Cruise Report for R/V Knorr Cruise 195-10 (KN195-10)

June 14 - July 13, 2009, Dutch Harbor, AK to Dutch Harbor, AK

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Knorr Captain: Kent Sheasley

Acknowledgements

A science party of 37 took part in the R/V Knorr research cruise 195-10, in addition to 24 ship's officers and crew. The cruise was complex logistically and required an on-load and off-load in Dutch Harbor, as well as an interdisciplinary suite of scientific research goals. The cruise included the deployment of moorings and sediment traps, over two hundred CTD casts, many net hauls and extensive on-deck work that took place around the clock. In the midst of all of this sampling work, there also were several educational outreach activities, both from the ship and in the form of visits by scientists and educators to St. Paul Island. The success of these many aspects of the cruise reflects the high level of expertise and cooperation of the officers and crew of the R/V Knorr. Although the science party gratefully acknowledges the help of the entire crew of the Knorr, the cooperation and expertise of Captain Kent Sheasley and his officers was outstanding. The scientists were uniformly appreciative of the dedicated work of mates Diedre Emrich, Jennifer Hickey and Alyson Paz as well as the tireless support of our work by the deck crew that included ABs Kevin Butler, Susan Coleman and William Dunn. These efforts during the cruise made the scientific work possible. Any and all science results from this cruise owe a large debt to this valued cooperation.

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Cruise Summary

This report summarizes the research cruise of the R/V Knorr 195-10 (hereafter KN195-10) that took place in the eastern Bering Sea from June 14 to July 13, 2009. This was the seventh NSF funded, dedicated cruise for the Bering Ecosystem Study (BEST) project that focuses on the impact of sea ice on the marine ecology of the region. In particular it focuses on pathways of nutrients and organic matter that lead to the abundant upper trophic levels and valuable fisheries on this extensive, high latitude continental shelf. Five prior cruises focused on the conditions associated with the retreating ice edge in March – May. KN195-10 was the seventh NSF funded, dedicated cruise for the BEST project and the second to characterize summer conditions on the eastern shelf, including the seasonal evolution of the nutrient and phytoplankton fields, as well as the distribution and abundance of zooplankton and ichthyoplankton. The cruise covered most of the eastern Bering Sea shelf from the Aleutian Islands to St. Lawrence Island. A complex, multidisciplinary sampling plan was carried out that included continuous measurements of meteorological and surface water characteristics with autonomous sensors on the ship as well as bird and marine mammal observations along the over 4300 nautical miles of cruise track. Sampling activities at the 212 unique stations occupied during the cruise included at least 1 CTD cast per station, 26 casts for productivity rates, 74 MOCNESS tows, 77 CalVet tows, 24 bongo tows, 20 multicore stations, 18 van Veen collections and 4 sediment trap deployments and recoveries. In addition, one of the NOAA moorings was replaced and surface drifters were deployed. Some of these samples were processed on-board by the 17 research groups that participated in the cruise, although thousands more will be analyzed on-shore. Initial results include the characterization of the shelf cold pool, as well as sampling of a huge eddy that impacted physical and biological features over the outer, northern shelf near Zhemchug Canyon over most of the month-long cruise. This feature influenced the distribution of an intense subsurface Chl *a* layer, as well as mesozooplankton and euphausiid distributions. Pollock larvae were found in greatest abundance along the Aleutian Peninsula and seaward of the Pribilof Islands. Education and outreach activities also were part of the cruise led by a teacher who reported to student and teacher groups on shore through webinars from the ship. He also organized community outreach at St. Paul Island during the cruise.

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1 Introduction

The Bering Ecosystem Study Project (BEST) focuses on the impact of seasonal sea ice on the environment of the eastern Bering Sea. More specifically, BEST seeks to clarify how sea ice influences the ecological pathways of nutrients and organic matter that lead to the abundant upper trophic level populations that include valuable fisheries on this extensive, high latitude continental shelf. More detailed background information can be found on the BEST home page (http://www.fish.washington.edu/research/best/). BEST also is part of a larger interagency effort to model the response of upper trophic levels to variations in climate forcing and more information on these collaborative efforts can be found on the web site of the Bering Sea Integrated Ecosystem Response Project (BSIERP; http://bsierp.nprb.org/index.htm). Science parties supported by both BEST and BSIERP participated in KN195-10.

The cruise described in this document was the seventh dedicated cruise for the BEST project. One took place in April-May of 2007 and three more in the spring and summer of 2008. Two more took place in the early part of 2009. All prior cruises except the last BEST cruise in 2008 (HLY0803) focused on the conditions directly associated with the retreating ice edge. KN195-10, like HLY0803, examined the summer conditions on the eastern Bering Sea shelf. Although this region is ice-free in summer, the presence of ice earlier in the year influences the subsequent development of physical and biological conditions. The overall goal was to improve the understanding of these influences significantly. The cruise covered the entire shelf from the Aleutian Islands to St. Lawrence Island. A multidisciplinary sampling plan was carried out that included the deployment of a mooring and physical oceanography, a hydrographic survey that collected discrete samples for a variety of chemical and biological analyses, zooplankton and ichthyoplankton net hauls, sediment sampling with a coring device, a variety of biological rate measurements that were done in on-board incubators, the deployment and retrieval of sediment traps that required extensive ship maneuvering, as well as a variety of underway observations both from autonomous instruments sampling the sea chest water and visual observation of birds and marine mammals from the bridge.

There were several unique features of this summer cruise of the BEST/ BSIERP program. Although no sea ice was present in the study region during the cruise, the residual effects of sea ice were still obvious. These effects included the cold bottom water that roughly reflected the extent of the earlier ice, and low salinity surface water that still retained the signature of the ice melt from April and May. KN195-10 provided an opportunity to build on the spring observations and importantly tool place almost 3 weeks earlier in the year than di the prior summer cruise. In addition to providing access to the physical development of the shelf waters in June therefore, KN195-10 focused on the biological populations during their early summer conditions. For example, extensive net hauls were done to determine how

far on the shelf populations of large oceanic grazers, that are important prey items for juvenile fish, had moved since the spring sampling. Another important question was to determine where and to what extent some of the key fish populations such as pollock were spawning as evidenced by the distribution of their larval populations. The earlier sampling window of KN195-10 provided an opportunity to sample earlier in the fish ontogenetic development when presumably, more larval fish were still present. Although the core hydrographic and primary productivity programs on KN195-10 were similar in nature to those done on the spring cruises, the sampling approach differed in that the lack of ice allowed for a more standard survey approach in comparison to the feature-based sampling that was focused on the productive ice edged of spring.

Final preparations for KN195-10 commenced on June 12 in Dutch Harbor. Most of the gear need to be on-loaded at this time after its storage in Dutch Harbor after the spring cruises of the Healy. The science party moved onto the ship on June 13 and there were no delays in beginning the cruise on June 14. The cruise was divided into 2 legs by a stop in St. Paul of the Pribilof Islands on June 29. This stop provided for a change out of some of the science party as well as an opportunity for the teacher on-board to interact with the some of the teachers fro the island. Among the first priorities was a meeting among the senior scientists and officers of the Knorr that would be interacting to implement cruise activities. David Schull from WWU agreed to act as co-chief scientist with R. Sambrotto on this ambitious and logistically complex cruise.

This report summarizes the sampling program carried out during KN195-10 along with a brief summary of the hydrographic conditions recorded. One of the main goals of bringing together the many lines of information in the current report is to serve as a guide for researchers in identifying information relevant to their work that was collected during KN195-10.

2 Science Groups & Participants

The major research components on KN195-10 and the associated participants were as follows:

Long-term NOAA moorings – Bill Floering with support of rest of NOAA group. This group re-deployed one of the NOAA 70m moorings during the cruise.

Hydrography – Whitledge/ Stabeno groups. This group analyzed salts, nutrients, oxygen and chlorophyll from the Niskin casts at each station as well as helped to manage cruise event information. Sigrid Salo was the Project leader during the cruise.

Carbon Productivity - Lomas group. This group was represented by John Casey and Matt Tiahlo and collected water for productivity experiments on special casts and water for various other analyses from the standard casts. They worked in the RadVan for their standard ^{14}C productivity experiments as well as size fractionated and cell sorted productivity.

Nitrogen uptake and cycling – Sambrotto group. This group was composed of Sambrotto and Kali McKee and carried out ^{15}N productivity experiments as well as urea and growth response experiments.

Particle flux – Moran group - Roger Kelly, URI. Roger deployed a floating sediment trap on 4 occasions that collected particles for 24 hr. periods as well as measured Radium and Radon concentrations.

Euphausiid and macrozooplankton collections - Alexei Pinchuk, UAF, and Tracy Shaw, OSU. Alexei collected macrozooplankton with a MOCNESS and CalVET net for quantitative distributions. Tracy collected live euphausiids with a Bongo net for rate measurements and organic tracer assays.

Euphausiid rate measurements – Lessard group - Tracy Shaw did grazing, growth and reproduction experiments with euphausiids collected with Bongo nets and water collected on CTD casts.

Organic tracers of trophic transfer/euphausiid population age structure – Harvey group - They extracted organic pools from zooplankton and their prey from net tows and water from CTD casts.

Ichthyolplankton –This group collected larval fish in collaboration with A. Pinchuk's net hauls.

Microzooplankton grazing – Diane Stoecker and Kristin Blattner, UMD. This group performed grazing experiments on water from the daily productivity cast.

Benthic biological characterization and fluxes – Shull group, WWU. This group collected benthic samples with the multicorer and measured nutrient fluxes and Radon.

Benthic biogeochemical fluxes – Devol group - Heather Whitney. This group measured benthic fluxes of oxygen and nutrients on cores retrieved from the multicorer.

Bird distribution and abundance – (guest investigator). They made observations from the bridge during the day.

Marine mammal distribution and abundance – (guest investigator). They made observations from the bridge during the day.

Water column bio-optics - Eurico J. D'Sa group (guest investigator). Puneeta Naik measured particle profiles in the upper 100 m from samples from the Niskin rosette.

Additional underway measurements were done by Lisa Eisner who installed an ISUS nitrate sensor and a WetLabs acs hyperspectral absorption instrument.

CTD operations and support - WHOI science techs.

Data support - John Allison (leg 1) and Scott Loehrer (leg 2)

Educational component - Mark McKay, a teacher, comprised the educational component on board.

3 Sampling Operations

3.1 Bridge Observations

During daylight hours, quantitative observations for birds and marine mammals were made from the bridge by the bird and marine mammal groups. Both groups recorded GPS coordinated observations on laptops on the bridge.

3.2 Autonomous measurements from the ship

Continuous and autonomous sensing was done from the ship's seawater system as well as from meteorological instruments and depth recorders. A complete listing of these measurements along with their data format and calibration is available in the data synopsis in the appendix to this report. Briefly, surface seawater was pumped from 3 m to the science laboratory were several measurements were made. These include temperature and salinity from a thermosalinograph, oxygen from a membrane electrode and chlorophyll *a* from a fluorometer. In addition to the ship's instruments, Lisa Eisner installed a nitrate sensor as well as a WetLabs ac-s that measured hyperspectral adsorption. Ray Sambrotto installed an Advanced Laser Fluorescence System (ALFS) for phytoplankton characterization for the parts of the cruise when it was not being used for discrete measurements.

3.3 On Station, Over-the-side Operations

Most stations began with a CTD cast that included water sampling from a rosette of 24 - 10 L Niskin bottles to within 5 m of the bottom. This provided water samples for nutrients and other hydrographic measurements such as chlorophyll *a*. A variety of additional discrete samples were taken that varied from station to station. The stations can most easily be grouped by length into short, intermediate and long stations as described below.

3.3.1 Short Stations

In addition to the CTD cast, a short station may include sampling activities that add not more than 30 minutes onto the length of the station. These additional sampling activities may include for example, a productivity cast, a CalVET Net tow or ring net tow from the 3/8" wire off of the stern and an optics cast from an ancillary winch. For these operations, the ship was stationary. The optics casts were done only during daylight hours with the optimum time period being within several hours of local noon (~14:30 ship time that remained on Alaska Time). In addition, the side of the ship from which the optics package was deployed faced the sun. After the CTD, the order of order of operations for short stations was the optics cast and then the net hauls.

3.3.2 Intermediate Stations

These stations may include almost any of the activities that were performed on KN195-10 with the exception of the sediment trap deployments that require 24 hrs. The difference between the intermediate and long stations is based on the number of activities carried out and the total water depth. Some of the activities that can be done during an intermediate station in shallow water (multicorer for example) required a long station over slope and basin regions. Intermediate stations provide time for a variety of process-oriented and experimental work including - CalVET net

tow (Pinchuk); Bongo Net tows (2-3) at night (Lessard group); MOCNESS net tow (1) with a 0.68" conducting wire (Pinchuk and Hillgruber). A number of MOCNESS only stations were done in the first phase of the cruise to provide adequate sampling for the ichthyoplankton.

The MOCNESS tow was conducted at a speed of 1-2 knots. The multicore casts were conducted with the ship stationary. Benthic sampling typically was done at the end of the station or at a location slightly offset from the station location in order to avoid washing sediment into the water column during sample sieving and processing and deck cleanup.

3.3.3 Long Stations

Several CTD casts were conducted at each long station to assess diurnal variation. For multi-day stations, CTDs were done on the morning of each day with succeeding casts interspersed with activities occurring on the stern in order to maximize efficiency and minimize down time while the CTD bottles are being emptied. Diurnal sampling was also done for the zooplankton collections. Long stations also provided enough time for sediment trap deployments consisting of a trap line (5/8" dia poly-dac rope) that is 110m long with samples collected at 25 m, 40 m, 50 m, 60 m and 100 m. Stations were limited to shelf-slope locations with water depths greater than 300 m, and deployments lasted approximately 24 hours. The traps were deployed and recovered from the ship. The ship typically continued to sample spatially during the trap deployments.

3.3.4 Mooring Deployment

The mooring deployment during the cruise replaced on of the 4 NOAA moorings along the 70 m isobath. These are described in more detail in the individual group report section on moorings.

4 Additional Logistical and Operational Considerations

4.1 Educational outreach and personnel swap at St. Paul on June 29

The Knorr stopped at St. Paul Island on June 29 to exchange several personnel between legs 1 and 2. It also provided an opportunity for the Polar trek teacher on-board (Mark McKay) to interact with some teachers from St. Paul. In addition to the teachers, several science personnel visited with the teachers that make marine science an important part of their curriculum. These visits coincided with sampling in the waters around the Pribilof Islands.

4.2 Existing Moorings to Avoid

We worked near four NOAA moorings. The positions are listed below.

Bering Sea 2 (M2) 56.877°N, 164.057°W, 73m water depth. (There also were some other moorings within 1 nm).
Bering Sea 4 (M4) 57.853°N, 168.870, 71m water depth (Note – This mooring was inoperable was located during the cruise).
Bering Sea 5 (M5) 59.898°N, 171.711°W, 72m water depth
Bering Sea 8 (M8) 62.194°N, 174.668°W, 73m water depth

5 Cruise Track and Narrative on 4 Cruise Phases

The overall cruise track consisted of several cross shelf sections together with a long shelf (70m) section that re-occupied lines that were sampled in prior BEST cruises (Figure 1). In addition to the division of KN195-10 into 2 legs by the

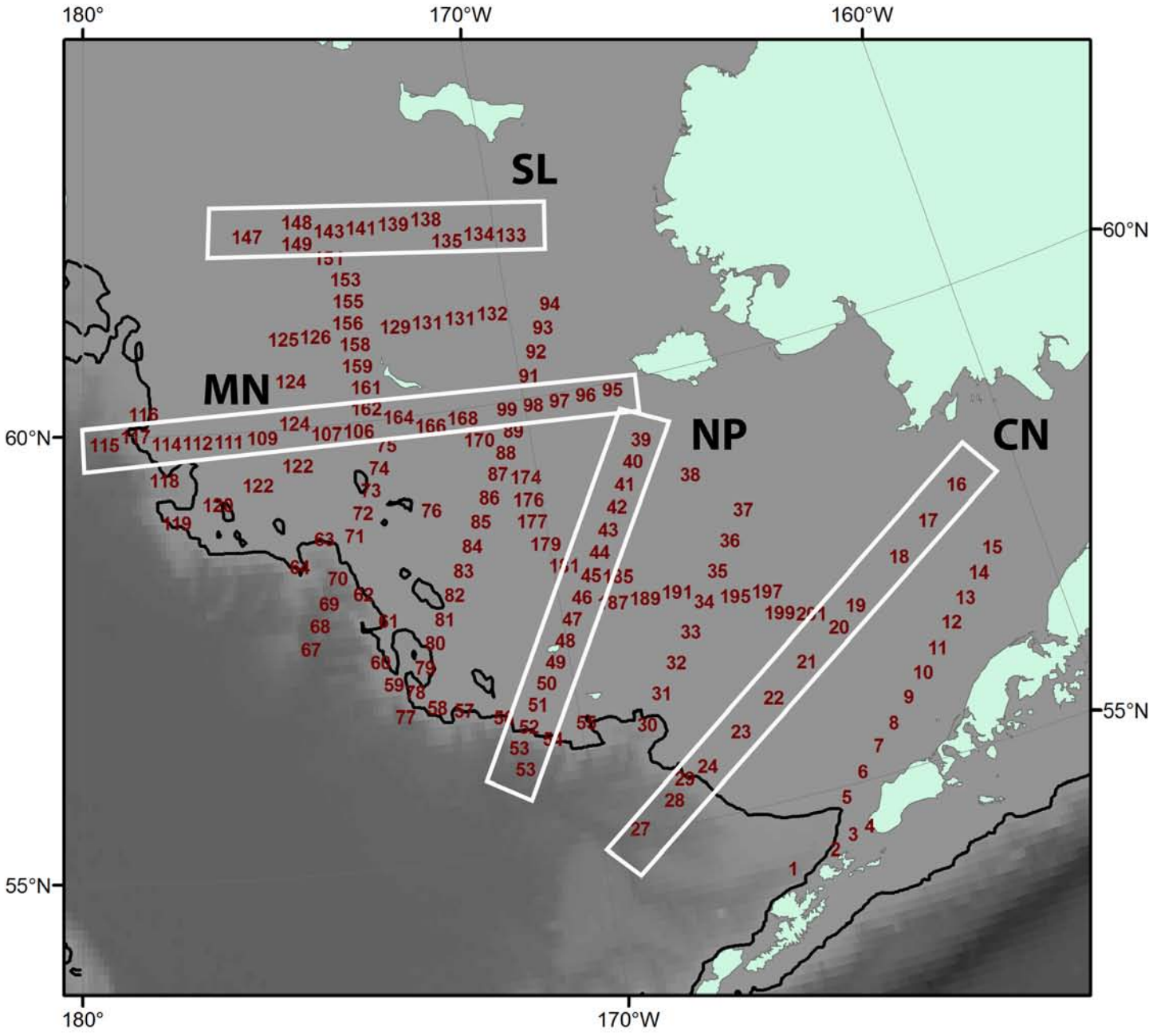


Figure 1. Map of stations occupied during KN195-10. (Note that for clarity, not all stations are shown). White boxes enclose stations comprising the major cross-shelf lines: CN – Cape Newenham; NP – Nunivak-Pribilof; MN – St. Mathew-Nunivak; SL – St. Lawrence. These cross shelf lines are connected by the long-shelf line along the 70 m isobath.

personnel exchange at St. Paul on June 29, the sampling activities were further organized into 4 phases of operation (2 phases before the St. Paul stop and 2 afterwards). The 4 phases and their respective major foci were as follows:

Phase 1 – June 12–19: *Sampling of the non-ice impacted region of southeastern Bering Sea and ichthyoplankton collection (stns. 1-29)*. Hydrographic sampling began in Unimak Pass in the southern part of the eastern Bering shelf (line UP). Four stations were occupied across this pass to characterize the water entering the Bering Sea from the Gulf of Alaska, particularly the fresh Alaska Coastal Current (ACC) that continues along the inner shelf of the eastern Bering. We next sampled along a series of cross-shelf sections in the southeastern Bering Sea (lines UAP, CN and CNN). The southern region was the only one not impacted significantly by ice this year and provides a contrast to the heavily ice-impacted northern shelf. In addition, it is one of the main spawning regions for pollock and other important commercial species and collections of ichthyoplankton were a top priority during this phase. A total of 29 MOCNESS deployments were done on this phase alone and the collection of larval fish by the Hillgruber and Pinchuk group reflected a variety of species including Pacific cod, arrowtooth flounder and walleye pollock. Both productivity incubations as well as multicore collections also were done. The phase included a sediment trap deployment at the deepest station on the CN line. We then worked back inshore along a line midway between the CN and NP lines that was intended to sample a region for larval fish that had not been well characterized previously.

