTION VII
ACOUSTIC MONITORING

PRINCIPAL INVESTIGATOR

DAVE HANNAY/SCOTT CARR

JASCO RESEARCH LTD

1.0 INTRODUCTION

The objectives of the acoustics program are to quantify the soundscape of the Chukchi Sea and to identify and localize marine mammal vocalizations to provide an improved understanding of marine mammal habitat usage, migration paths and temporal and spatial presence. The results of the program will be used to assist in the assessment of the potential effects of sound associated with oil and gas exploration and production on marine mammals.

The 2009 acoustics program will involve deploying 44 autonomous acoustic recorders, including a regional array of 20 recorders and two focused arrays of 12 recorders each. The regional deployment pattern will be similar to that used by ConocoPhillips and Shell for acoustics programs in the Chukchi Sea in the 2006-2008 open-water seasons. The regional recorders will be augmented by two sets of clusters of 12 recorders each in uniform grid patterns centered over the Burger and Klondike wells. The acoustic data acquired by all 44 recorders will be analyzed to detect vocalizations and classify the calling species using approaches similar to that employed for analysis of the previous seasons' data. Call localizations will be performed for calls detected on the two cluster arrays.

2.0 Program Description

Marine mammal species in the Chukchi Sea use sound for communication, navigation, predator avoidance, defense, breeding, care of young and feeding. Industrial activities by ConocoPhillips and other operators in the Chukchi will generate underwater sound that may interfere with the natural uses of sound listed above. Sound exposures, if significant, may induce physiological responses that could lead to secondary effects such as habitat abandonment and reduction of foraging or breeding efficiency. To date adverse physiological impacts to marine mammals such the above secondary effects are realized, have not been documented in the arctic.

The arctic seas have historically experienced less industrial activity than most other marine environments (e.g., Gulf of Mexico), however with the recent changes in ice presence, some countries are taking advantage of the new shipping routes to transport goods to market. Marine mammals in the Chukchi consequently have had less opportunity to habituate to anthropogenic noise. In addition, with minimal anthropogenic activity, the impetus for federal agencies to conduct comprehensive multi-disciplinary baseline studies has been a low priority. Regulatory permitting for recent projects has acknowledged that a lack of information on the marine ecosystem has resulted in the application of stricter requirements for operators working in the Chukchi Sea in order to quantify and mitigate sound exposures of marine mammals. Acoustic programs have been performed by CPAI and Shell and other operators since 2006 to address these permitting requirements related to noise for offshore operations there. In fact, in 2008, the National Marine Mammal Lab (NMML) counted over 100 acoustic recorders in the OCS, including both the U.S. and Canada waters. CPAI, responsible for the operation

and execution of the 2009 program on behalf of its partner Shell. has designed a program that will extend the multi-year dataset and provide new information about detailed call locations near the lease block areas where work is expected to be focused over the next few years.

2.1 Acoustics Program Purpose

The proposed acoustics program has been designed to address the following main goals: 1) to assess ambient and industrial noise levels and 2) to detect, classify species and localize vocalizing marine mammals over the Alaskan Chukchi Sea and in vicinity of the Burger and Klondike well locations. The proposed field program involves continuing the measurement programs performed by JASCO Research Ltd and Bioacoustics Research Program at Cornell University in 2006-2008 for CPAI and Shell. The 2009 acoustics program will be performed by JASCO Research.

The regional program will instrument a large area of the Chukchi Sea off the Alaskan coast out to approximately 160 km (100 miles) offshore. The focused programs will use two arrays of 12 recorders each deployed on a triangular grid pattern with recorder separations of 8 km (5 miles) on Lease Area 193 near the Klondike and Burger sites. The acoustic field measurement program will directly measure sound levels produced by the CPAI research vessel, coring vessel, and Shell's Shallow Hazard survey operations near these sites. The arrays will also will detect, classify and localize vocalizations from several marine mammal species including belugas (*Delphinapterus leucas*), bowheads (*Balaena mysticetus*), gray whales (*Eschrichtius robustus*), fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), killer whales (*Orcinus orca*), walruses (*Odobenus rosmarus*) and several species of ice seals.

2.2 Methods

2.2.1 Equipment and Sampling Parameters

All acoustic measurements will be performed using JASCO's calibrated autonomous multi-channel acoustic recorders (AMARs) that are shown in Figure VII-1 and described in 2.2.5. These recorders sample continuously or on a pre-programmed schedule. We plan to set the programmable sample rate to 16384 samples per second using 24-bit samples. This is the sampling rate that JASCO has employed in 2007 and 2008 (though at 16-bit samples) and it is higher than the frequencies used by other long-period sound recording programs in the Chukchi. The recorders can also be programmed to sample at much higher rates but the proposed 16384 Hz rate provides 8 kHz of acoustic bandwidth which is sufficient to capture a sufficient component of beluga vocalizations and most of the frequency content of the other present species' vocalizations.

AMARs can be configured with omni-directional sensors and directional sensors. We will utilize omni-directional hydrophones for all 44 recorders deployed in 2009. Even though the hydrophones are non-directional we will be able to localize calls on the focused deployment areas by examining arrival time differences on the synchronized recorders. Detections on at least three synchronized omni-directional systems are required to localize vocalizations. The localization accuracy depends on the signal to noise ratio of received signals. Greater positional accuracies will be obtained if signals are received simultaneously on greater numbers of systems.

The hydrophones are calibrated in the lab prior to deployment, and a final calibration is performed in the field immediately prior to deployment and upon retrieval using a

pistonphone calibrator that generates a reference signal accurate to 0.1 dB at 250 Hz. The calibration signals are recorded into the data stream for confirmation of overall recording system gain upon data analysis.

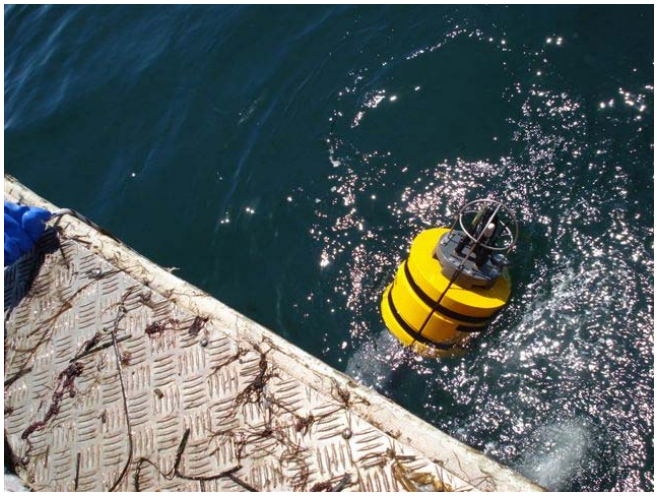

Figure VII-2: Photograph of AMAR acoustic buoy.

2.2.2 Deployment Geometry and Schedule

The recorders will be deployed on the seabed as shown in the diagram in Figure VII-3 at similar locations to the configurations employed by CPAI and Shell in their 2007-2008 regional programs and CPAI's 2008 focused program at the Burger and Klondike prospects. The planned deployment locations are shown in **Error! Reference source not found.**. A regional array of 20 recorders will be deployed in four strings of between 4 and 6 recorders each at Cape Lisburne, Point Lay, Wainwright and Point Barrow. Most of these deployment locations are at the same sites instrumented in 2007 and 2008.

The cluster arrays of 12 AMAR recorders each will be deployed at the study areas in late July 2009 before shallow hazards survey activities start. The planned deployment configuration will positions recorders on triangular grids at spacing of 8 km (5 miles) to allow for vocalization call detections on multiple units simultaneously so that localization can be performed. The AMAR recorders will be set to record continuously until mid-October 2009. At that time the recorders will be retrieved and a subset of the recorders will be redeployed to record on extended duration mode for up to a full year. This approach was used successfully in 2007-2008 by JASCO.