Phase 2 – June 22-29: *Sampling of NP, shelf break and P14 lines*. This phase started with the occupation of the NP line from the inshore to offshore direction. The NP line was sampled in less than 2 days and produced a synoptic hydrographic survey of one of the main BEST lines. The only extended interruption from the sampling along this line was for Bill Floering to search for the NOAA mooring at M4 that had failed earlier. The mooring was found and marked for later retrieval. A second sediment trap deployment was done at the end of the NP line. We then proceeded north along the shelf break between the end of the NP line and Zhemchug Canyon. This provided an opportunity to sample along the 200 m isobath (stns. 54-64) to characterize the exchange of water between the shelf and slope. At Zhemchug Canyon, we ran the P14 line from the slope water of the Canyon to the intersection of the 70 m and MN line. Although not a major cross shelf line, the P14 line reoccupied the northern end of the WOCE P14 line that had been sampled 20 years earlier. This provided for calibration between the deep water salt and nutrient measurements as well as for the sampling of a region of the outer shelf that was routinely productive during both spring and summer. Of particular interest during KN195-10, was the presence of a large eddy in Zhemchug Canyon that was observed in the MODIS Chl *a* images at the start of the cruise. The P14 sampling was the first opportunity to sample what turned out to be one of the largest biological features of the cruise (see below). Once back on the middle shelf at the end of the P14 line, the Knorr went to St. Paul for the scheduled personnel exchange and this took place as planned.

The three microplankton productivity groups (Ray Sambrotto's nitrogen productivity group, Mike Lomas's carbon productivity group and Diane Stoecker's microzooplankton group) coordinated their sampling activities on the daily productivity cast. Euphausiid rate measurements were done when enough animals were obtained by Evelyn Lessard's group and these conditions were found at several stations in the outer shelf. Roger Harvey's group collected samples for later organic analyses. David Shull has been able to collect a number of sediment cores with the multicore, and together with Al Devol's group worked on the sediment profiles and fluxes. Samples were taken to calibrate Lisa Eisner's underway nitrate measurements against the on-board autoanalyzer system and the results from the continuous nitrate sensor appear useful. The CTD operations continued without major problems and the data support group has been able to utilize the existing resources to update and expand the BEST field catalog as we progress. The PolarTrek teacher on board worked with the underway Advanced Laser Fluorescence System (ALFs) and became proficient with this new instrument.

Phase 3 – June 29-July 8: *Sampling of the northern shelf region* (stns. 77-147). This region has been the most consistently impacted by the ice edge during the last decade. The region supported intense primary production in spring 2007 and 2009 and less intense production in spring 2008. To refine the spatial sampling in this important region, we sampled along an additional cross-shelf line between the NP and P14 lines (stns. 77-94). A surface drifter was deployed by NOAA at the outer shelf region of this line. This line took us well inshore, and included a region northeast of St. Mathew Island that had not previously been sampled by the BEST program. After this line, we were positioned to occupy the MN line from the coastal region to the shelf break (stns. 95-115). NOAA mooring M5 was re-deployed by Bill Floering during this section as planned. A third drifting sediment trap was deployed at the seaward end of this line. After retrieving the sediment trap, stations along the 200 m depth were occupied to continue the sampling along this isobath that was started in the south. We then sampled our way back across the shelf filling in unsampled regions south of the MN line and between the MN and SL lines (stns. 116-132). This put us in position to sample the SL from east to west (stns. 133-147). After completing the SL line, we had sampled more cross shelf lines than any prior BEST cruise and established a well distributed data set for the analysis of summer conditions.

Phase 4 – July 8-13: *Mid-shelf sampling along 70 m isobath and characterization of the shelf cold pool*. This provided an early summer sampling of the middle shelf and contributed towards a better understanding of the seasonal evolution of the physics, chemistry and biological distributions. In particular, it helped to define the extent of the shelf cold pool that is formed in winter in associated with ice production. This current occupation of the 70 m line, and the prior occupations done on previous BEST and NOAA cruises, has provided several years of seasonal observations on the changes in the middle shelf.

6 Meteorological Conditions

The transition to lower wind speeds and fairly calm sea states that typically occurs in the eastern Bering Sea during June was evident in KN195-10. Although winds cycled through peaks about every 3-4 days throughout the cruise, mean wind speeds, particularly in the first half of the cruise were relatively low (Figure 2A). Peak wind speeds during the first part of the cruise generally were associated with winds from the north (Figure 2B). This was similar to the association between stronger winds and northwesterly directions that was observed in the prior summer cruise (HLY0803). The exception in KN195-10 was the strongest storm encountered during the cruise around July 4 that had sustained winds of over 12 m/s for most of a 48 hr. period and was dominated by winds from the east and south. Wind speeds dropped significantly during Phase 4 as we progressed down the 70 m line. Sea state did not stop sampling activities at any time during the cruise and ocean conditions had no appreciable impact on the planned sampling.

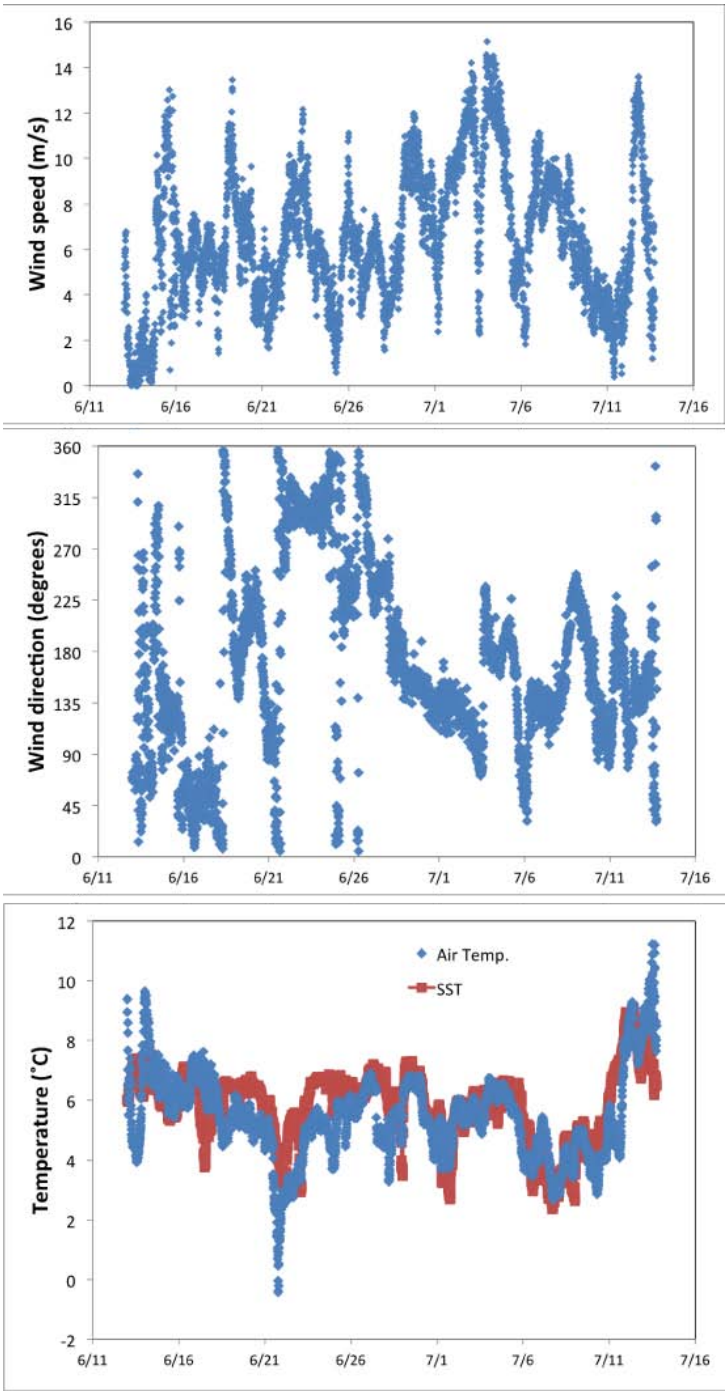


Figure 2. Meteorological conditions during KN195-10. Top – wind speed; middle – wind direction; 3 – sea surface and air temperatures.

7 Validation of Temperature, Salinity and Chl *a* measurements

The salinity and temperature data were processed on the ship to remove spurious measurements and to calibrate the sensor values against the salinometer measurements that were made. The T-S plot for all of the CTD casts made on KN195-10 is shown in Figure 3. The plot clearly shows the high salinity 'tail' of deep basin and slope water mixing into the lower salinity shelf waters as denoted by the decrease in temperature as the water mixes below a salinity of 33.5. This temperature decrease indicates the mixing between the warmer slope waters and the shelf cold pool water. This mixing is largely at depth as reflected by the elevated AOU (~100 uM) along the mixing line between the slope water and the cold/ fresh (-1.7˚C/ ~31.7) cold pool water. The warming of this slope/ shelf mixture is associated with increases in oxygen as AOU falls to negative values. This is compatible with the mixing of this water into the surface where it ventilates with the atmosphere and gains oxygen from photosynthesis. Based on the salinometer calibration and initial analysis of the salinity and temperature relationships from the

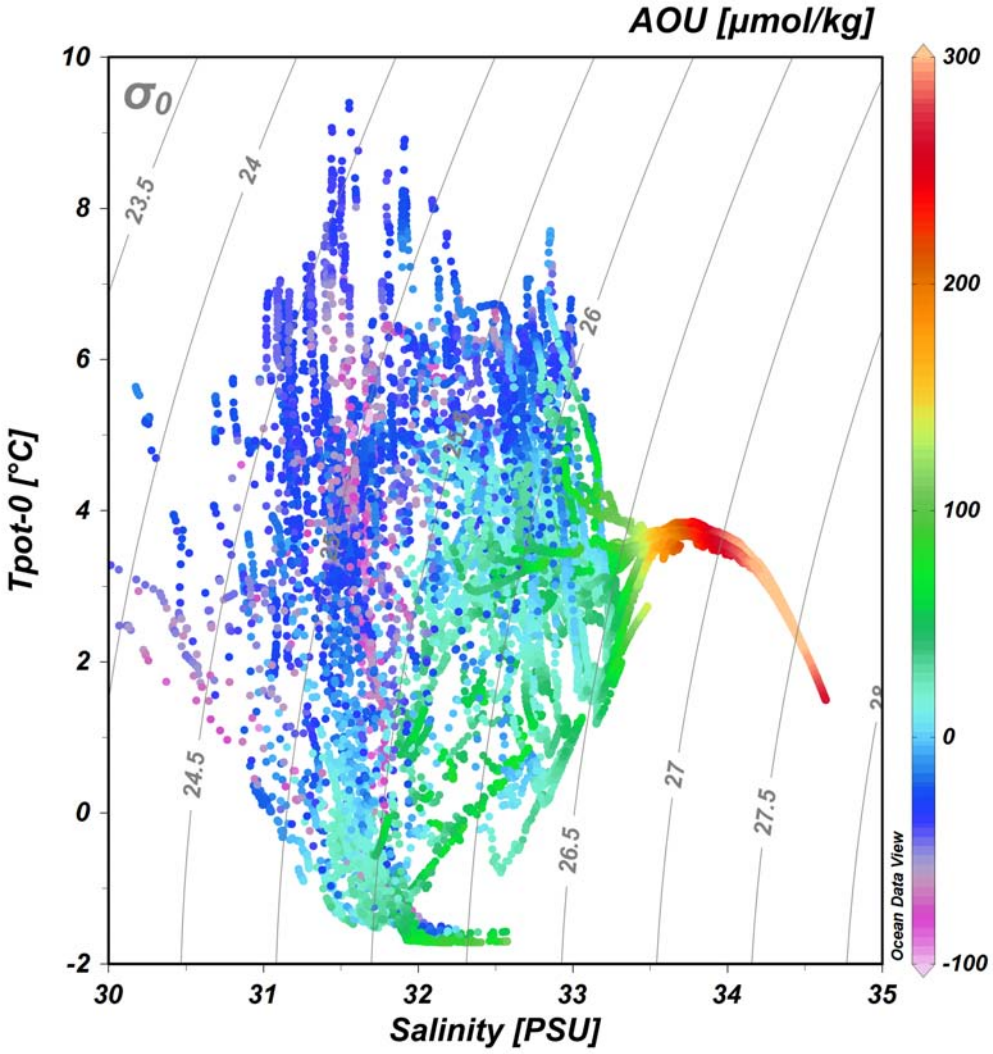


Figure 3. T-S diagram of all KN195-10 CTD data. Labeled isopleths are lines of constant density. Data have ben color coded to reflect the Apparent Oxygen Utilization (AOU, uM, defined as the difference between the saturation value of oxygen and its measured value).

CTD therefore, it appears that the KN195-10 data are robust and ready to use for further data analyses.

The CTD package also included a Chl *a* fluorometer that was logged with every cast. Although this instrument had a factory calibration, an independent calibration was done with discrete samples from the Nisken bottles by Dean Stockwell from UAF. The discrete Chl *a* samples were collected on Whatman GFF filters and analyzed with an acetone extraction method on a fluorometer whose chlorophyll fluorescence values were calibrated spectrophotometrically. The output of the in situ fluorometer was then calibrated against the discrete samples (Figure 4). The calibration provides a basis for using the in situ fluorometer data to estimate Chl *a* from the CTD casts.

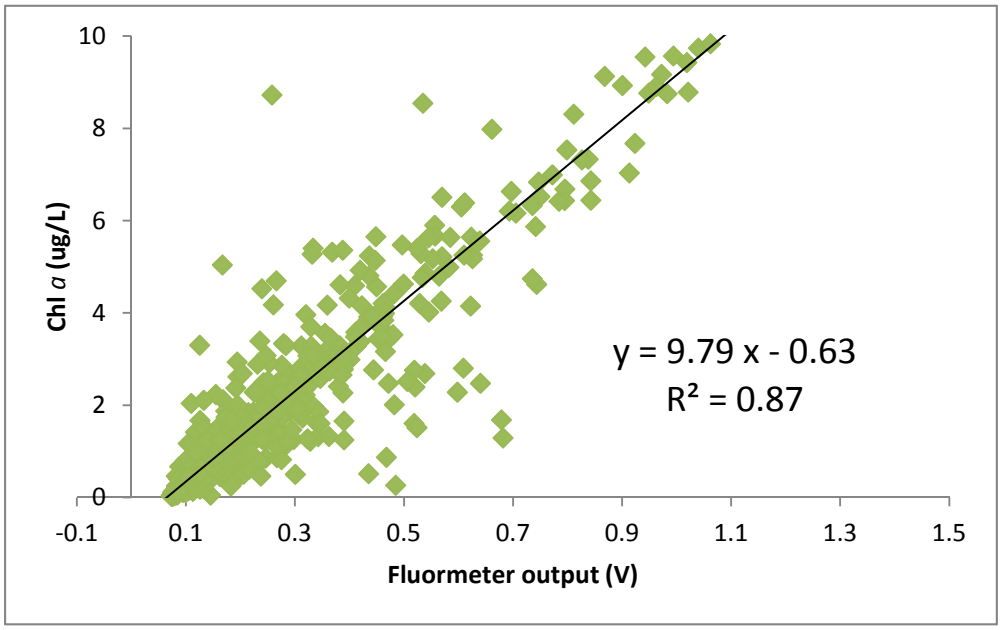


Figure 4. Calibration of extracted Chl a measurements against the raw voltage output of the in situ fluorometer during the KN195-10 cruise.

8 Underway and Remotely Sensed Data

The continuously measured properties from the ship's underway system provide a natural compliment to the remotely sensed features of surface waters and depicted distributions broadly comparable to those recorded in the summer, 2008 cruise a year before. The sea surface temperature and salinity measured along the ship's track during KN195-10 are shown in Figure 5. As in 2008, the ship recorded the coolest waters around Nunivak Island and these cold temperatures extended well offshore north of the Pribilof Islands (Figure 5A). Another patch of cool water covered the region between St. Matthew and St. Lawrence Islands. Water over the outer shelf and slope regions was generally the warmest, although surface waters of the southern shelf were the warmest water found (> 8˚C). Slightly cooler water was found west of Unimak Pass and around St. Paul Island. The halo of low salinity around St Paul may reflect the mixing of cooler, sub-surface water to the surface by tides.

The pattern of surface salinity was similar to that of temperature in the northern and central shelf regions (Figure 5B). The similarity was reflected in the fresher waters recorded in the region of the cooler surface waters in the inner zones of the central and northern shelf. This similarity broke down in the southern shelf however, where surface waters retained a lower salinity signature despite being some of the warmest waters found. Surface salinities were much lower in the middle shelf waters of the northern region than in the south. Together, the surface temperature and salinity data reflect the impact of sea ice earlier in the year. The cooler, fresher waters of the northern shelf likely reflect the longer presence of ice and the greater melting that occurred there. The reduced low surface salinity signal on the central and southern shelf reflects the lower volume of melt water received in these regions and the higher temperatures in the south reflect the longer ice-free time and subsequent greater heat absorption.

The region bounded by Nunivak, St. Matthew and the Pribilof Islands is particularly dynamic. Here, warm, salty water extends to the 70 m line south of St. Mathew, but appears to retreat offshore just north of the Pribilof Islands. It is not clear if this pattern reflects actual cross shelf exchange, but as will be shown in hydrographic section data below, this region does exhibit salinity and temperature differences at deep water that are compatible with enhanced cross-shelf mixing. Thus, similar to the results of the summer cruise in 2008 (HLY0803), there is a good example of the link we hope to make between the earlier ice extent and the subsequent patterns of shelf hydrographic development.

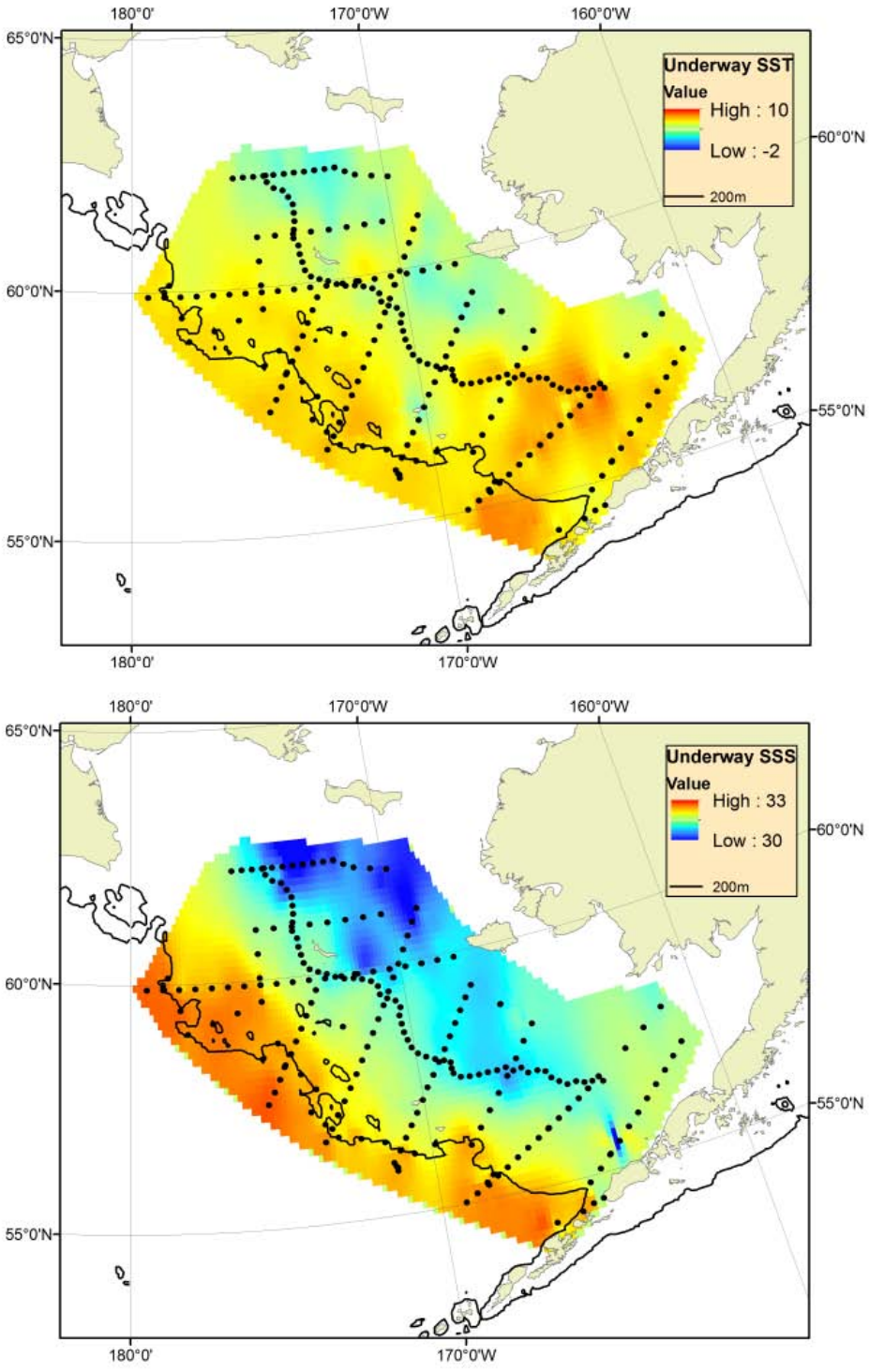


Figure 5. Results of underway mapping of Top:. Sea surface temperature, and Bottom: Sea surface salinity from KN195-10.

Several clear MODIS images of the eastern Bering Sea are available for the time period around the KN195-10 cruise. The 8-day composite images were more informative than the monthly composites because they record smaller scale features that can be averaged away in the monthly images. Two particularly clear 8-day composites are shown in Figure 6 for the periods of June 3-9 and June 19-26. The shots are separated by approximately 16 days and show several features relevant to the distribution of surface phytoplankton biomass during KN195-10. The earlier shot that was collected just before the start of the cruise (Figure 6 top), is the clearest image of the eastern shelf from the June – July period. It shows intense production along the UAP line as well in the inner shelf region from the CN line to north of the MN line near Nunivak Island. The middle shelf just seaward of the 70 m line has much less phytoplankton and a long stretch of low Chl *a* water extends from the CN line to St. Lawrence Island at these depths. This pattern is consistent with the roll of the inner, tidally mixed front at 30-50 m in supplying surface waters with nutrients for biological production throughout the summer. In deeper shelf waters, there is not enough mixing to resupply the euphotic zone with nutrients after the initial spring bloom removes the end-of-winter supply. The low Chl *a* middle shelf region is broader and has lower Chl *a* levels near St. Matthew Island and up to St. Lawrence Island. This distribution is similar to the region of low surface salinity in Figure 5 (Bottom) and may reflect the intensification of vertical stratification caused by the ice melt in this region.

One of the most obvious biological features in both MODIS scenes is the large anticyclonic eddy recorded in Zhemchug Canyon (along the P14 line) in both scenes. The peak biomass associated with the ring structure is clear in both images, as is the lower, but still elevated Chl *a* in the surrounding slope region. An intense band of Chl *a* inshore of the 200 m isobath also is apparent in both scenes. These structures in the Zhemchug Canyon region first appear in a MODIS image from late May and are a consistent feature of all clear images in this region until late July. The Chl *a* levels also are greater in the June 3-9 period than they are 16 days later. The Knorr sampled the P14 line that went through this region on June 26 and 27. Such eddies are a common feature along the shelf break region of the eastern Bering Sea, although during KN195-10, we had a unique opportunity to sample a large and long-lived feature that potentially had a large impact on the summer productivity of the region.

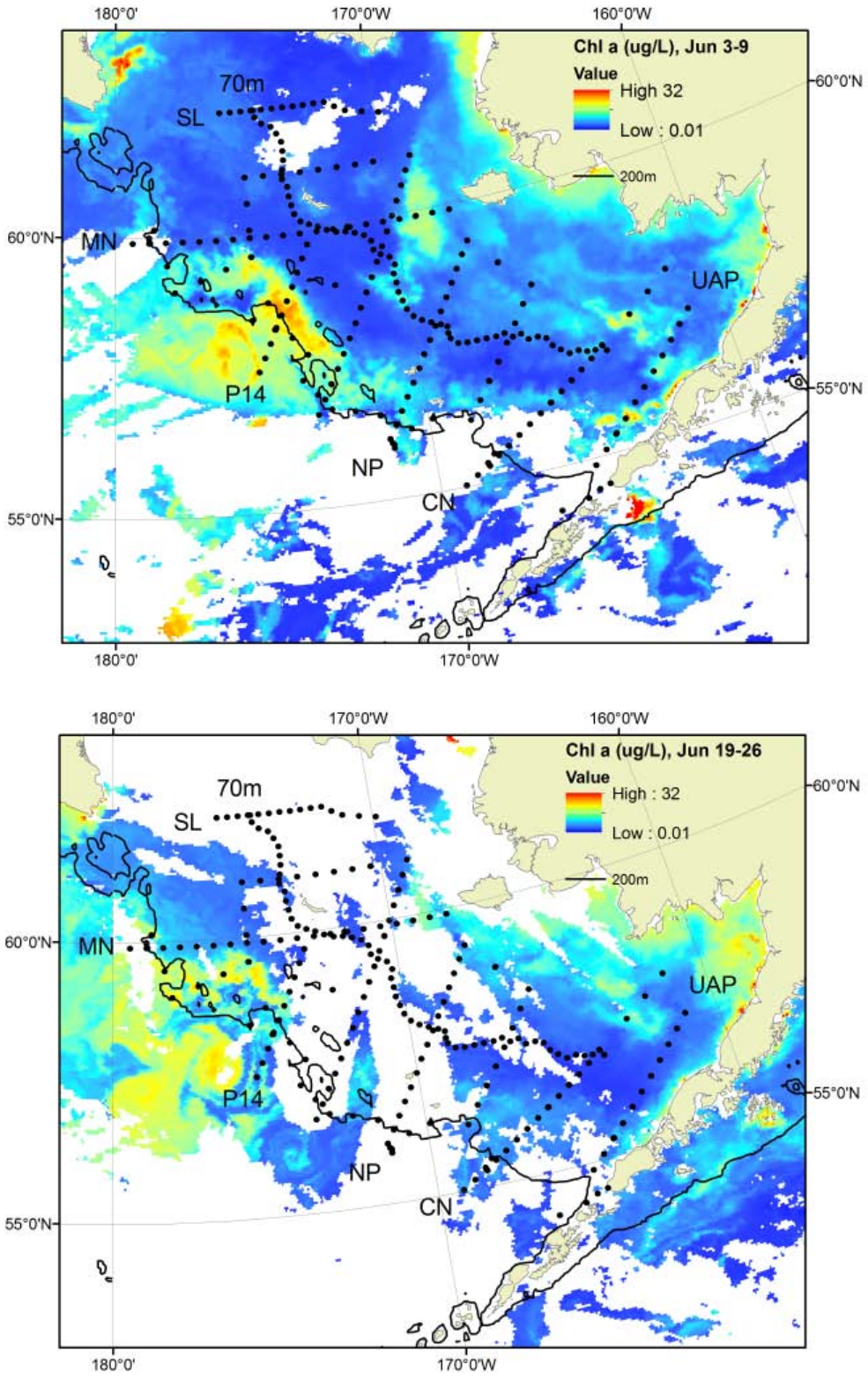


Figure 6. Remotely sensed Chl a in the Bering Sea in and around the time of KN195-10. Top – MODIS Terra Chl a image for the 8-day period from June 3-9, 2009; Bottom - Chl a image for the 8-day period from

9 Preliminary Hydrographic results

Although the nutrient data measured under the direction of Fred Menzia during the cruise has not been finalized, it is suitable for developing sections for preliminary review of data from the cruise. For this report, 9 properties were plotted for each of the 5 major sections (CN, NP, MN, SL and 70m lines). The properties include salinity, temperature, the 5 nutrients (nitrate, nitrite, ammonium, phosphate and silicate), Chl *a* (from the in situ sensor) and density. Even at this stage of processing, the property distributions are very interpretable and show little if any spurious data. It appears that the hydrographic data from KN195-10 will soon be ready to use and yield extensive information on the summer conditions on the eastern shelf.

Although it is not the purpose of this report to analyze the hydrography from the cruise in detail, a brief overview will serve to illustrate the robust nature of the data and some of the ways it can be used. For each of the sections, the 9 properties have been grouped into 5 sections, each with one property distribution colorized and another overlain as labeled isopleths. The five combinations are: temperature with salinity overlain; nitrate with density overlain; fluorescence with nitrate overlain; ammonium with nitrite overlain; phosphate with density overlain; and finally silicate with density overlain. Starting from the southern cross-shelf section CN (Figures 7 & 8), the salinity distributions shows the higher salinity slope water encroaching on the middle shelf at depth (Figure 7A). Colder (<1˚C) water persists at depth in the deeper middle shelf region. This is a pattern common to all cross shelf sections on the eastern shelf and also manifests itself in the distribution of nutrients. The deep-water nutrients nitrate, phosphate and silicate, all show the same spatial distribution as salinity (Figures 7B & 8 top & bottom). Although Chl *a* levels are much lower than they were in spring (Figure 7C), there is still significant Chl *a* in the surface waters of the southern shelf, particularly in the inshore region and along the shelf break. These are the same regions that exhibited elevated Chl a in the MODIS imagery as well (Figure 6). A major feature of the summer shelf is the intense regeneration signal associated with the middle shelf sediments, here illustrated by the elevated ammonium levels (Figure 6D). The ammonium distribution also displays another feature that is consistent on this shelf. This is the subsurface ammonium maximum that connects the high ammonium bottom waters on the middle shelf to the surface waters of the shelf break front. The distributions of the other deep water nutrients phosphate and silicate are similar to that of nitrate (Figure 8). The exception is the more rapid decrease of silicate along the bottom as the slope water mixes on-shore.

The distributions along the NP line provide a useful contrast with the other cross-shelf sections because they show the large impact of the Pribilof Islands and the vertical mixing in the nearby water (Figures 9 & 10). This mixing is reflected by the elevated nutrient and Chl *a* concentrations around the islands. Elevated nutrients remain in the cold pool water inshore of the islands, perhaps having mixed around the islands in the clockwise circulation that dominates in this region (Figures 9B &

10). The elevated ammonium levels at depth and their extension offshore between the 25.5 and 26 isopycnals are still obvious however (Figure 9D). In fact, the sloping isopycnals that connect shelf and slope waters near the Pribilof Islands are much steeper than they are in the other sections and suggest that the exchange of material between these regions also is greater near the islands.

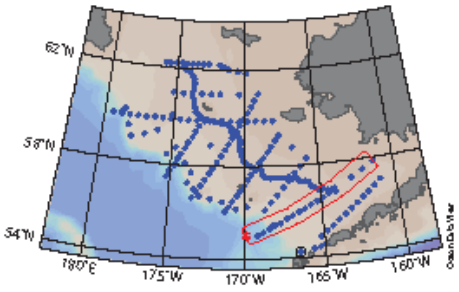
The relationship between the deep-water nutrients and the salinity distributions remain clear along the MN line (Figure 11 & 12). The MN line passes through a much colder region of the shelf cold pool and had lower surface salinity values than the more southerly sections, however (Figure 11A). The MN line also exhibits a more intense Chl *a* maximum near the shelf break that likely reflects the same elevated biomass suggested by the MODIS images in Figure 6. The sub-surface ammonium layer below this Chl *a* layer was more intense than was seen in the south (Figure 11 C&D). The middle shelf ammonium maximum at depth was also present, but in the colder bottom water had a lower ammonium concentration than in the south.

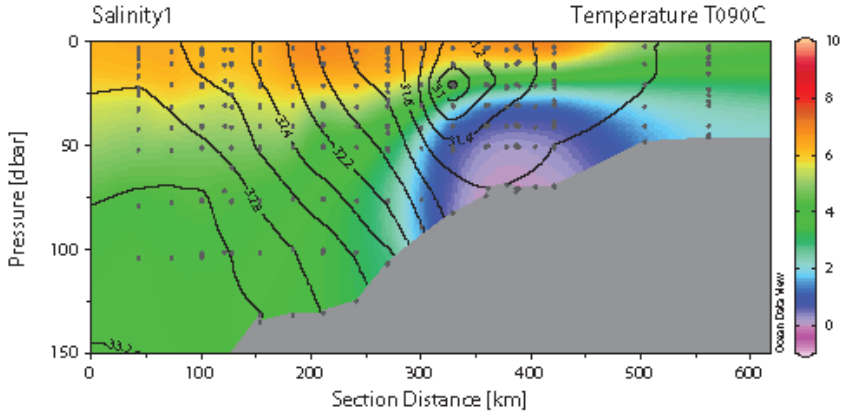
The SL line terminates at the international boundary and does not include the slope region that the more southerly sections do (Figures 13 & 14). The relationship between the slope water and deep-water nutrients is still clear however. Unique features of the SL line as compared to the more southerly sections include the greater levels of sub-surface Chl *a* along the SL line as well as its more extensive cold pool. The surface Chl a levels at the western end of the SL line are similar to the increased levels suggested by the MODIS imagery here (Figure 6). The mid-shelf ammonium levels at depth along the SL line are as large as those along the CN line (Figure 13D).

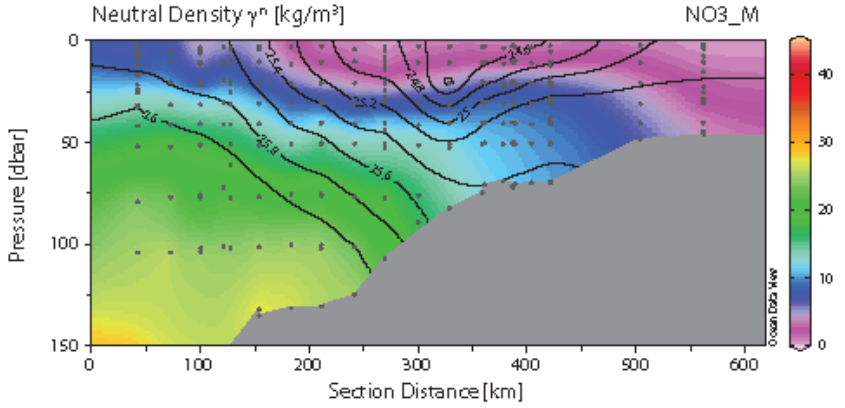
The distributions along the 70 m line tie together many of the features seen in the cross shelf sections as well as those seen in the underway mapping (Figure 15 & 16). Most obvious is the warming of the surface waters and the lessening of the cold pool from north to south (Figure 15 A). For example, the 70 M line shows the disappearance of the sub-zero cold pool temperatures between 400 and 600 km (just off Nunivak Island). It also shows the long shelf extent of the low salinity surface waters that show up at several places along the section. These distinct low salinity pools probably reflecting the residual melt water from the spring. The surface horizontal temperature and salinity gradients are not associated with large changes in surface nitrate levels. Deep-water nutrient levels are greater in the higher salinity deep waters of the northern shelf and a smaller patch of higher salinity water just north of the Alaskan Peninsula however, and confirm their slope origin. The 70 M line also shows that subsurface Chl *a* layers are an important biological feature of the eastern Bering Sea shelf in summer and were found at several places along the line, particularly near the low surface salinity regions. There also was an association of elevated bottom water ammonium with these patches.

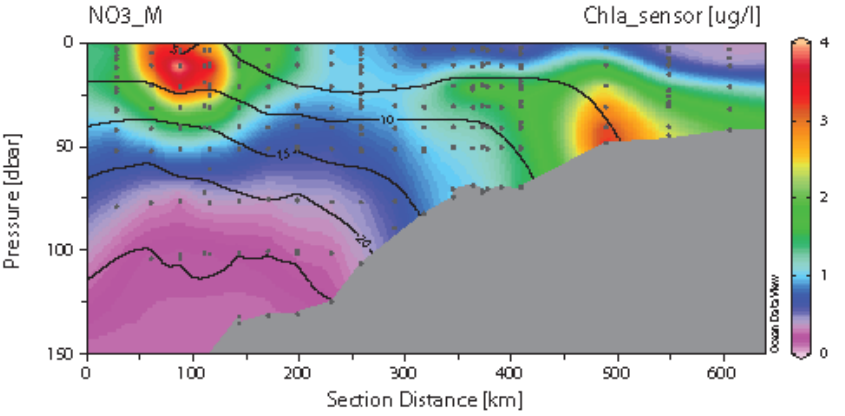
The smooth variations and interpretable nature of the representative sections shown here is encouraging. There results of the KN195-10 sampling will be of

significant use in analyzing the core trophic level hypotheses of the BEST BSIERP program, particularly as the discrete biological and chemical samples continue to be analyzed.









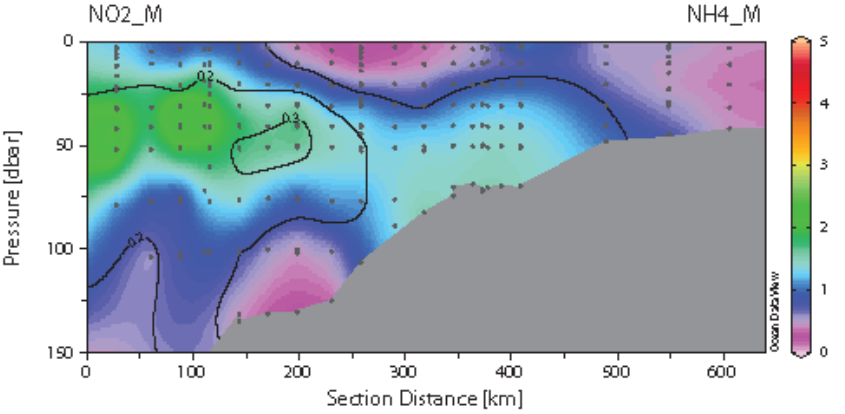


Figure 7. Sections from the CN line (Fig. 1 & inset above; distances are from northern end of line). A. Temperature (˚C; color bar) with salinity (labeled isopleths). B. Nitrate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths). C. Chl a fluorescence (ug l^{1}; color bar) with nitrate (mM; labeled isopleths). D. Ammonium (mM; color bar) with nitrite (mM; labeled isopleths).