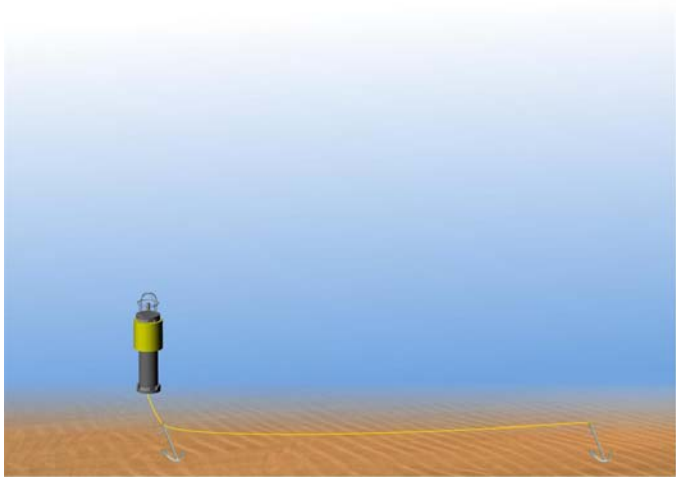

Figure VII-3: AMAR deployment configuration planned for CPAI 2009 acoustics program. Retrievals are made by grappling the line between the two anchors. This method has been used successfully in the previous Chukchi season programs and nothing is left on the seafloor.

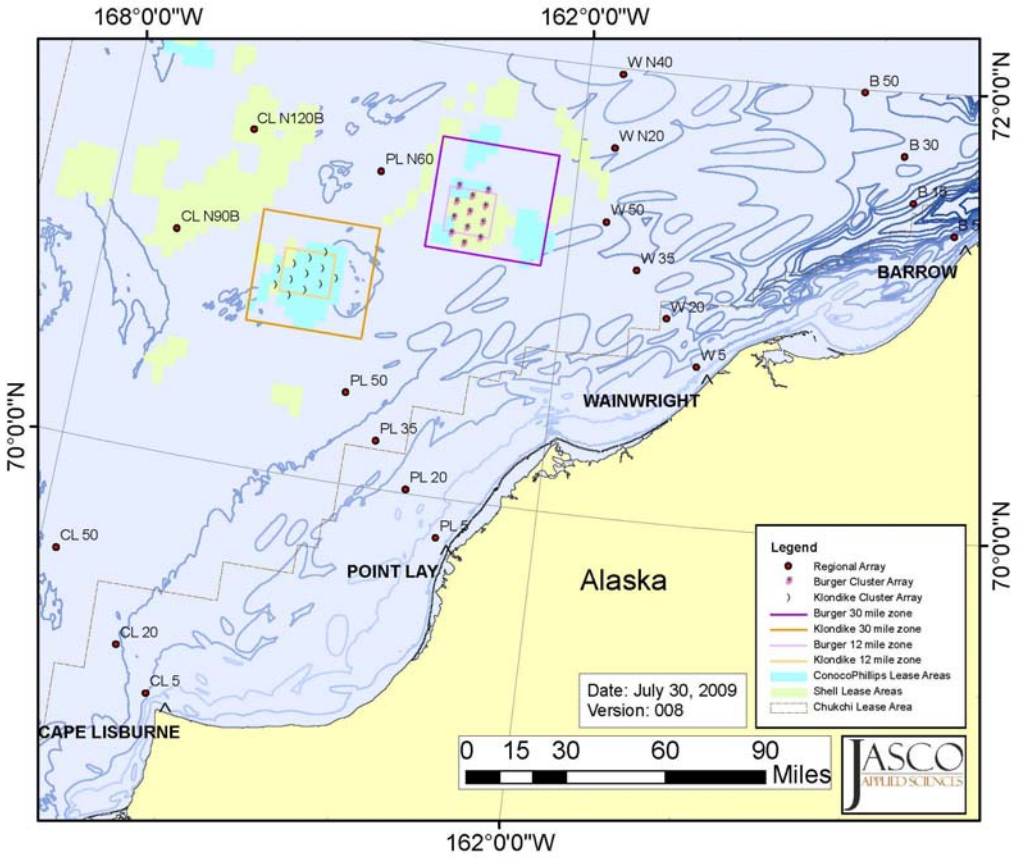

Figure VII-4: Planned AMAR acoustic recorder deployment locations for 2009. The circles indicate locations for regional array buoy deployments. The orange triangles and yellow squares represent the focused array buoy locations at Burger and Klondike respectively.