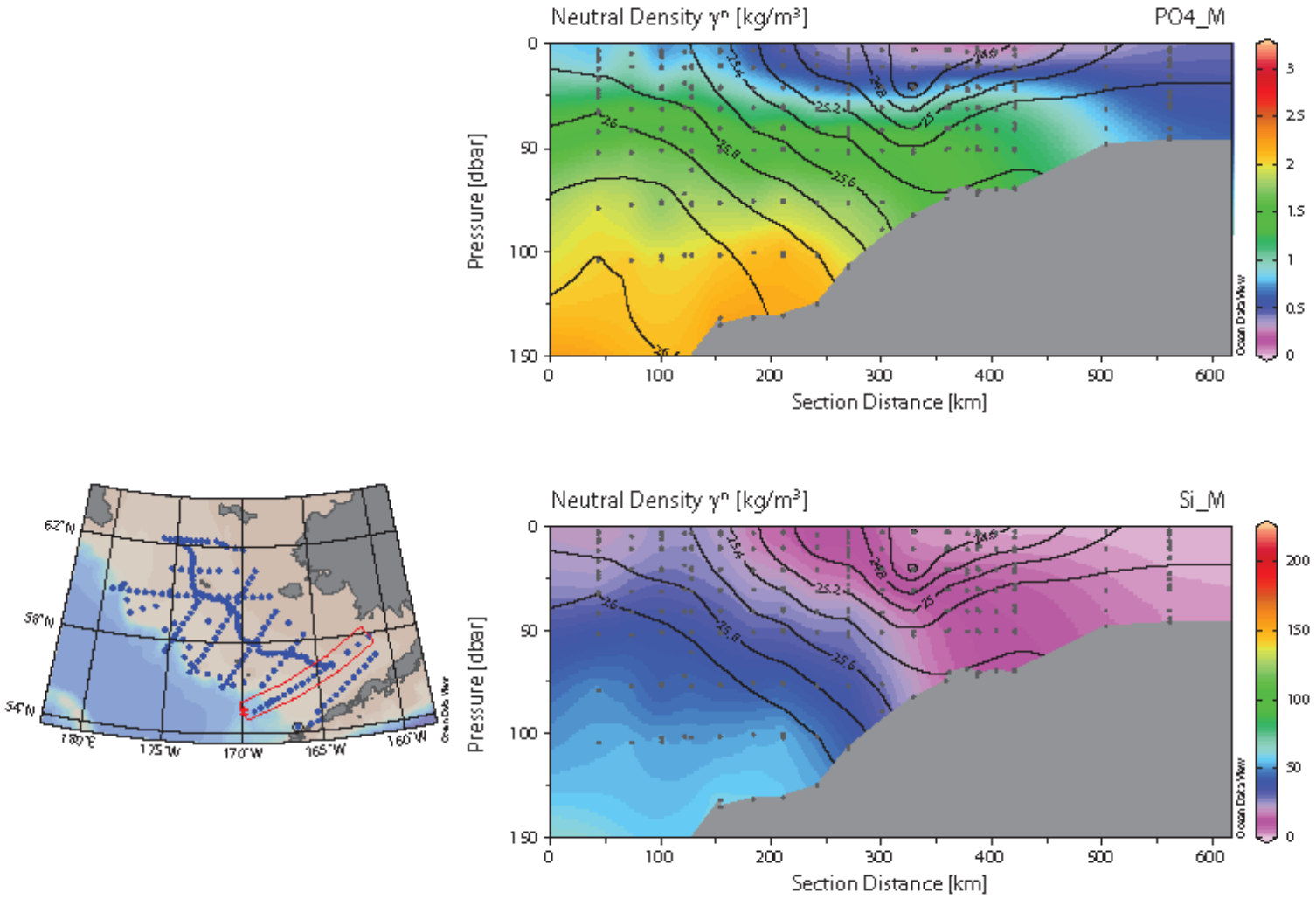
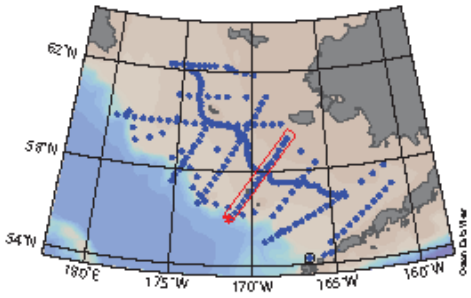
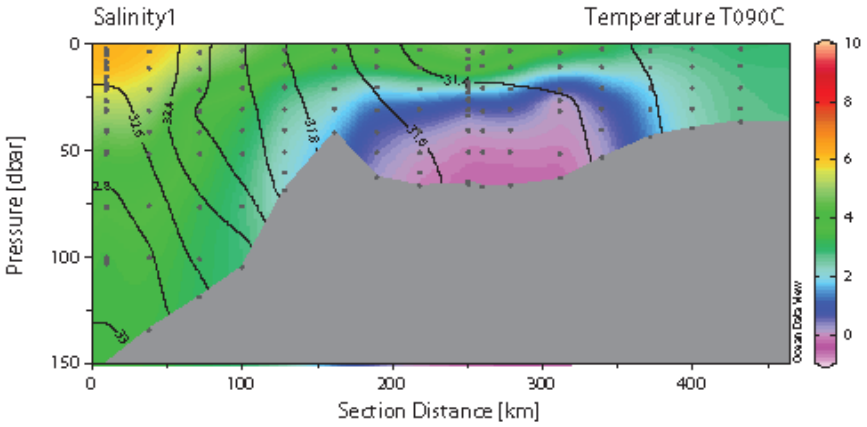
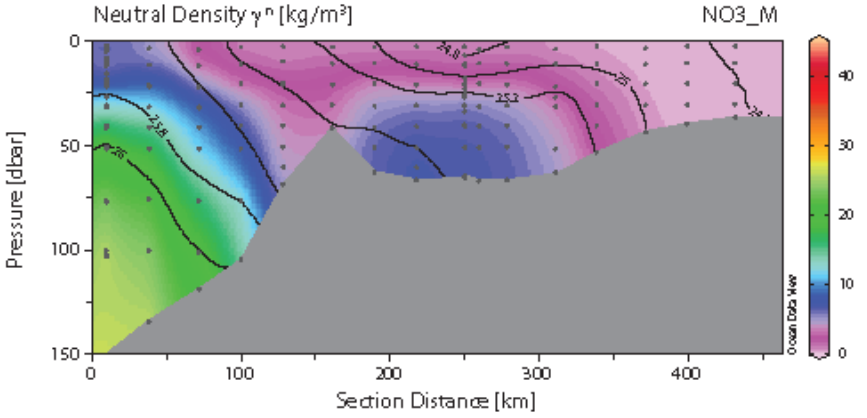
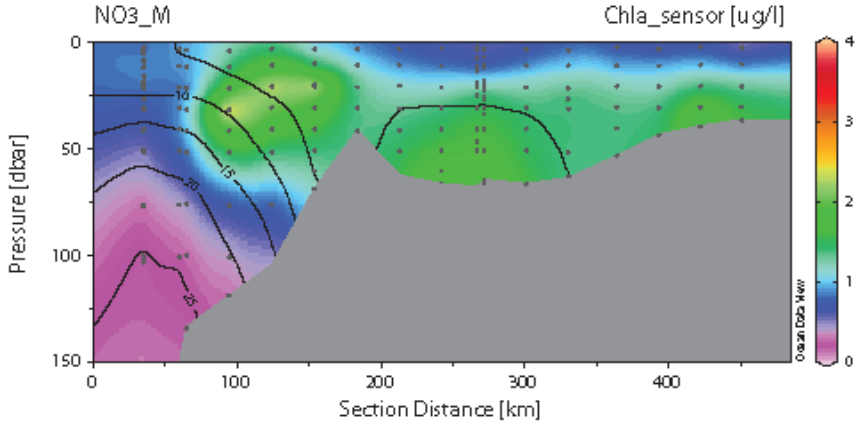


Figure 8. Sections from CN line, continued. Top. Phosphate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths). Bottom. Phosphate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths).









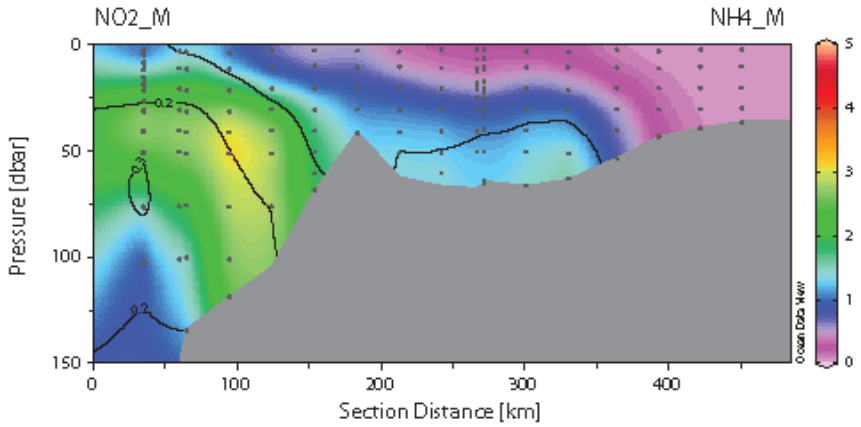


Figure 9. Sections from the NP line (Fig. 1 & inset above; distances are from northern end of line). A. Temperature (˚C; color bar) with salinity (labeled isopleths). B. Nitrate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths). C. Chl a fluorescence (ug l^{-1}; color bar) with nitrate (mM; labeled isopleths). D. Ammonium (mM; color bar) with nitrite (mM; labeled isopleths).

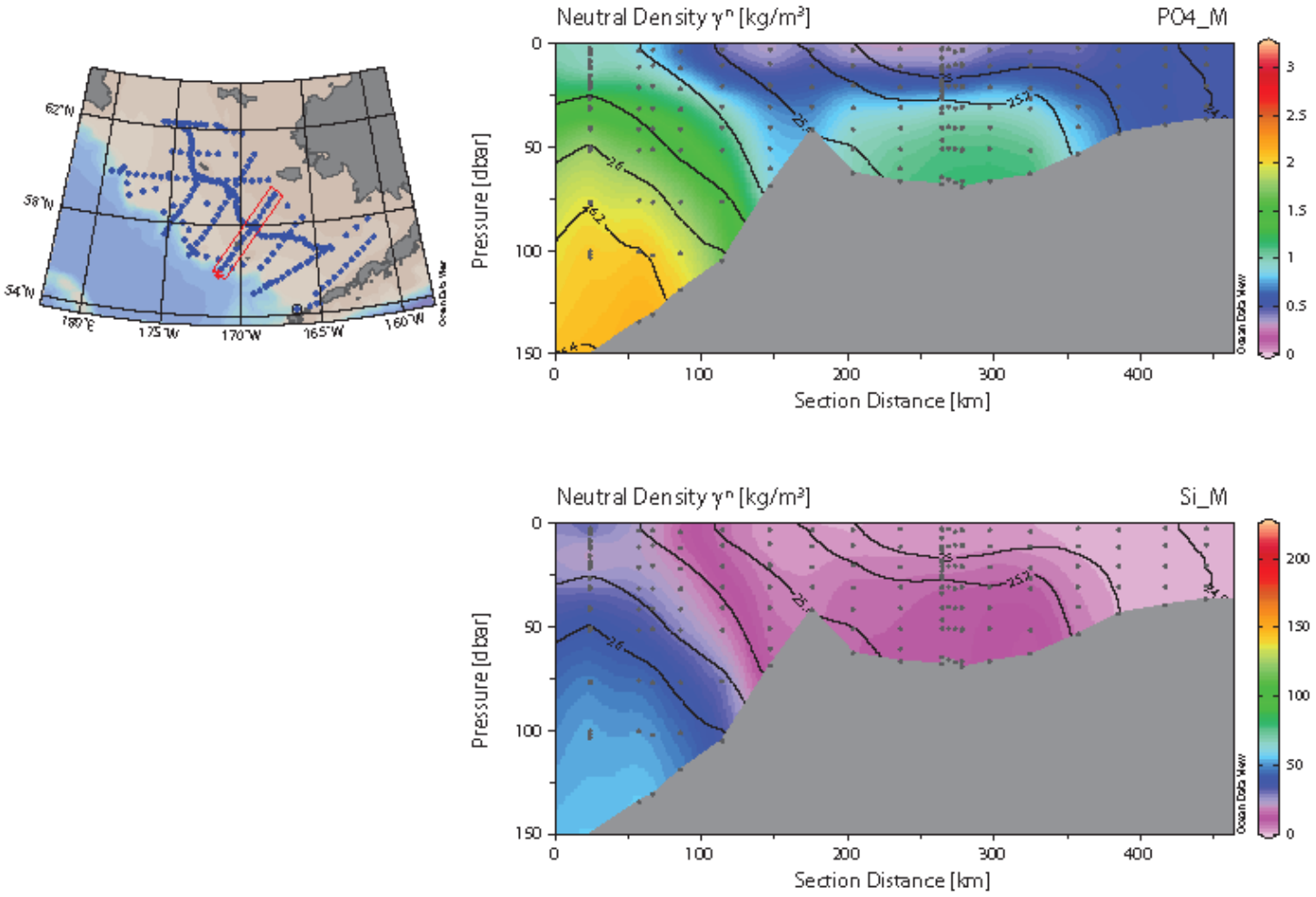
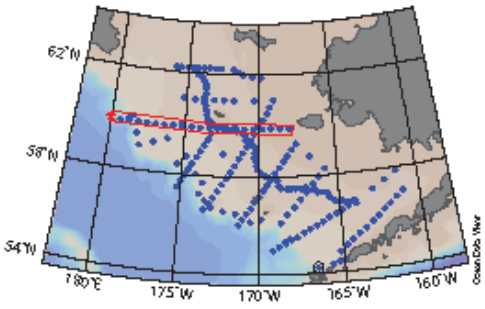
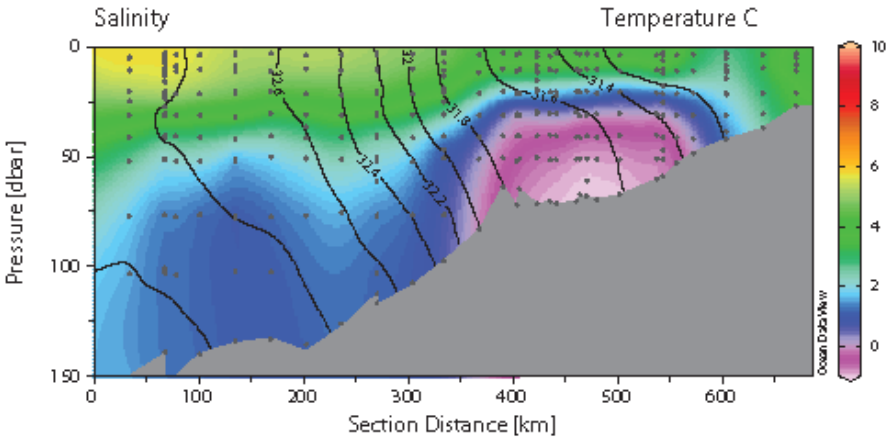
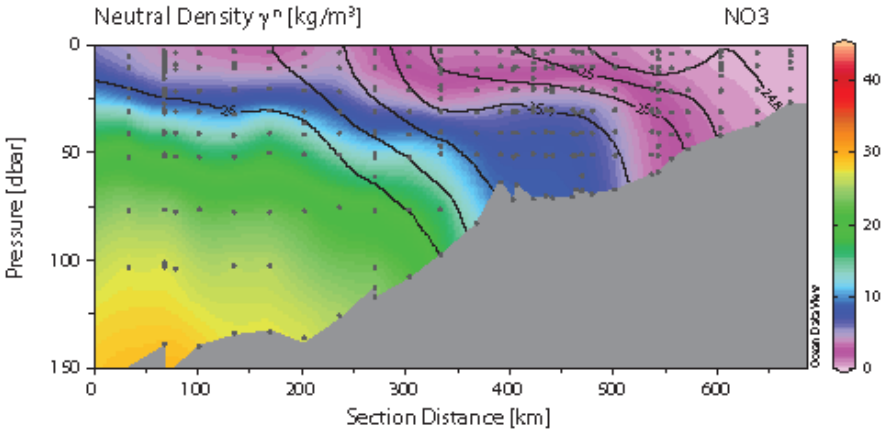
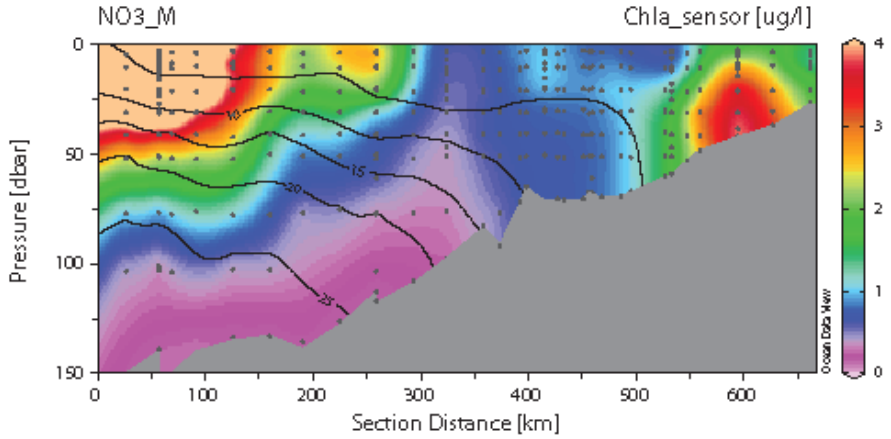


Figure 10. Sections from NP line, continued. Top. Phosphate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths). Bottom. Phosphate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths).









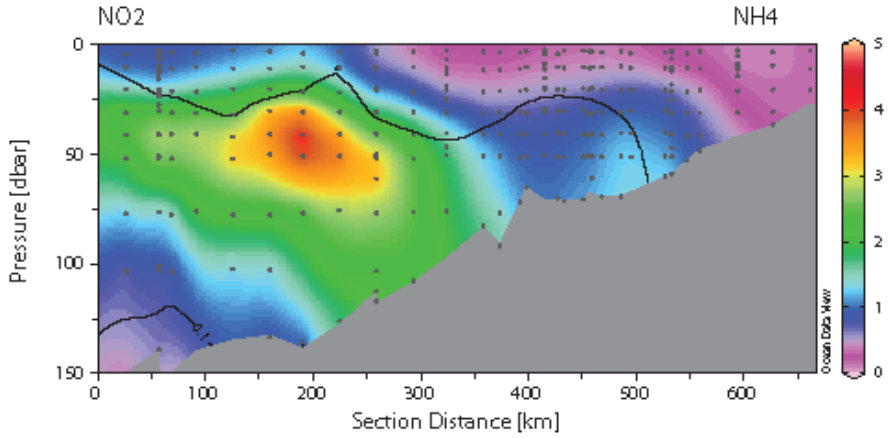


Figure 11. Sections from the MN line (Fig. 1 & inset above; distances are from northern end of line). A. Temperature (˚C; color bar) with salinity (labeled isopleths). B. Nitrate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths). C. Chl a fluorescence (ug l^{1}; color bar) with nitrate (mM; labeled isopleths). D. Ammonium (mM; color bar) with nitrite (mM; labeled isopleths).

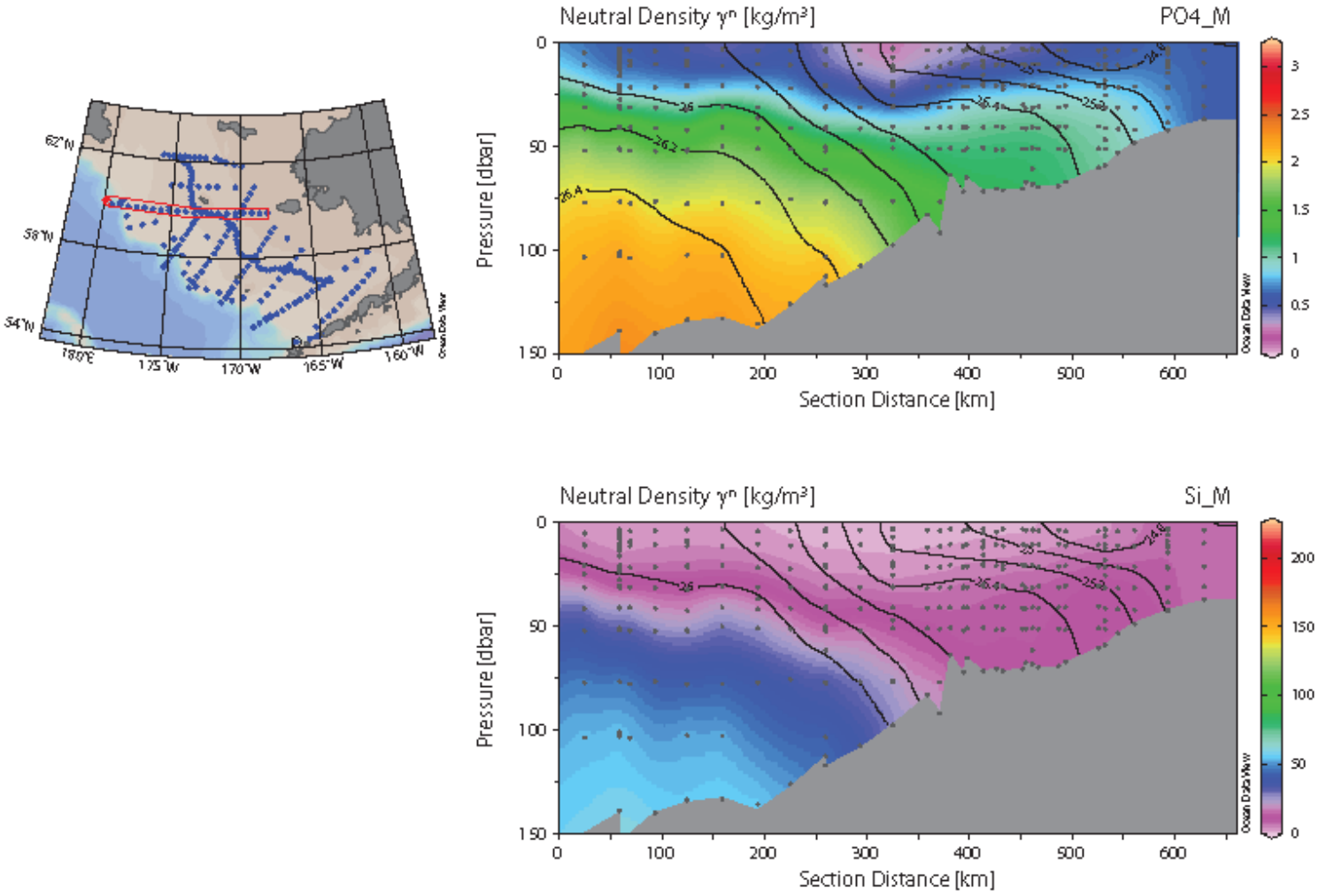
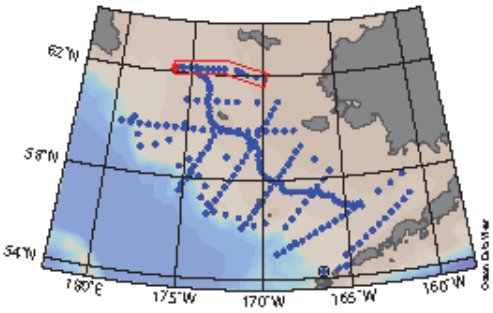
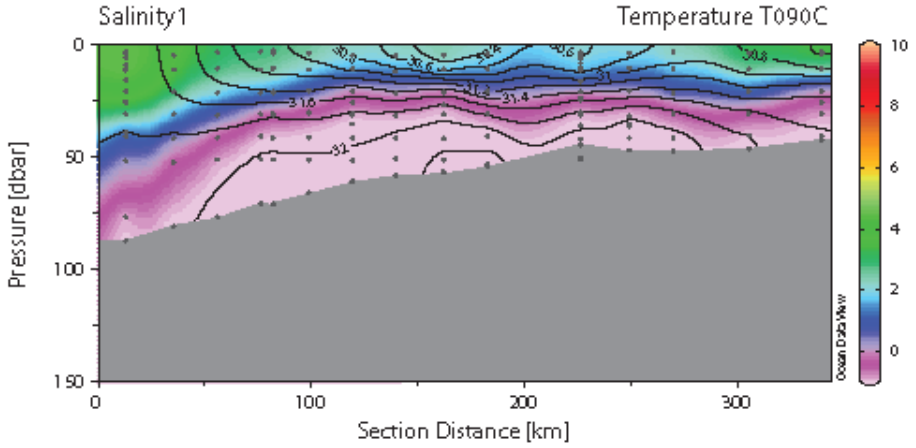
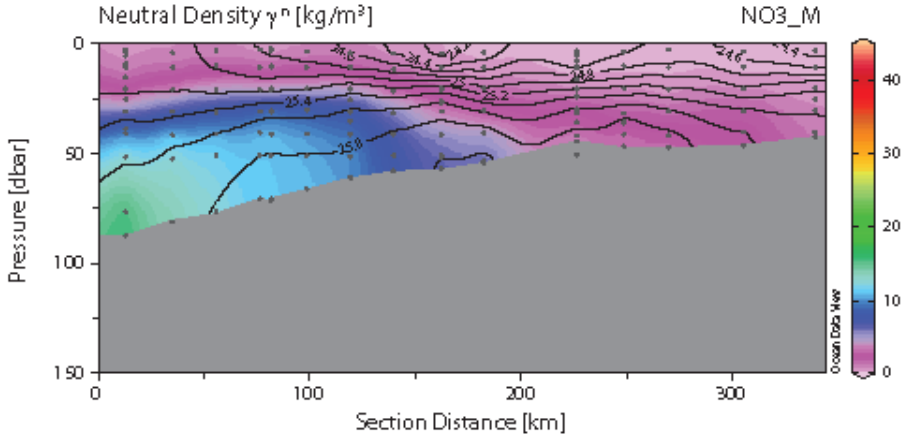
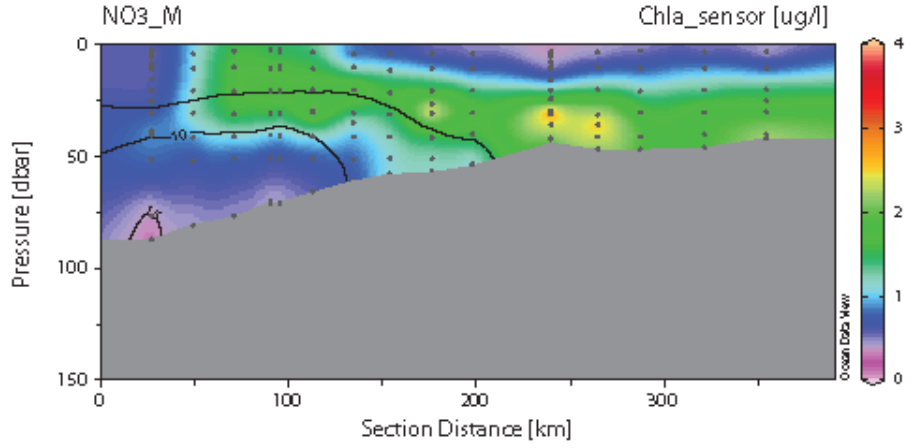


Figure 12. Sections from MN line, continued. Top. Phosphate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths). Bottom. Phosphate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths).









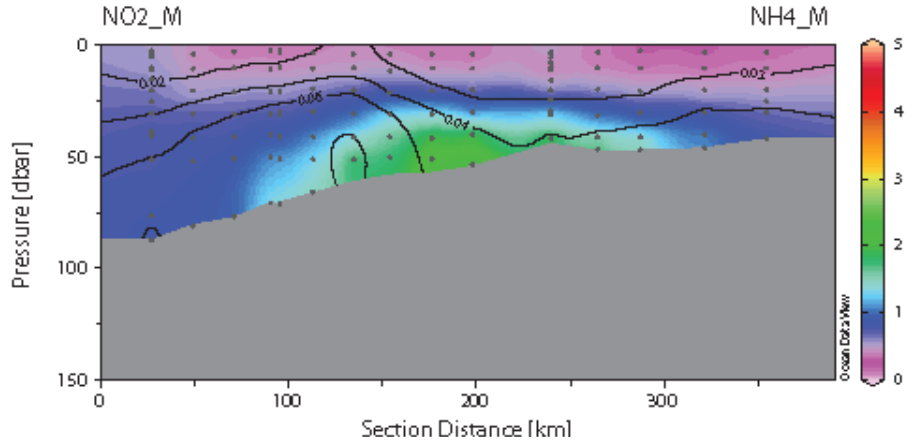


Figure 13. Sections from the SL line (Fig. 1 & inset above; distances are from northern end of line). A. Temperature (˚C; color bar) with salinity (labeled isopleths). B. Nitrate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths). C. Chl a fluorescence (ug l^{-1}; color bar) with nitrate (mM; labeled isopleths). D. Ammonium (mM; color bar) with nitrite (mM; labeled isopleths).

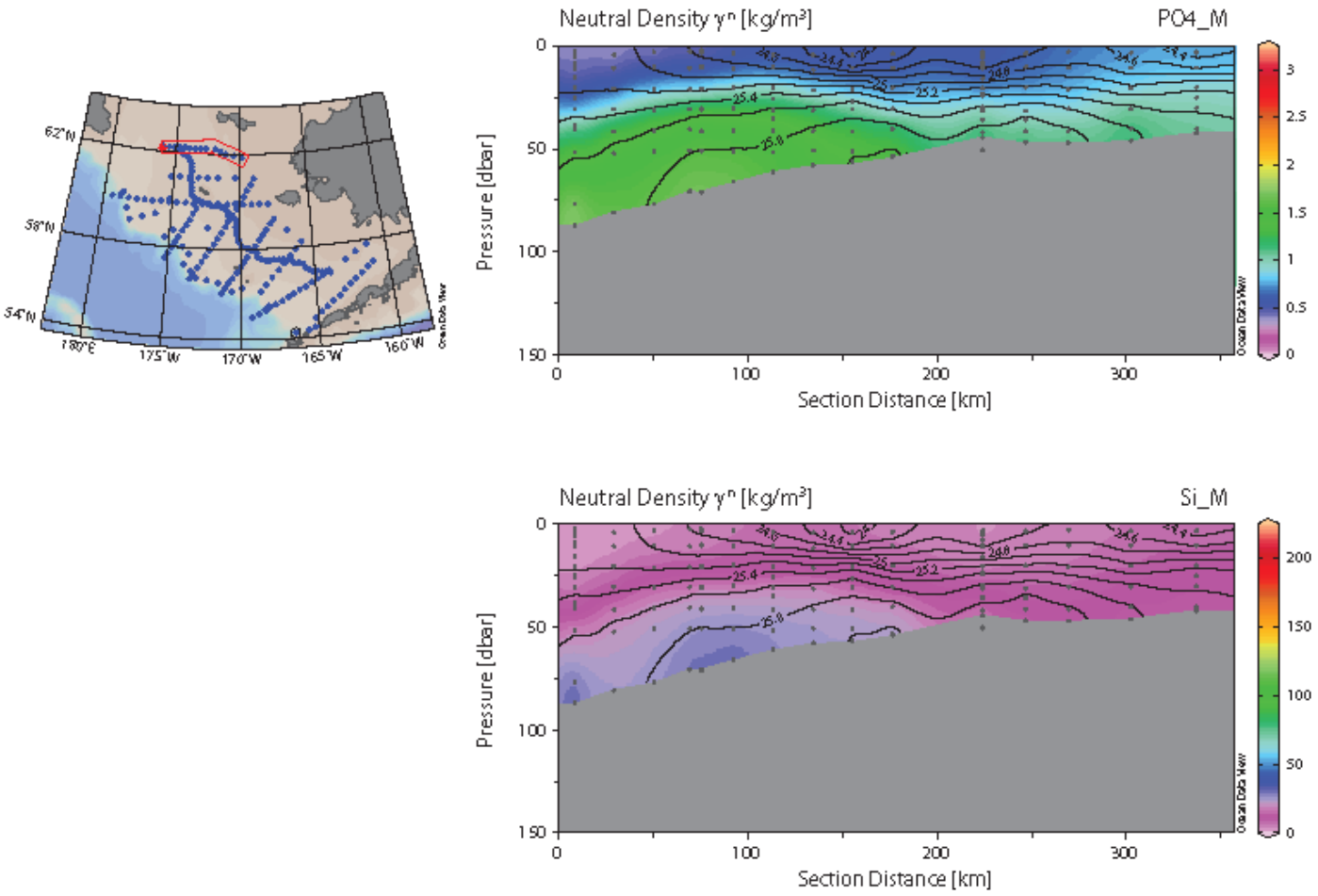
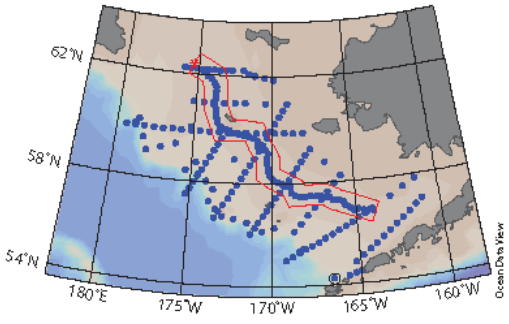


Figure 14. Sections from SL line, continued. Top. Phosphate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths). Bottom. Phosphate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths).



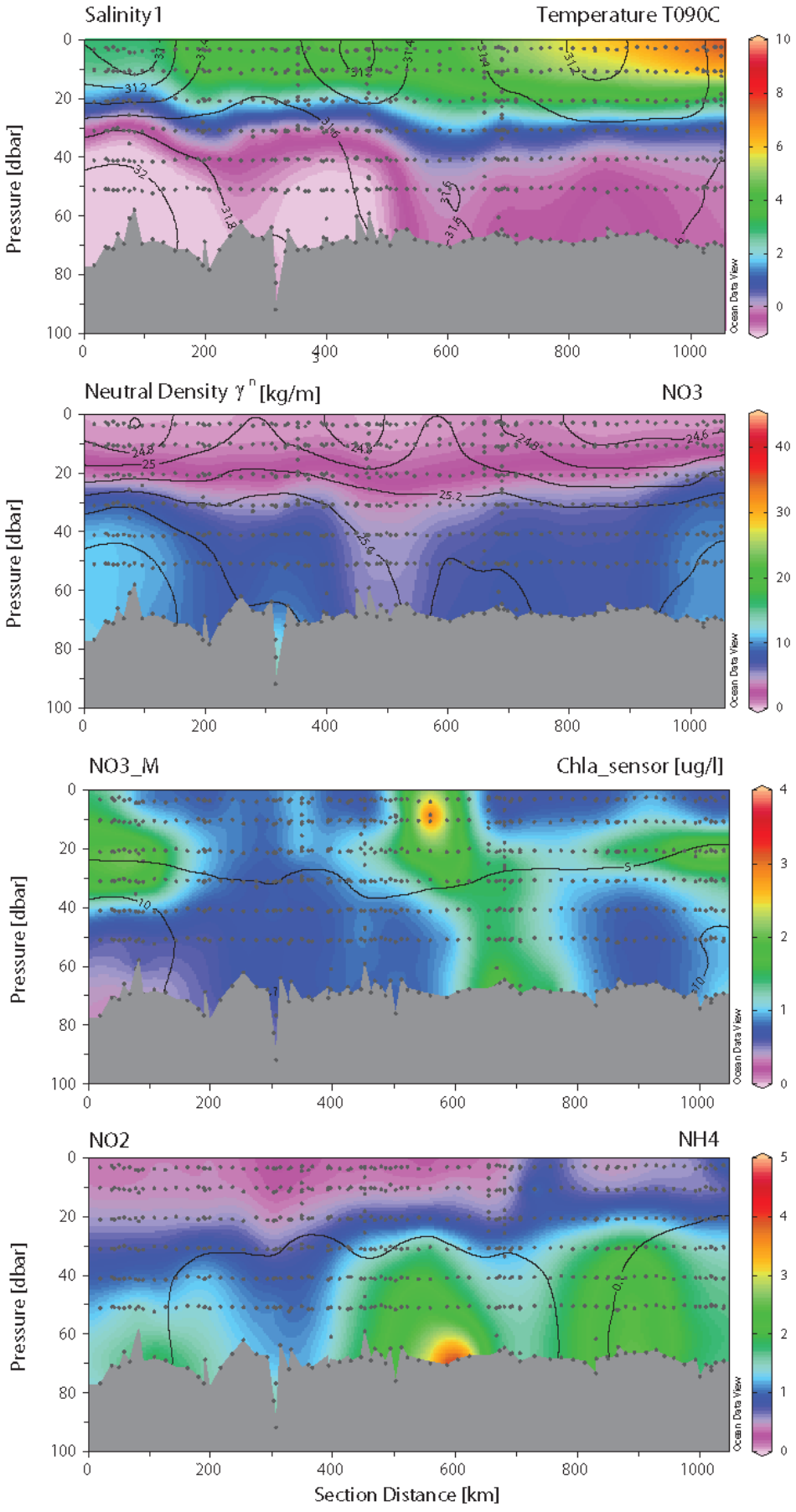


Figure 15. Sections from the 70 m line (Fig. 1 & inset above; distances are from northern end of line). A. Temperature (˚C; color bar) with salinity (labeled isopleths). B. Nitrate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths). C. Chl a fluorescence (ug l^{-1}; color bar) with nitrate (mM; labeled isopleths). D. Ammonium (mM; color bar) with nitrite (mM; labeled isopleths).

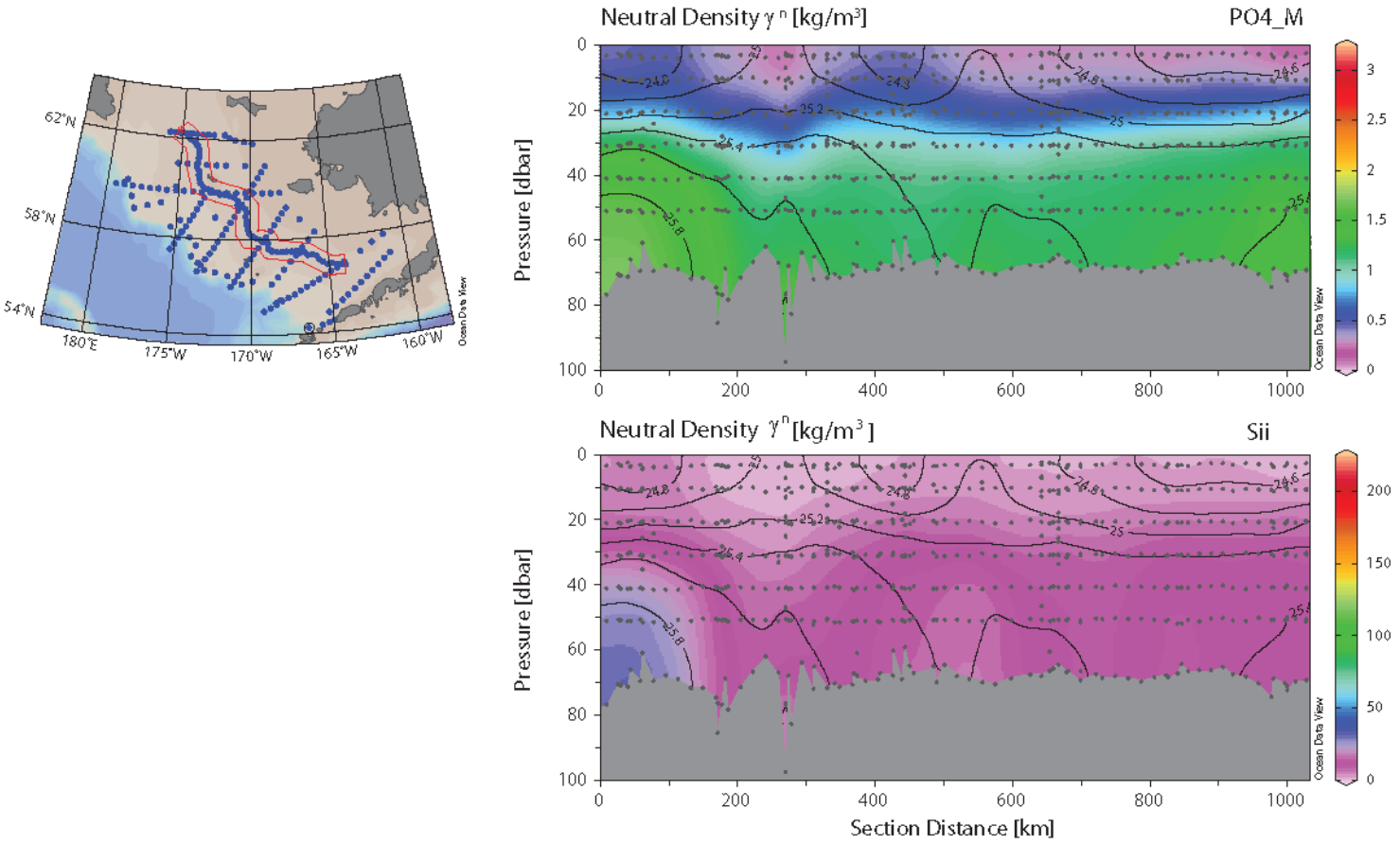


Figure 16. Sections from 70 m line, continued. Top. Phosphate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths). Bottom. Phosphate (mM; color bar) with neutral density (kg m^{-3}; labeled isopleths).

10 Net Production During Summer

A comparison between the Chl *a* and the AOU fields was constructed as a final verification and summary of the KN195-10 results (Figure 17). This comparison was chosen to assess the relative rates of productivity associated with the phytoplankton biomass that was measured during the cruise as this rate is a key parameter in determining the organic material that was available for trophic transfer in the regions. AOU levels remain positive in the subsurface Chl *a* layers along the SL line (Figure 17A) indicating that respiration exceeds production in these layers. The Chl *a* layers are at depths of rapid vertical decreases in AOU however, suggesting that the oxygen generated by the photosynthesis of these phytoplankton was an important source at these depths. Most of the surface waters along the SL line had negative AOU and were clearly supporting positive net primary production (NPP).