2.2.3 Data Analysis Procedures

Acoustic data will be extracted from the AMARs upon retrievals in mid-October 2009. The data will be immediately backed up and then mounted on JASCO's high speed detection/classification system that is described in Section 2.2.7. A data catalog will be prepared and data tests performed to evaluate signal to noise levels. Calibration signals from in-field pistonphone calibrations will be processed to ensure constant sensitivity by checking calibration levels at start and end of recording periods.

The detection/classification processing suite will be applied to the data. JASCO has already trained the automatic classification system with a very large number of calls received from several species identified from the 2007 dataset. The classification system will produce call counts for each species by time period throughout the deployments. These results are stored in XML files that contain metadata sufficient to query for multiple report types. We will manually process 5% of the data to compare and validate the automated detection results.

2.2.4 Reporting

Following classification result validation, the results will be discussed in a comprehensive report. The report will discuss in detail the goals of the program, methods used, and results. The results will address at minimum the following main points:

- vocalization detection counts as a function of time by species;
- vocalization spatial distributions from localization analysis (see below);
- ambient sound levels and spectra as a function of time. Spectra will also be plotted in weekly quartile levels;
- vessel sound detections and levels as a function of distance for identified vessels if navigation information is available; and
- shallow hazards survey pulse detections and noise levels.

Marine mammal detections on the focused arrays at Burger and Klondike will be examined to identify individual vocalizations that are present on more than one recorder. The arrival times of these detections on the different recorders will be accurately determined using a cross correlation approach. Differences in the arrival times correspond with animal-to-recorder distance differences. These can be triangulated to obtain the position of the vocalizing animal. The approach will be applied first to bowhead detections, and if time permits to other species vocalizations. The primary goal of this analysis will be to determine if there are preferred locations near the prospects that may be used, for example, for feeding.

2.2.5 AMAR Acoustic Recorders

JASCO Applied Sciences's autonomous multichannel acoustic recording systems (AMAR) will be deployed for this acoustics program. These systems are designed with very low power draw to facilitate long deployments using relatively small battery packs. They use solid state memory instead of hard drives, and can accommodate up to 1 TB of memory. Solid state memory is much less sensitive to temperature and vibration extremes than hard drive storage systems. The AMARs can record 24-bit audio and 3-axis water particle acceleration (vector sensors) with sample rate up to 500 MHz (divided by number of channels). These systems also log temperature and include serial inputs

for other sensor types (e.g. GPS, CTD). For CPAI's 2009 Chukchi Acoustics Program we plan to record only single channel 24-bit audio continuously at 16 kHz for 3 months.

2.2.6 Quality-control Procedures

All AMAR buoys will be subjected to an acceptance test plan prior to sending to the field. The test plan involves comprehensive environmental testing including subjecting to cold water temperatures that are typical of the near-freezing conditions of the Chukchi Sea. The hydrophones and recording systems are calibrated prior to leaving the laboratory, and pistonphone calibrations will be carried out immediately prior to deployment and upon retrieval. These pistonphone tests ensure full system sensitivity is accurately quantified.

Automated detection and classification systems will be used to process the very large amount of data that are expected to be acquired in this program. The performance of these systems will be evaluated against the results of manual analysis of a subset of the data. We intend to manually process 5% of the total dataset. The data chosen for manual analysis will be taken from all recorders and distributed over the full deployment time period.

2.2.7 Automated Analysis Suite

The acoustic data obtained in CPAI's 2009 Chukchi program will be processed mainly using automated detection/classification methods. JASCO has developed a high-performance computing system for analysing this type of data. It detects and classifies several species of marine mammals, quantifies ambient noise levels, detects and quantifies shipping activity, and detects and quantifies seismic survey activity. This software allows us to perform rapid, repeatable analysis of the data. It results in more consistent and timely reporting of the program results. A processing block diagram for the software suite is shown in Figure VII-4.

Processing is performed on a cluster of Sun High Performance Computing servers connected to a large RAID disk array. The computers are tasked and monitored using the Sun-1 Grid Engine. This infrastructure allows us to process large data sets consistently and quickly. For example, the 5 TB dataset from 2007 can be processed in about 60 hours, which is equal to approximately 700 times faster than the data were recorded (i.e. 700 hours of recording can be processed in 1 hour).