Positive NPP clearly also was occurring in the surface layer of the outer shelf waters along the MN line (Figure 17B). The MN line also displays negative AOU (positive NPP) in the inshore region, a feature that is shared by the other southerly lines as well. The entire water column at stations less than 50 m bottom depth was supersaturated with oxygen from the region of Nunivak Island and south (Figures 17 B-D), despite the fact that no surface maxima of Chl *a* were found in this region. The more shallow Chl *a* layers near the Pribilof Islands and outer shelf of the CN line also were regions of intense photosynthesis. The sampling during KN195-10 identified regions across the shelf therefore, that were capable of supporting elevated primary production and trophic transfer.

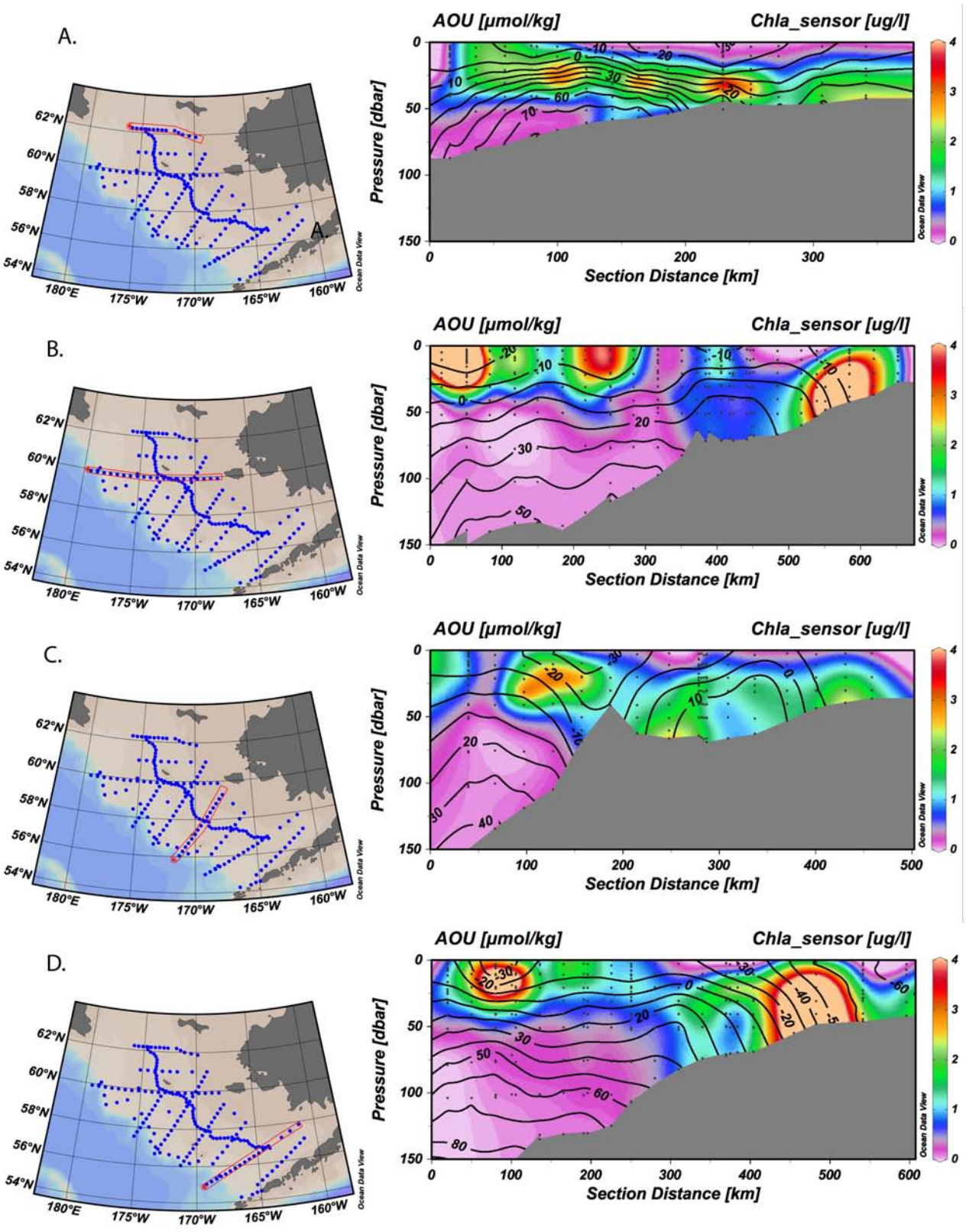


Figure 17. Sections of Chl a (from fluorescence sensor on CTD; color bar at right). Overlaid on each Chl a section are isopleths of Apparent Oxygen Utilization (AOU). The lines depicted are A. SL; B. MN, C. NP; and D. CN. The location of each line is shown on the map at left.

11 Individual Group Reports

11.1 Hydrography & PMEL group

The group conducted CTD casts which included nutrient samples from up to 12 10-liter Niskin bottles, two or more Winkler oxygen samples for calibration of the CTD oxygen sensor, three O^{18} samples for Tom Weingartner of the University of Alaska Fairbanks (UAF), and two to seven Dissolved Organic Carbon (DOC) and Dissolved Inorganic Carbon (DIC) samples for Jeremy Mathis of UAF.

Nutrient Measurements
Nutrient samples were collected from the Niskin bottles in acid-washed 35-ml polyethylene bottles after three complete seawater rinses and typically analyzed within 12 hours of sample collection. Nutrients were analyzed with a continuous flow analyzer (CFA) using the standard and analysis protocols for the WOCE hydrographic program as set forth in the manual by L.I. Gordon, et al (2000). Approximately 1900 samples were analyzed for phosphate (PO_4^{3-}), nitrate (NO_3^-), nitrite (NO_2^-), orthosilicic acid (H_4SiO_4), and ammonium (NH_4^+).

A mixed stock standard consisting of silicic acid, phosphate and nitrate was prepared at PMEL by dissolving high purity standard materials (KNO_3, KH_2PO_4 and Na_2SiF_6) in deionized water using a two step dilution for phosphate and nitrate. This standard was stored at room temperature. Nitrite and ammonium stock standards were prepared about every 10 days by dissolving in distilled water, and these standards were stored in the refrigerator. Working standards were freshly made at each day by diluting the stock solutions in low nutrient seawater. The low nutrient seawater used for the preparation of working standards, determination of blank, and wash between samples was filtered seawater obtained from low-nutrient Pacific surface waters.

A typical analytical run consisted of distilled water blanks, standard blanks, working standards, a standard from the previous run, samples, replicates, and working standards, and standard and distilled water blanks. Four replicates were usually measured on each run, plus any samples with questionable peaks, and the overall precision of the analysis was within 1% of full range.

Oxygen Measurements
Winkler titrations were conducted according to WOCE protocols. On each cast, the number of samples and the depths sampled were dependent on the oxygen profile from the CTD. In deep water, samples were typically collected at every depth below 100m. On the shelf, samples were usually collected in the upper layer, and in the bottom layer. End point determinations of the Winker titration were determined poteniometrically. Thiosulfate was standardized for each batch of sample titrations, and blanks were measured periodically during the cruise.

DIC and DOC Sampling
The sampling protocol for the DIC sampling was as follows: Samples were drawn into glass bottles immediately after oxygen sampling directly from the Niskin bottles using tubing to reduce the amount of bubbles entrained in the sample. The bottles

were rinsed three times and then filled almost full. A little head space was allowed for gas expansion, but the level in the bottle was not below the white tape on the bottle neck. After the bottle was filled, it was injected with mercuric chloride. The lid was screwed on as tightly as possible, and the bottle shaken a little. Glass bottles were labeled with the station number, cast number and bottle number on each sample.

The sampling protocol for the DOC sampling was as follows: The plastic bottles were rinsed three times from the Niskin and then filled about 70% full. The caps were screwed on tight, labeled the same as the DIC samples and placed in a freezer for the duration of the cruise.

Lisa Eisner, NOAA Auke Bay Laboratory arranged for the underway seawater sampling system to be augmented for this cruise. Seawater samples were collected from the system and analyzed for dissolved oxygen, nitrate and chlorophyll concentration for calibration.

11.2 Shull/Devol Group Report

The primary goal of the benthic biogeochemistry group for KN195-10 is to measure benthic denitrification rates, nutrient fluxes, and sediment bioirrigation rates in order to evaluate the role of the benthos in the nitrogen cycle of the Bering Sea. A secondary goal is to quantify particle bioturbation rates using ^{234}Th and address the question of how organic-matter degradation rates and pathways vary with bioturbation. We are examining the kinetics of organic-matter degradation and ammonification by incubating aliquots of sediment from different depths under anoxic conditions. We are also collecting sediment samples for phytoplankton pigments to characterize sedimentary organic matter and to look for associations between pigments in the sediment and overlying water. While we are conducting these projects independently, they are linked to projects of other investigators. For example, our nutrient flux work is linked to the NOAA/PMEL group's work on water-column nutrients and hydrography, our research project using ^{234}Th is in collaboration with the Moran research group and our pigment studies are in collaboration with the Lomas research group.

Core samples

During the cruise KN1895-10 we sampled nineteen stations using an Ocean Instruments MC-800 multicorer equipped with eight 10-cm diameter polycarbonate core tubes (Table 1). Two drops were made at most stations resulting in as many as sixteen cores per station. The actual number of usable samples from a given station ranged from one to sixteen and averaged approximately ten. Cores were processed on deck and, depending upon the number of usable cores recovered, were generally allocated as follows:

2 - 3 flux cores (incubated for ca. 5d and overlying water sampled for, N_2/Ar, O_2/Ar, O_2 by optode, nitrate, nitrite, ammonium, phosphate, and silicate). Following flux measurements, these were frozen for later CT-scanning of burrow distributions

1 squeeze core

Profiles of dissolved oxygen measured by microelectrode and by optode
Profiles of dissolved nutrients (nitrate, nitrite, ammonia) by whole-core squeezing

2 section cores cut at 0.5- or 1-cm intervals and centrifuged for pore-water nutrients, nitrate, nitrite, ammonium, phosphate, silicate to 20 cm.

1 core sectioned at 0.5- to 1-cm intervals for measurement of $^{234}Th/^{238}U$ disequilibrium and pigments as bioturbation and organic-matter tracers. Remaining sediment reserved for solid-phase Fe, Mn, Al, C, N, ^{210}Pb analysis.

2 - 3 cores sieved over 0.5-mm sieve and preserved in 10% buffered formalin for later enumeration of benthic infauna

2 - 4 cores sectioned and combined into 0-1cm, 1-2cm, 3-4cm, 6-7cm, and sometimes 9-10cm depth sections and incubated in glass vials for up to three weeks at near-*in situ* temperature.

Initial results

Table 1. Multicore locations

Coring station information						Measurements						
Stn No.	Stn name	Date	Latitude	Longitude	Depth	[O2]pw	Flux	[Nut]pw	^{234}Th	Benth	Ano	DIC
1	Ber Can	2009-06-14	54° 14.433	166° 33.27	1246	X	X	X	X	X		
17	CN-2	2009-06-17	57° 33.647	162° 7.56	51				X	X		
22	CN-12	2009-06-18	56° 7.694	166° 7.836	113	X	X	X	X	X	X	X
27	CN-20	2009-06-19	55° 1.394	169° 13.0	2344	X	X	X	X	X	X	
32	CNN-6	2009-06-20	56° 48.157	167° 52.25	104	X	X	X	X	X	X	
45	NP-7	2009-06-22	57° 53.93	169° 14.49	70X	X	X	X	X			
53	NP-15	2009-06-23	56° 3.817	171° 20.26	2800	X	X	X	X	X	X	X
60	SB-7	2009-06-25	57° 16.747	173° 50.52	196	X	X	X	X	X		
67	P14-10	2009-06-26	57° 29.751	175° 14.56	3492	X	X	X	X	X	X	X
79	XB-16	2009-06-29	57° 9.836	172° 56.76	121	X	X	X	X	X	X	X
89	XB-6	2009-06-30	59° 42.86	170° 19.27	66X	X	X	X	X	X	X	
106	MN-11	2009-07-02	59° 54	173° 59.98	105	X	X	X	X	X	X	X
113	MN-19	2009-07-02	59° 53.684	178° 44.59	152	X	X	X			X	X
115	MN-20	2009-07-02	59° 53.569	179° 22.13	2779				X	X		
122	XB2-12	2009-07-05	59° 33.803	175° 12	136	X	X	X	X	X	X	X
130	XB2-4	2009-07-06	61° 0.0038	171° 45.32	65X	X	X	X	X	X	X	
137	SL-6	2009-07-07	62° 12.063	171° 53.39	51				X	X		
140	SL-9	2009-07-07	62° 12.076	173° 6.381	62X	X	X	X	X	X		
147	SL-16	2009-07-08	62° 11.98	175° 58.51	95X	X	X	X	X	X		

Figure 1. Examples of oxygen consumption from stations occupied early in the cruise

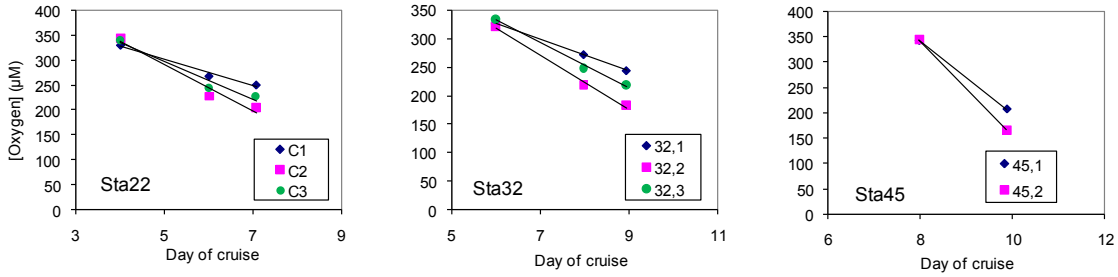
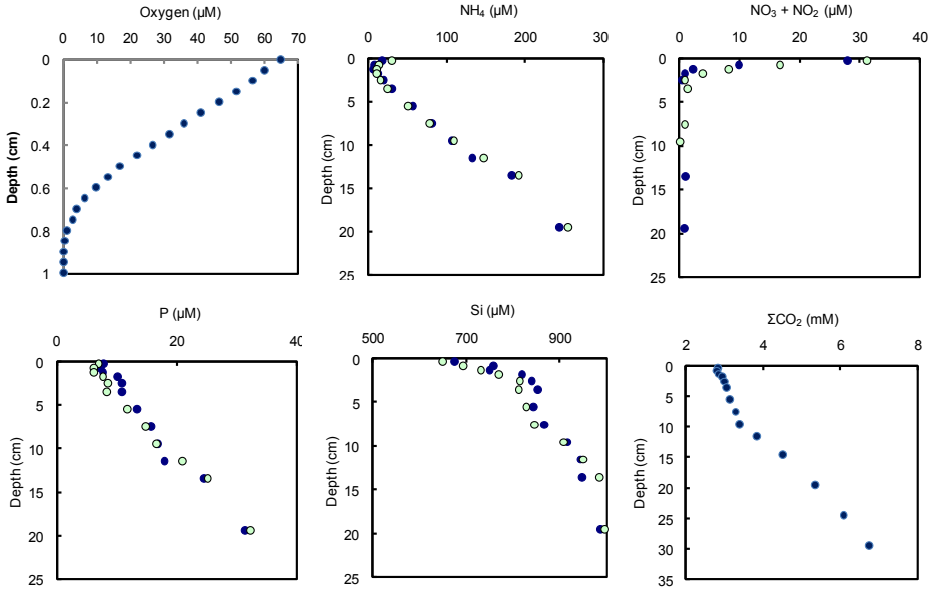


Figure 2. Example pore-water profiles from a deep station (P14-10)



Oxygen, nutrient and DIC profiles, Station 67, P14 -10, 3492 m

Data submission estimate: We estimate that we will post the data on nutrients, dissolved oxygen profiles, and pigments to the BEST database within one year of the end of KN195-10 (July 15, 2010). We estimate that the data on benthic community structure, gas ratios and radionuclide activities will be posted within two years.

11.3 Carbon productivity – Lomas/ BIOS group

Component goals:

1. Quantify the magnitude and regional variability of gross primary production and net community production in MIZ and open-water blooms associated with seasonal and interannual changes in sea ice extent.
2. Quantify the main floristic patterns (using a diversity of chemotaxonomic methods) and autotrophic cell size distributions in MIZ and open-water blooms.
3. Quantify the export flux of organic carbon associated with MIZ and open-water blooms in deeper waters (outer-shelf/slope), and link carbon export to primary production and benthic oxygen utilization to assess the efficiency of pelagic-benthic coupling associated with seasonal and interannual changes in sea ice extent.

To achieve these objectives we have used the following methods:

- Obj 1. Net primary production was estimated by use of 14C incubations. Taxon-specific carbon turnover will be estimated from samples taken in collaboration with Ray Sambrotto that will be sorted on a flow cytometer after returning to BIOS.
- Obj 2. We are documenting phytoplankton community structure by several methods. Microplankton (>10um) are being quantified using traditional Utermohl setting chambers. We are estimating the C content of each cell (and after multiplying by cell abundance - Carbon in each population or functional group) using the Strathman equations and the Montagnes et al. equations using approximate geometric shapes for each species. Pico and Nano-plankton, and heterotrophic bacteria are being quantified using flow cytometry. Cell abundance is calculated based upon the volume analyzed method. Lastly, we are taking samples for HPLC analysis that will be converted to approximate taxonomic groups based upon the CHEMTAX algorithms.
- Obj 3. We are quantifying POC fluxes using surface-tethered traps and elemental analysis. We are also collecting samples for pigment analyses from the trap material to attempt to link phytoplankton community structure in the euphotic zone with the composition that is collected in the traps (with all appropriate caveats).

Expected Results are:

1. size-fractionated (whole and >5um) chla (fluorometry) and HPLC pigment concentrations, and size-fractionated rates of primary production.

2. estimates of Synechococcus abundance, pico- and nano-eukaryotes, and identification, abundances and carbon content of microphytoplankton.
3. Export flux estimates for POC and HPLC pigments.

Data availability:

1. Chla and HPLC pigments, and primary production will be available by the end of the calender year 2008.
2. Pico/nano-plankton analyses and a subset of the microplankton analyses will be completed by the end of 2008.
3. No samples for KN195-10 have been analyzed as yet, and therefore nothing to show at this time.

11.4 Nitrogen productivity & cycling – Sambrotto/ LDEO group

Project objectives:

1) Measure new (nitrate) and regenerated productivity during summer as a comparison to the spring measurements made on earlier BEST cruises.
2) Measure isotopic signatures of particulate carbon and nitrogen to determine their variations with production and regeneration.
3) Determine the seasonal development of the production in the regions that supported elevated levels of productivity during the earlier ice edge.

Expected results:

1) Spatial pattern of productivity.
2) Vertical pattern of productivity – Particularly the productivity associated with sub-surface Chl a layers.
3) Pattern of isotopic fractionation of marine particulate material and its relationship to productivity and regeneration.

11.5 Particle flux – URI group

Project Objectives:

1) Quantify the flux of particulate organic carbon (POC) from the surface water to the deep waters of the Bering Sea using ^{234}Th as a tracer of particle export.
2) Determine POC/^{234}Th ratio and phytoplankton community values for particles collected in drifting sediment traps at five different depths (25, 40, 50, 60, and 100m).
3) Estimate particle export using measurements of total ^{234}Th – ^{238}U disequilibrium in the water column determined using small-volume thorium extractions with a manganese oxide precipitate.
4) Estimate gross primary production within the surface mixed layer using triple-oxygen isotope method.
5) Estimate cross-shelf exchange and self-break front isopycnal mixing using short-lived radium isotopes ($^{223, 224}$Ra).

Data Summary

Trap Results:

Measurable quantities of ^{234}Th have been collected in the sediment traps, though further comment is unwarranted due to incomplete analysis. CHN and pigment analysis will be completed upon return to URI-GSO. Samples archived for pigment analysis may also be analyzed for ∂^{13}C and ∂^{15}N by Dr. Sambrotto, as well as organic biomarkers by Dr. Goes.

Small Volume Results:

Measurable quantities of ^{234}Th have been collected, though further comment is unwarranted due to incomplete analysis.

Triple Oxygen Productivity Results:

Samples will be analyzed post-cruise, no comment is warranted at this time.

Short Lived Radium Results:

Analysis of only sample collected up to this point revealed low activities of ^{223}Ra and ^{224}Ra, typical of open ocean values. Near shore, shallow water column samples had highest activities (~2 dpm/100L for ^{224}Ra, and 0.15 dpm/100L for ^{223}Ra). Near-bottom samples collected where the 25.5 σ_t isopycnal was in contact with the sediments had the next highest activities (0.7-0.8 dpm/100 L for ^{224}Ra, and 0.05 dpm/100 L for ^{223}Ra). Lowest radium activities were found where the 25.5 σ_t isopycnal shoaled (0.14-0.19 dpm/100L for ^{224}Ra and 0.007 dpm/100L for ^{223}Ra). These values are not corrected for supported values, which will be made after the cruise in the lab. However, these results indicate some advection of radium from the sediments along the 25.5 σ_t isopycnal. Values for longer-lived ^{228}Ra and ^{226}Ra will be determined at URI-GSO. Euphausiid and macrozooplankton collections – UAF & OSU group

Meso-Zooplankton Distribution and Abundance (A. Pinchuk)

The primary task of the zooplankton component was to assess the abundance, biomass and species composition of the mesozooplankton and micronecton on the shelf-break/outer, middle and inner shelf domains of the southeastern Bering Sea. The data from these samples will aid in determining the fate of new and recycled production on the shelf. We obtained MOCNESS tows, CalVET samples at selected CTD stations along NP, MN, and SL transect lines and at selected locations along 70M line.

The large mesozooplankton component was sampled using a 1-m MOCNESS (Multiple Opening Closing Net and Environmental Sensing System), equipped with 0.5 mm mesh nets. The MOCNESS was equipped with salinity, temperature and fluorescence sensors to provide depth profiles of physical oceanographic data during the tows. Samples were consistently taken in 20 m depth increments from 100 m or the bottom to the surface.

The small mesozooplankton were sampled with a 25 cm CalVET (CalCOFI Vertical Egg Tow) net equipped with 0.15 mm mesh nets. The net was towed vertically from the bottom to the surface and from 100 m to the surface at sites deeper than 100 m. The nets were equipped with General Oceanics digital flow meters to monitor volume filtered. The CTD sample number was recorded with each net to facilitate comparison of CalVET samples with physical oceanographic data.

Samples were preserved in 10% formalin seawater and returned to the lab for processing. Samples will be split and organisms identified to the lowest possible taxonomic category. Copepods will be staged and wet weights will be determined for each species and stage. The above procedure will generate the species composition, abundance and wet weight biomass for all identified taxa from each tow.

Casual observation of the samples indicates that oceanic zooplankton species were common in the shelf-break and outer shelf region, but large copepods were rare or absent from the middle and inner domains stations. It appears that the mesozooplankton community was dominated by medium-sized and small copepods, gelatinous zooplankton and, at some stations, euphausiids and hyperiids. Oceanic Neocalanus spp., Eucalanus bungii and Thysanoessa longipes were abundant on the offshore ends of NP and MN transects indicating advection of oceanic water on the outer shelf (up to ~100 m isobath). Calanus marschallae and Thysanoessa raschii comprised bulk of zooplankton on the middle shelf, while Sagitta elegans and small copepod Pseudocalanus spp. were especially abundant in the inner domains. Cold water hyperiids Parathemisto libellula were common on the northern part of the shelf. Large numbers of juvenile scyphozoan Chrysaora melanaster (bell diameter <15 cm) were observed on the southern middle shelf. A detailed assessment of zooplankton abundance, biomass and distribution will be made after the samples have been processed.

11.6 Euphausiid rate measurements – Lessard/ Harvey/UW group

The Trophic Role of Euphausiids in the eastern Bering Sea: Ecosystem Responses to Changing Sea-Ice Conditions (Lessard and Harvey)

The goal of our project is to understand how climatically-driven changes in sea-ice conditions may affect the ecology and population dynamics of euphausiids in the eastern Bering Sea. Our primary hypothesis is that seasonal and interannual variation in the timing and coverage of sea-ice and associated food resources will lead to differences in age structure, diet history, and nutritional condition for euphausiids, which ultimately translate into differences in production rates and availability as prey to higher trophic levels. To determine diet, nutritional condition, and feeding rates, we are performing shipboard krill feeding experiments to measure ingestion rates of specific prey taxa (phytoplankton, heterotrophic protists, copepods) and we are determining the lipid profiles of both euphausiids and prey field. We are also isolating and culturing specific prey species to identify prey biomarkers. Identifying the lipid profiles and specific biomarkers for different prey taxa (particularly the poorly known heterotrophic protists) will enable us to infer diets from lipid profiles of field-caught euphausiids. We are also measuring euphausiid growth and egg production rates and estimating euphausiid age using the lipofuscin method. Our colleague, Alexei Pinchuk, will conduct laboratory rearing to allow calibration of the lipofuscin aging method when eggs can be collected in the field.

<u>Bongo net tows</u>

We performed 25 Bongo tows to capture live euphausiids for feeding and growth experiments and for lipid, carbon and lipofuscin analyses. The nets were towed obliquely.

Feeding experiments

We performed seventeen feeding experiments across the Bering Sea shelf and slope. For the feeding experiments, we captured live euphausiids with a Bongo net and added known numbers and species to bottles filled with seawater and incubated, along with control bottles without animals, for 24 hours on a rotating wheel in a flowing seawater incubator. The prey for each experiment were unaltered seawater plankton or seawater supplemented with concentrated seawater targeting the addition of protists. Shipboard, herbivorous feeding was assessed by measuring changes in size-fractionated chlorophyll. Samples were also fixed for microscopic counts of phytoplankton and heterotrophic protists to be analyzed back in the laboratory.

Growth experiments

We performed growth experiments, assessing instantaneous growth rates on euphausiids. Euphausiids were captured with a Bongo net and one euphausiid was added to a sideflask filled with 200um filtered seawater captured from the CTD. The euphausiids were checked twice a day for molts for two days. We provided >700 euphausiids with species and size determinations, from the feeding and growth experiments, to Harvey for lipid profiles, carbon and lipofuscin content (an index of age).

11.7 Organic tracers of trophics/ euphausiid age structure – Harvey/ UMD group

- KRILL GRAZING AND AGING EXPERIMENTS
- **Water Column Particles and Krill Collection**
- Grazing Experiments for Determination of Euphausiid Grazing Rates and Food Source Preferences

For characterization of food resources and tracking of consumption, euphausiids were collected and incubated over a 24-hour period in CTD water from the same station. Water from designated Niskin bottles was filtered at T_0 through combusted GF/F filters for carbon and detailed lipid analysis to characterize the algal and detrital food available to krill. At the conclusion of each of the grazing experiments conducted by the Lessard group, water from the four bottles containing animals was combined and filtered onto particulate filters for lipid analysis to compare food amounts and potential for selective grazing. Water from each of the control bottles was treated likewise.

At the beginning of each grazing experiment, animals were collected from the bongo tow and individually frozen in the -80°C to serve as T_0 samples. Euphausiids incubated for 24 hours were also individually frozen (T_{final} animals). The frozen samples will be taken back to the lab for lipid analysis using a Gas Chromatograph

coupled with Mass Spectrometry. The results will illustrate the types and quantities of organisms that euphausiids utilize for food

Total Energy Content

Animals of a wide range of body lengths were frozen, 95 in total, to measure total carbon content using calorimetry.

Determination of Age in Euphausiids Found in the Bering Sea

Eight growth experiments were performed over the course of the cruise; the animals from these experiments were also used for lipofuscin measurements. These experiments have included animals of a large size range to provide a first estimate of lipofuscin indices in field animals of differing ages. Alexei Pinchuk will conduct growth experiments, when euphausiid eggs are made available, that will span a minimum of two years in order to allow age calibration of the field specimens that have been analyzed.

At the conclusion of the first growth experiment, the experiment animals were sacrificed. The eyes and eye stalks were removed; both the lipofuscin (Part A) and protein content (Part B) in each pair of eyes was extracted and quantified via flow-through fluorescence using an Agilent 1100 HPLC. This preliminary analysis of the first growth experiment could not be completed due to the malfunction of the fluorescence flow cell, for which there was no replacement. Euphausiids from subsequent experiments were frozen in the -80^{o}C chest freezer for future lipofuscin analysis.

Lipofuscin Sample Analysis

High Performance Liquid Chromatography for the Identification and Quantification of Lipofuscin - Part A

Lipofuscin - an oxidation product that accumulates in euphausiid neural tissue - from *Thysanoessa inermis* was determined by running a three-dimensional fluorescent scan of the extracted product present in a composite of samples of krill neural tissue. That scan allowed a qualitative identification of lipofuscin for that species, and was used to measure lipofuscin content in euphausiids for the duration of the cruise. A calibration curve using quinine sulfate allowed quantitative measurements of fluorescence intensity to be performed for each run.

Part B

For protein analysis of krill neural tissues, tryptophan fluorescence – a proxy for protein quantification – was measured using known excitation and emission wavelengths. Bovine Serum Albumin (BSA) was used to generate a calibration curve, which acted as a means to quantify protein in the eye tissues.

ORGANIC TRACERS

Water Column Particles and Sediment Collection

Investigating the input and preservation of bacterial derived organic matter

Sediment cores were collected as detailed in the report from David Shull. Surface sediment (0-2 cm) and downcore samples (sliced in 1 cm increments) were obtained from thirteen stations and frozen in I-Chem jars for the characterization of bacterial derived organic matter using intact bacteriohopanepolyols (BHPs). Intact BHPs are recalcitrant membrane lipids and thus considered ideal biomarkers for tracing microbial sources of organic carbon, and potentially bacterial populations and processes within marine environments. To trace the remnants of the spring bloom and also compare recent inputs and preservation of intact BHPs in the Bering Sea, water sampled below the chlorophyll maximum was taken from Niskin bottles and filtered through combusted GF/F filters for carbon and lipid analysis. Reversed-phase high-performance liquid chromatography-atmospheric pressure chemical ionization tandem mass spectrometry (RP-HPLC-APCI-MSn) will be applied for the analysis of intact BHPs, and all work will be completed at the University of Maryland Center for Environmental Science Chesapeake Biological Laboratory.

11.8 Ichthyolplankton – UAF group

The effect of environmental factors on distribution, abundance, and energy density of late larval and early juvenile stages of walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), and arrowtooth flounder (*Atheresthes stomias*)

Statement of objectives

Our main objectives were to (1) characterize the larval/early juvenile summer fish assemblages in the eastern Bering Sea, (2) determine the effect of environmental factors on the abundance, distribution, and composition of ichthyoplankton, and (3) examine the energy density of larval and early juvenile stages of three target species, namely walleye pollock (*Theragra chalcogramma*), Pacific cod (*Gadus macrocephalus*), and arrowtooth flounder (*Atheresthes stomias*). Our participation on this research cruise was supported by the North Pacific Research Board's Bering Sea Integrated Ecosystem Research Program (BSIERP) and the National Science Foundation's Bering Ecosystem Studies (BEST). Our data will contribute to the collaborative effort of improving the understanding of the effects of climate variability on spatial and temporal variability in abundance, distribution, and condition of the early life stages of these three target fish species in the eastern Bering Sea. Ultimately, these data will allow for the better prediction of transport pathways of early life stages and of production of the three target taxa under changing climatic conditions in the eastern Bering Sea.

Field Methods

Sampling was conducted in collaboration with Alexei Pinchuk. We sampled ichthyoplankton using a 1 m^2 MOCNESS (Multiple Opening Closing Net and Environmental Sensing System) equipped with nine 500 μm mesh nets. In addition, the MOCNESS was equipped with sensors for conductivity, temperature, and fluorescence, thus recording data to characterize the sampled water column. Sampling was

conducted obliquely in 20-m increments from 100 m depth (or 15 m above the bottom) to the surface. After retrieval of the gear, all net bags were carefully rinsed down, codends were detached, and samples were preserved in 10% formalin seawater. Samples will be brought to the lab for further processing. In addition, the contents of the drogue net of the MOCNESS were examined on board and all larval and early juvenile fishes were removed for identification. Early life stages of target taxa were counted and frozen at -80 ºC for further analysis of energy density in the lab.

The examination of the drogue net of the MOCNESS resulted in the collection of early life stages of all three target taxa - *T. chalcogramma*, *G. macrocephalus*, and *Atheresthes* spp. were frozen for future analysis of energy density. Future lab analysis will provide data on the horizontal and vertical distribution, size, and condition of early life stages of the target fish taxa.

11.9 Microzooplankton grazing – UMD group

Project: Microzooplankton abundance, biomass and grazing impact on phytoplankton during summer in the eastern Bering Sea (funded by BSIERP)
PI: Diane Stoecker; Research Assistant: Kristen Blattner

Science Goals for Cruise:
1. Obtain samples for determination of microzooplankton (MZ) abundance, biomass and composition in the mixed layer and chlorophyll maximum layer.
2. Estimate the grazing impact of microzooplankton on phytoplankton in the mixed layer.

Methods:
Water samples were collected on "Prod" and some regular CTD casts from the mixed layer and chlorophyll maximum layer, if present, and preserved with 10% acid Lugol's solution. These samples will be shipped to HPL for enumeration of the larger microzooplankton (>20 micron microzooplankton). In addition, 20 ml samples were preserved with alternative fixatives including Basic Lugol's solution, acid Lugol's solution and 1 % glutaraldehyde. These smaller samples were observed onboard to characterize the phytoplankton and microzooplankton communities used in the dilution experiments and to make note of the presence or absence of plastids and fluorescence of the larger protists. This information will be useful in identifying and characterizing microzooplankton when the samples are counted in the laboratory. It has also been useful in understanding optical signals, particularly orange fluorescence, detected by in situ sensors. Water samples for microzooplankton enumeration were collected in association with the dilution experiments and at additional selected stations.
Two point dilution grazing experiments (with and without the addition of N) were conducted to estimate grazing rates of microzooplankton assemblages on phytoplankton. Water for the experiments was collected from the mixed layer. Grazing on total chlorophyll and chlorophyll in the >20 micron size was determined from 24 h incubations conducted in a flowing seawater on deck incubator screened to

achieve an irradiance of ~50% Io. Treatments from the experiments are being analyzed by Dr. Sambrotto to investigate the role of microzooplankton razing in urea production. These collaborative efforts should provide some data on nutrient regeneration by microzooplankton and phytoplankton physiology in the Being Sea during summer.

Expected Results:
We will have data on the abundance, biomass, and taxonomic composition of microzooplankton (primarily ciliates and dinoflagellates) from different regimes. We observed and sampled a diversity of phytoplankton and microzooplankton communities, some containing unusual organisms. In low nutrient waters, the phytoplankton was dominated by very small cells and microzooplankton (primarily ciliates), not phytoplankton, were the dominant microplankton (20-200 micron fraction). At many stations, the phytoplankton were N limited and their growth was stimulated by the addition of nitrate: at other stations, although the phytoplankton appeared to be nutrient limited, they did not grow in response to added nitrate in the incubations. Nutrient regeneration by microzooplankton appeared to be important to phytoplankton growth in many experiments. Cryptophytes, single cell *Phaeocystis* and other small flagellates were usually the dominant phytoplankton in low chlorophyll waters. These small cells made up the chlorophyll maximum at some stations at the edge of the shelf.

Dilution grazing experiments were conducted. Microzooplankton grazing was a large source of mortality to phytoplankton at most stations. Photosynthetic mixotrophic ciliates appeared to be the dominant large micrograzers in low chlorophyll waters. Large non- thecate dinoflagelates were important grazers in chlorophyll maximum layers dominated by diatom chains. They were a source of fecal particles containing diatom frustules.

11.10 Educational Activities

Mark McKay, a high school teacher from Sacremento, CA participated in the cruise supported by PolarTrek. Mark worked mainly with the primary productivity groups during the ship and learned about the incubation based measurement of primary production. He also familiarized himself with an Advanced Laser Fluorometerm an experiment instrument that was brought on the cruise to characterize phytoplankton and photosynthetic capacity. Mark kept this instrument going in underway mode and also made numerous measurements of discrete samples. Mark will develop educational activities around these experiences after the cruise.

12 Appendix – Final Station Plan

Cruise phase	Consec. Stn. #	Line	Line stn#	addl. Info	Lat deg.	min.	Long deg.W	min.	Water Depth (m)	CTD (hydro)	Station Activities <---------- CTD - Prod./ uzoop. (Lomas/ Sambr/ Stoecker)	CTD (Other)	MOCNESS (Pinchuk et al.)	CalVET (Pinchuk)	Vertical Nets (Lessard/ Harvey)	van Veen (Iken)	Multicore (Shull/ Devol)	Sed. Trap D/R (Moran)	Other ---------->	Arrive Local Date/Time
				Dutch	53	53.903	166	37.661											2880	6/12/09 9:00
1	1	U	1	Bering Canyon	54	14.500	166	34.000	1200	X	X						X			6/14/09 10:52
1	2	U	2	NASC	54	20.315	165	41.131	70	X			X							6/14/09 16:46
1	3	U	3	Unimak Pass	54	26.860	165	18.000	80	X	X									6/14/09 19:14
1	4	U	4	ACC	54	29.857	164	57.288	70	X			X							6/14/09 21:09
1	5	UAP	8		54	52.000	165	14.000	326	X			X							6/15/09 2:31
1	6	UAP	7		55	5.140	164	48.850	326	X	X		X							6/15/09 5:24
1	7	UAP	6		55	18.280	164	23.710	93	X			X				X			6/15/09 8:37
1	8	UAP	5		55	31.400	163	58.570	91	X			X							6/15/09 12:22
1	9	UAP	4		55	45.000	163	33.430	89	X	X		X							6/15/09 15:08
1	10	UAP	3		55	57.700	163	8.280	83	X			X							6/15/09 18:11
1	11	UAP	2		56	10.840	162	43.140	80	X			X							6/15/09 20:53
1	12	UAP	1		56	23.980	162	18.000	75	X			X							6/15/09 23:35
1	13	UAP	0		56	37.120	161	52.860	75	X			X							6/16/09 2:17
1	14	UAP	-1		56	50.260	161	27.720	75	X			X				X			6/16/09 4:58
1	15	UAP	-2		57	3.400	161	2.580	70	X			X							6/17/09 4:00
1	16	CN	0		57	50.680	161	19.720	55	X			X							6/17/09 6:41
1	17	CN	2		57	33.580	162	7.420	55	X			X							6/17/09 9:21
1	18	CN	4		57	16.480	162	55.120	52	X	X		X		X					6/17/09 13:15
1	19	CN	6	M2(act.)	56	52.620	164	3.420	71	X										6/17/09 19:11
1	20	CN	8		56	42.280	164	30.520	76	X										6/17/09 21:16
1	21	CN	10		56	25.302	165	18.168	80	X			X							6/18/09 0:33
1	22	CN	12		56	8.238	166	6.210	100	X	X		X				X			6/18/09 4:33
1	23	CN	14		55	51.042	166	54.432	133	X			X							6/18/09 9:45
1	24	CN	16		55	33.372	167	42.060	**134**	X			X							6/18/09 13:51
1	25	CN	17	ST deploy	55	25.932	168	3.690	**200**	X										6/18/09 16:20
1	26	CN	18		55	18.492	168	25.320	510	X	X		X		X		X			6/18/09 18:13
1	27	CN	20		55	1.392	169	13.020	2500	X										6/19/09 0:12
1	28	X	1	outer frt. Bloom	55	18.492	168	25.320	350	X										6/19/09 5:15
1	29	X	2	ST recovery	55	30.000	168	30.000	350	X	X		X		X					6/19/09 6:57
1	30	CNN	8		56	9.000	168	42.000	100	X			X							6/20/09 3:50
1	31	CNN	7		56	27.000	168	17.143	90	X			X							6/20/09 7:02
1	32	CNN	6		56	45.000	167	52.286	80	X	X		X							6/20/09 10:13
1	33	CNN	5		57	3.000	167	27.429	75	X			X							6/20/09 13:43
1	34	CNN	4		57	21.000	167	2.571	70	X			X							6/20/09 16:53
1	35	CNN	3		57	39.000	166	37.714	65	X	X		X							6/20/09 20:01
1	36	CNN	2		57	57.000	166	12.856	60	X										6/20/09 23:29
1	37	CNN	1		58	15.000	165	47.998	60	X										6/21/09 1:56
1	38	X	3		58	46.700	166	42.769	61	X										6/21/09 6:15
2	39	NP	1		59	17.000	167	36.000	60	X			X							6/21/09 10:23
2	40	NP	2		59	3.369	167	53.144	65	X	X							X		6/21/09 12:16