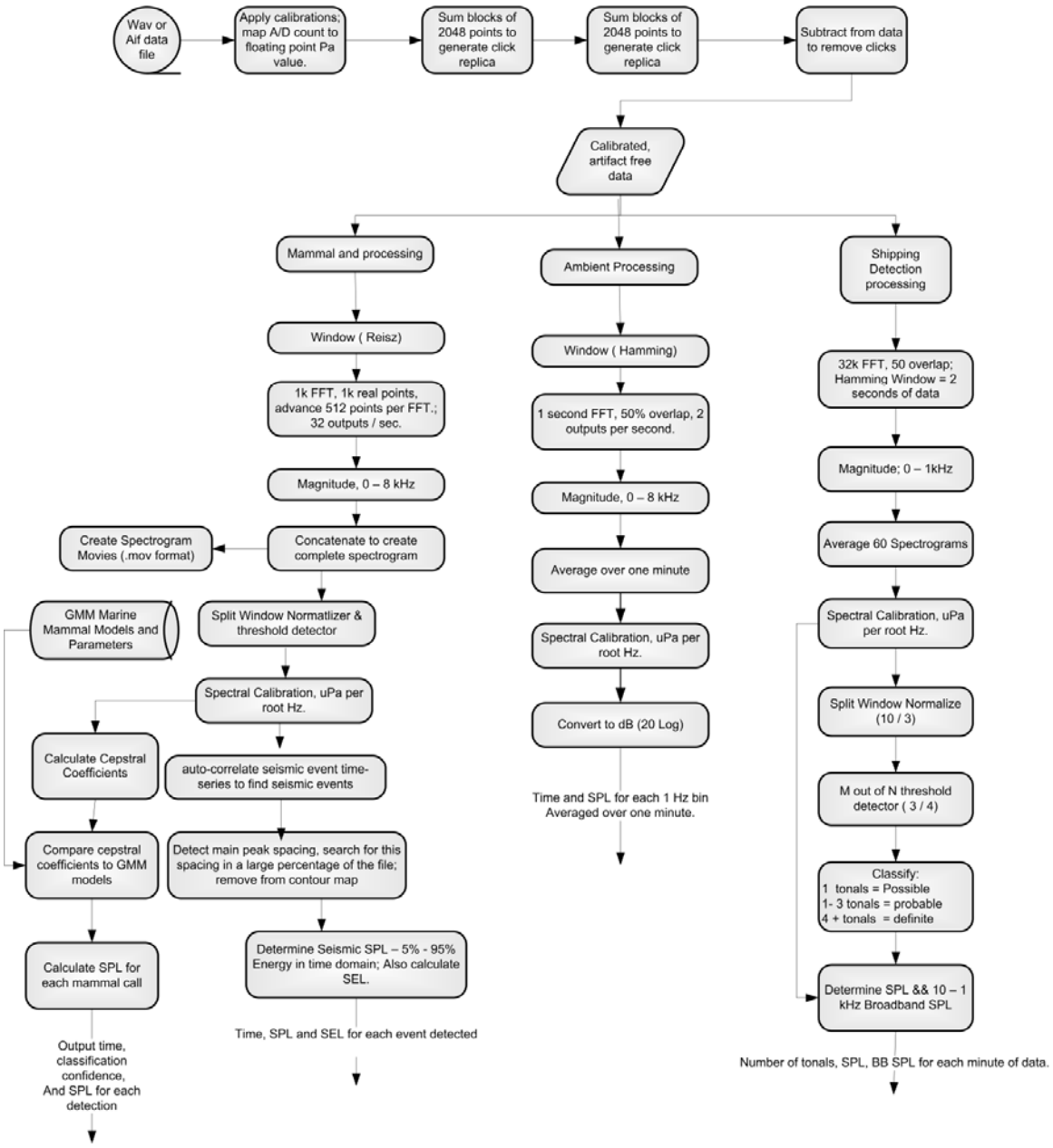

Figure VII-5: Automated Acoustic Recorder Data Processing Suite Computing Block Diagram.