Cruise phase	Consec. Stn. #	Line	Line stn#	addl. Info	Lat deg.	min.	Long deg.W	min.	Water Depth (m)	CTD (hydro)	Station Activities <---------- CTD - Prod./ uzoop. (Lomas/ Sambr/ Stoecker)	CTD (Other)	MOCNESS (Pinchuk et al.)	CalVET (Pinchuk)	Vertical Nets (Lessard/ Harvey)	van Veen (Iken)	Multicore (Shull/ Devol)	Sed. Trap D/R (Moran)	Other ---------->	Arrive Local Date/Time
2	41	NP	3		58	49.506	168	9.431	65	X			X	X			X			6/21/09 14:09
2	42	NP	4		58	35.644	168	25.719	70	X										6/21/09 16:02
2	43	NP	5		58	21.781	168	42.006	75	X			X	X	X					6/21/09 17:56
2	44	NP	6		58	7.919	168	58.294	75	X										6/21/09 19:51
2	45	NP	7		57	54.056	169	14.581	75	X				X						6/21/09 21:47
2	46	NP	8	M4 search	57	40.194	169	30.869	80	X			X							6/21/09 23:42
2	47	NP	9		57	26.331	169	47.154	80	X	X									6/22/09 1:38
2	48	NP	10		57	12.469	170	2.277	85	X					X					6/22/09 20:27
2	49	NP	11		56	58.606	170	17.400	95	X			X	X						6/22/09 22:22
2	50	NP	12		56	44.744	170	33.000	105	X										6/23/09 0:19
2	51	NP	13		56	30.881	170	48.000	135	X										6/23/09 2:16
2	52	NP	14		56	17.019	171	3.000	450	X										6/23/09 4:15
2	53	NP	15	ST deploy - 24 h	56	3.156	171	18.000	2370	X	X							X		6/23/09 8:00
2	54	SB	2	shelf break	56	10.403	170	35.050	204	X			X	X						6/24/09 12:16
2	55	SB	1	Head of Prib. Ca	56	17.650	169	52.100	100	X										6/24/09 16:13
2	56	SB	3		56	29.612	171	30.248	150	X										6/24/09 21:46
2	57	SB	4		56	37.983	172	16.326	150	X			X	X	X	X				6/25/09 0:44
2	58	SB	5		56	42.962	173	0.846	150	X	X									6/25/09 5:41
2	59	SB	6		57	0.074	173	24.458	150	X										6/25/09 8:40
2	60	SB	7		57	16.746	173	50.529	150	X			X	X		X	X			6/25/09 11:11
2	61	SB	8		57	43.559	173	35.243	150	X										6/25/09 17:26
2	62	SB	9		58	5.449	174	3.325	150	X										6/25/09 20:22
2	63	SB	10		58	42.815	174	45.587	150	X			X	X						6/26/09 0:50
2	64	SB	11		58	25.477	175	20.405	150	X					X					6/26/09 4:49
2	65	P14	6	P14N-2	58	28.470	174	19.910	149	X			X							6/26/09 15:33
2	66	P14	7		58	13.838	174	33.638	500	X	X							X		6/27/09 1:22
2	67	P14	10	P14N-4	57	29.940	175	14.820	3500	X			X	X			X			6/26/09 17:07
2	68	P14	9		57	44.573	175	1.093	3000	X										6/26/09 23:10
2	69	P14	8	P14N-3	57	59.205	174	47.365	3030	X			X	X	X					6/27/09 1:22
2	70	X	4		58	13.838	174	33.638	500	X	X							X		6/27/09 5:41
2	71	P14	5		58	43.103	174	6.183	130	X				X						6/27/09 12:30
2	72	P14	4	P14N-1	58	57.735	173	52.455	85	X			X							6/27/09 14:49
2	73	P14	3		59	12.368	173	38.728	80	X										6/27/09 17:14
2	74	P14	2		59	27.000	173	25.000	75	X					X					6/27/09 19:10
2	75	P14	1		59	41.633	173	11.273	70	X			X	X						6/27/09 21:35
				St Paul	57	7.663	170	21.258	35										60	6/28/09 15:01
	76			**St. Paul net stn?**																
3	77	XB1	18	X-bloom	56	38.721	173	27.463	500	X			X	X	30					6/29/09 1:38
3	78	XB1	17	NOAA drifter#	56	54.090	173	11.730	150	X	X	X					60			6/29/09 5:27
3	79	XB1	16		57	9.459	172	55.997	150	X			X	X						6/29/09 9:35
3	80	XB1	15		57	24.829	172	40.264	130	X										6/29/09 12:43

Cruise phase	Consec. Stn. #	Line	Line stn#	addl. Info	Lat deg.	min.	Long deg.W	min.	Water Depth (m)	CTD (hydro)	Station Activities <---------- CTD - Prod./ uzoop. (Lomas/ Sambr/ Stoecker)	CTD (Other)	MOCNESS (Pinchuk et al.)	CalVET (Pinchuk)	Vertical Nets (Lessard/ Harvey)	van Veen (Iken)	Multicore (Shull/ Devol)	Sed. Trap D/R (Moran)	Other ---------->	Arrive Local Date/Time
3	81	XB1	14		57	40.198	172	24.531	120	X			X	X						6/29/09 14:48
3	82	XB1	13		57	55.567	172	8.798	110	X										6/29/09 17:54
3	83	XB1	12		58	10.937	171	53.064	100	X			X	X		30				6/29/09 19:58
3	84	XB1	11		58	26.306	171	37.331	90	X					30					6/29/09 23:32
3	85	XB1	10		58	41.676	171	21.598	80	X	X	X	X	X			60			6/30/09 2:04
3	86	XB1	9		58	57.045	171	5.865	90	X										6/30/09 7:16
3	87	XB1	8		59	12.414	170	50.132	85	X			X	X						6/30/09 9:18
3	88	XB1	7		59	27.784	170	34.399	80	X										6/30/09 12:20
3	89	XB1	6		59	43.153	170	18.666	75	X			X	X						6/30/09 14:22
3	90	XB1	5		59	58.522	170	2.933	75	X										6/30/09 17:23
3	91	XB1	4		60	13.892	169	47.199	70	X			X	X						6/30/09 19:24
3	92	XB1	3		60	29.261	169	31.466	70	X										6/30/09 22:24
3	93	XB1	2		60	44.631	169	15.733	65	X			X	X	X					7/1/09 0:24
3	94	XB1	1		61	0.000	169	0.000	65	X										7/1/09 3:54
3	95	MN	1		59	54.000	168	0.000	35	X		X	X	X	X					7/1/09 4:34
3	96	MN	2		59	54.000	168	36.000	42	X	X				X					7/1/09 8:37
3	97	MN	3		59	54.000	169	12.000	48	X					X					7/1/09 11:29
3	98	MN	4		59	54.000	169	48.000	50	X			X		X		X			7/1/09 13:53
3	99	MN	5		59	54.000	170	24.000	64	X					X					7/1/09 18:41
3	100	MN	6		59	54.000	171	0.000	66	X					X					7/1/09 21:06
3	101	MN	7		59	54.000	171	36.000	70	X			X		X					7/1/09 23:30
3	102	MN	8		59	54.000	172	12.000	66	X	X				X		X			7/2/09 3:35
3	103	MN	9	M5	59	54.000	172	48.000	70	X					X				deploy M5	7/2/09 7:00
3	104	MN	10		59	54.000	173	24.000	76	X					X					7/2/09 9:24
3	105	MN	11		59	54.000	174	0.000	80	X			X		X		X			7/2/09 11:50
3	106	MN	12		59	54.000	174	36.000	90	X					X					7/2/09 13:08
3	107	MN	13		59	54.000	175	12.000	100	X					X					7/2/09 15:34
3	108	MN	14		59	54.000	175	48.000	100	X			X		X		X			7/2/09 18:01
3	109	MN	15		59	54.000	176	24.000	100	X	X	X	X		X		X			7/2/09 22:08
3	110	MN	16		59	54.000	177	0.000	100	X					X					7/3/09 5:13
3	111	MN	17		59	54.000	177	36.000	135	X					X					7/3/09 7:40
3	112	MN	18		59	54.000	178	12.000	173	X					X					7/3/09 10:09
3	113	MN	18b	ST deploy	59	54.000	178	48.000	500	X							X		X		7/3/09 12:41
3	114	MN	19		59	54.000	178	48.000												
3	115	MN	20		59	54.000	179	24.000	1360	X			X	X	X					7/3/09 17:32
3	116	SB	12		60	7.893	178	36.297	200				X				X			7/3/09 22:03
3	117	X	5	ST recovery, NC	59	59.250	178	48.330	500	X	X					X		X		7/4/09 2:40
3	118	SB	13		59	28.602	178	10.908	150	X				X						7/4/09 13:00
3	119	XB2	15		58	59.886	177	56.240	150	X			X	X						7/4/09 16:33
3	120	XB2	14		59	11.191	177	1.493	120	X										7/4/09 20:50

Cruise phase	Consec. Stn. #	Line	Line stn#	addl. Info	Lat deg.	min.	Long deg.W	min.	Water Depth (m)	CTD (hydro)	Station Activities <---------- CTD - Prod./ uzoop. (Lomas/ Sambr/ Stoecker)	CTD (Other)	MOCNESS (Pinchuk et al.)	CalVET (Pinchuk)	Vertical Nets (Lessard/ Harvey)	van Veen (Iken)	Multicore (Shull/ Devol)	Sed. Trap D/R (Moran)	Other ---------->	Arrive Local Date/Time
3	121	XB2 -	13		59	22.495	176	6.747	110	X		X		X	X					7/5/09 0:04
3	122	XB2 -	12	spring bloom ex	59	33.800	175	12.000	90	X	X		X	X		X	X			7/5/09 4:37
3	123	XB2 -	11		60	2.533	175	12.000	90	X										7/5/09 10:56
3	124	XB2 -	10		60	31.267	175	12.000	90	X				X						7/5/09 14:01
3	125	XB2 -	9		61	0.000	175	12.000	90	X			X	X	X					7/5/09 17:25
3	126	XB2 -	8		61	0.000	174	30.667	80	X				X						7/5/09 21:02
3	127	XB2 -	7		61	0.000	173	49.333	75	X	X			X			X			7/5/09 23:38
3	128	XB2 -	6		61	0.000	173	8.000	75	X										7/6/09 3:44
3	129	XB2 -	5		61	0.000	172	26.667	75	X			X	X		X				7/6/09 6:00
3	130	XB2 -	4		61	0.000	171	45.333	75	X				X						7/6/09 9:36
3	131	XB2 -	3		61	0.000	171	4.000	70	X										7/6/09 12:12
3	132	XB2 -	2		61	0.000	170	22.667	70	X			X	X	X					7/6/09 14:28
3	133	SLN -	2		61	52.000	169	52.000	50	X			X	X						7/6/09 21:09
3	134	SLN	3		61	56.000	170	30.000	55	X										7/7/09 0:14
3	135	SLN -	4	N55	62	0.000	171	8.000	55	X		X		X	X					7/7/09 2:19
3	136	SLN -	5		62	5.752	171	30.88	60	X	X		X	X		X	X			7/7/09 5:11
3	137	SL -	6		62	12.000	171	53.450	60	X										7/7/09 9:58
3	138	SL -	7		62	12.000	172	17.955	60	X				X						7/7/09 11:26
3	139	SL -	8		62	12.000	172	42.460	65	X			X	X	X					7/7/09 13:14
3	140	SL -	9		62	12.000	173	6.965	65	X						X				7/7/09 16:03
3	141	SL -	10		62	12.000	173	31.470	65	X	X			X						**7/7/09 15:20**
3	142	SL -	11		62	12.000	173	55.975	65	X				X						7/7/09 17:38
3	143	SL -	12		62	12.000	174	20.480	65	X			X	X		X				7/7/09 19:26
3	144	SL -	13	M8	62	12.000	174	44.985	65	X				X					X	7/7/09 22:15
3	145	SL -	14		62	12.000	175	9.490	65	X				X						7/8/09 2:03
3	146	SL -	15		62	12.000	175	33.995	65	X			X	X	X					7/8/09 3:51
3	147	SL -	16		62	12.000	175	58.500	65	X	X		X	X		X	X			7/8/09 6:40
4	148	70m -	58	**M8**	62	12.000	174	45.000	71	X										7/8/09 12:53
4	149	70m -	57		62	4.000	174	38.000	70	X										7/8/09 14:06
4	150	70m -	56		61	56.580	174	22.680	70	X			X	X	X					7/8/09 15:29
4	151	70m -	55		61	52.680	174	2.580	70	X										7/8/09 18:11
4	152	70m -	54		61	44.220	173	51.480	70	X										7/8/09 19:32
4	153	70m -	53		61	35.100	173	42.000	70	X										7/8/09 20:53
4	154	70m -	52		61	24.840	173	42.000	70	X										7/8/09 22:16
4	155	70m -	51		61	14.640	173	42.780	70	X			X	X						7/8/09 23:38
4	156	70m -	50		61	4.560	173	46.140	70	X										7/8/09 19:35
4	157	70m -	49		60	54.480	173	49.080	70	X				X						7/8/09 20:57
4	158	70m -	48		60	45.480	173	39.840	70	X										7/8/09 22:38
4	159	70m -	47		60	35.220	173	39.540	70	X										7/9/09 0:01
4	160	70m -	46		60	25.260	173	35.700	70	X				X						7/9/09 1:22
4	161	70m -	45		60	15.360	173	31.380	70	X										7/9/09 3:04

Cruise phase	Consec. Stn. #	Line	Line stn#	addl. Info	Lat deg.	min.	Long deg.W	min.	Water Depth (m)	CTD (hydro)	<---------- Station Activities ---------> CTD - Prod./ uzoop. (Lomas/ Sambr/ Stoecker)	CTD (Other)	MOCNESS (Pinchuk et al.)	CalVET (Pinchuk)	Vertical Nets (Lessard/ Harvey)	van Veen (Iken)	Multicore (Shull/ Devol)	Sed. Trap D/R (Moran)	Other	Arrive Local Date/Time
4	162	70m -	44		60	7.020	173	19.680	70	X										7/9/09 4:26
4	163	70m -	43		60	3.000	173	1.620	70	X	X		X	X	X		X			7/9/09 5:46
4	164	70m -	42		59	59.100	172	43.320	70	X										7/9/09 9:56
4	165	70m -	41		59	54.300	172	25.380	70	X			X	X	X	X				7/9/09 11:18
4	166	70m -	40		59	50.760	172	6.300	70	X										7/9/09 14:30
4	167	70m -	39		59	49.800	171	46.200	70	X										7/9/09 15:52
4	168	70m -	38		59	46.860	171	27.060	70	X										7/9/09 17:13
4	169	70m -	37		59	43.140	171	8.340	70	X										7/9/09 18:35
4	170	70m -	36		59	35.880	170	55.020	70	X										7/9/09 19:55
4	171	70m -	35		59	25.920	170	53.340	70	X			X	X						7/9/09 17:14
4	172	70m -	34		59	19.740	170	39.960	70	X										7/9/09 19:21
4	173	70m -	33		59	15.540	170	22.620	70	X				X						7/9/09 20:40
4	174	70m -	32		59	6.600	170	14.400	70	X										7/9/09 22:21
4	175	70m -	31		58	57.060	170	19.560	70	X										7/9/09 23:41
4	176	70m -	30		58	46.980	170	17.580	70	X										7/10/09 1:03
4	177	70m -	29		58	36.660	170	16.260	70	X			X	X	X					7/10/09 2:25
4	178	70m -	28		58	26.820	170	10.800	70	X										7/10/09 5:07
4	179	70m -	27		58	16.980	170	5.280	70	X			X	X		X	X			7/10/09 6:30
4	180	70m -	26		58	8.700	169	54.840	70	X										7/10/09 10:10
4	181	70m -	25		58	2.820	169	39.000	70	X	X		X	X						7/10/09 11:32
4	182	70m -	24		57	58.440	169	21.540	70	X										7/10/09 11:25
4	183	70m -	23		57	54.540	169	3.660	70	X										7/10/09 12:48
4	184	70m -	22		57	51.000	168	51.250	70	X										7/10/09 13:55
4	185	70m -	21	M4	57	44.000	168	51.780	70	X									X	7/10/09 14:59
4	186	70m -	20		57	37.680	168	49.320	70	X			X	X						7/10/09 18:01
4	187	70m -	19		57	31.380	168	36.720	70	X										7/10/09 20:08
4	188	70m -	18		57	30.000	168	18.180	70	X				X						7/10/09 21:29
4	189	70m -	17		57	30.000	167	59.100	70	X										7/10/09 23:11
4	190	70m -	16		57	30.000	167	40.020	70	X										7/10/09 21:20
4	191	70m -	15		57	30.000	167	20.940	70	X				X						7/10/09 22:43
4	192	70m -	14		57	31.320	167	2.400	70	X										7/11/09 0:24
4	193	70m -	13		57	25.440	166	48.420	70	X										7/11/09 1:42
4	194	70m -	12		57	26.580	166	31.380	70	X				X						7/11/09 2:59
4	195	70m -	11		57	19.200	166	19.560	70	X										7/11/09 4:38
4	196	70m -	10		57	19.200	166	0.600	70	X										7/11/09 6:01
4	197	70m -	9		57	15.720	165	44.820	70	X										7/11/09 7:17
4	198	70m -	8		57	6.480	165	36.780	70	X				X						7/11/09 7:40
4	199	70m -	7		57	0.000	165	22.740	70	X										7/11/09 9:20
4	200	70m -	6		56	53.640	165	8.220	70	X										7/11/09 10:42
4	201	70m -	5		56	54.540	164	50.100	70	X										7/11/09 11:45
4	202	70m -	4		56	51.000	164	34.260	70	X				X						7/11/09 13:02

Cruise phase	Consec. Stn. #	Line	Line stn#	addl. Info	Lat deg.	min.	Long deg.W	min.	Water Depth (m)	CTD (hydro)	<---------- Station Activities ----------> CTD - Prod./ uzoop. (Lomas/ Sambr/ Stoecker)	CTD (Other)	MOCNESS (Pinchuk et al.)	CalVET (Pinchuk)	Vertical Nets (Lessard/ Harvey)	van Veen (Iken)	Multicore (Shull/ Devol)	Sed. Trap D/R (Moran)	Other	Arrive Local Date/Time
4	203	70m -	3		56	49.920	164	18.660	70	X										7/11/09 14:35
4	204	70m -	2	**M2**	56	52.500	164	3.000	72	X										7/11/09 15:50
4	205	70m -	1		56	46.250	163	57.500	70	X										7/11/09 16:55
4	206	CN -	8		56	42.28	164	30.52	72	X										7/11/09 19:02
4	207	CN -	9		56	33.79	164	54.34	76	X				X	X					7/11/09 20:54
4	208	CN -	10		56	25.30	165	18.17	80	X										7/11/09 23:36
4	209	CN -	11		56	16.77	165	42.19	91	X										7/12/09 1:28
4	210	CN -	12		56	8.24	166	6.21	107	X										7/12/09 3:22
4	211	CN -	13		55	59.64	166	30.32	125	X										7/12/09 5:17
4	212	CN -	14		55	51.04	166	54.43	133	X										7/12/09 7:14
4	213	CN -	15		55	42.21	167	18.25	134	X										7/12/09 9:12
4	214	CN -	16		55	33.37	167	42.06	134	X										7/12/09 11:10
4	215	CN -	**17**		55	25.93	168	3.69	204	X										7/12/09 13:09
4	216	CN -	18		55	18.49	168	25.32	**510**	X										7/12/09 15:02
4	217	CN	19	C248	55	9.94	168	49.17	1200	X										7/12/09 17:04
				Dutch Harbor	53	54.178	166	31.650												7/13/09 4:00