FINAL REPORT SBI I
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Benthic Community Structure and Biomass in the Western Arctic:
Linkage to Biological and Physical Properties

Research and Education Activities:

The ultimate goal of our research was to link patterns of benthic community structure and biomass in the Chukchi and Beaufort Seas to associated physical and biological processes that can be identified as key determinants of global change. The spatial and temporal patterns in benthic faunal biomass can provide important information about overlying water column productivity and the coupling of carbon between pelagic and benthic communities. An understanding of the linkages between arctic circulation processes and spatial patterns in benthic faunal biomass is critical to our ability to predict the consequences of global climate change on arctic marine ecosystems with respect to biological productivity on arctic shelves.

An extensive effort was put forth to gather all known benthic biomass measurements taken within the western Arctic Ocean. Large and invaluable historical databases existed in unpublished records from the western Arctic region that had never been synthesized, including thousands of records on the biomass, density, and composition of benthic organisms from the northern Bering, Chukchi, Beaufort, and East Siberian seas. The result is a retrospective (1970-1995) dataset of 1,093 benthic biomass point measurements (Figure 1). In addition, 2,514 integrated chlorophyll *a* values, 222 temperature readings at the time of sampling, and depth readings at all sample stations were collected to provide additional information regarding the spatial distribution of benthic biomass.

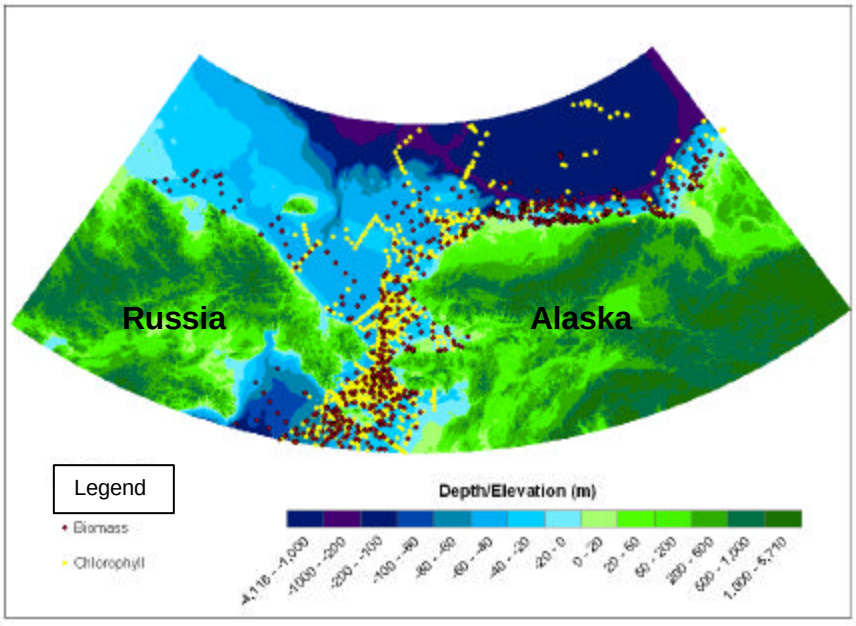

Figure 1. Location of stations where biomass data (brown points) and chlorophyll *a* data (yellow points) were collected.

ArcInfo, a Geographic Information System (GIS), was used to manage, analyze, and display the spatially referenced point samples, as well as the interpolated continuous surface of benthic biomass. The geostatistical interpolation produced both mean predictions and prediction standard errors on a continuous scale within the study region.

Benthic biomass data was difficult to work with using geostatistical interpolation due to the

unevenness or "patchiness" of its distribution. Therefore, extensive exploratory data analyses were performed on the raw samples to understand the basic statistical distributions in time and space before a geostatistical model was selected to interpolate the benthic biomass. The interpolated surfaces were subjected to uncertainty analysis that displayed prediction errors that indicated how well the model estimated the unmeasured locations.

Following examination of the raw data, three types of geostatistical analyses were performed on the data set. First, a spatial trend analyses of biomass and chlorophyll *a* data were used to create maps of predicted continuous spatial distribution over the defined study area. The resulting maps provided visual images of where biomass and chlorophyll were abnormally high or low. Secondly, temporal analyses of two areas located north and south St. Lawrence Island in the Bering Sea were performed to determine if there was a significant change in benthic biomass over a 30 year time span. Thirdly, correlations between benthic biomass and chlorophyll *a*, bottom water temperature, and depth were examined to test for significant relationships among these variables with biomass.

Suggestions for Future Research

There should be a more systematic and coordinated approach for the collection of biological, chemical, and physical data within the study area. Specific locations should be established where benthic biomass can be collected repeatedly over time. This would provide useful information when analyzing data for temporal trends. Our research shows that benthic biomass is roughly correlated over a 150 km distance (the range of the semivariogram for the raw sample points). Therefore, we recommend that future explorations collect samples at stations located 50-100 km apart for optimum results. Denser sampling provides unnecessary information and less dense sampling will not provide enough data for accurate spatial correlations of benthic biomass.

The project web page is: http://www.utmsi.utexas.edu/staff/dunton/sbi/index.htm

Findings:

1. Spatial Trend Analyses

The main objectives of the spatial trend analysis were to 1) predict the continuous spatial distribution of benthic biomass and chlorophyll *a* and, 2) identify "hot" and "cold" spots where biomass is abnormally high or low.

Biomass

The distribution of benthic biomass over space was best represented using data aggregated on 100 km square grid cells (Figure 2). Geostatistical block averages, or block kriging, can be used to estimate an attribute value over an area instead at one point. The purpose of the up-scaled grid was to soften small scale variability (patchiness) in order to amplify large scale trends. The smoothing traded detail for confidence. A 100 km grid was chosen over 50 km, 10 km, and 1 km grid sizes because it provided the appropriate balance of detail with smoothness necessary for the purposes of this study.

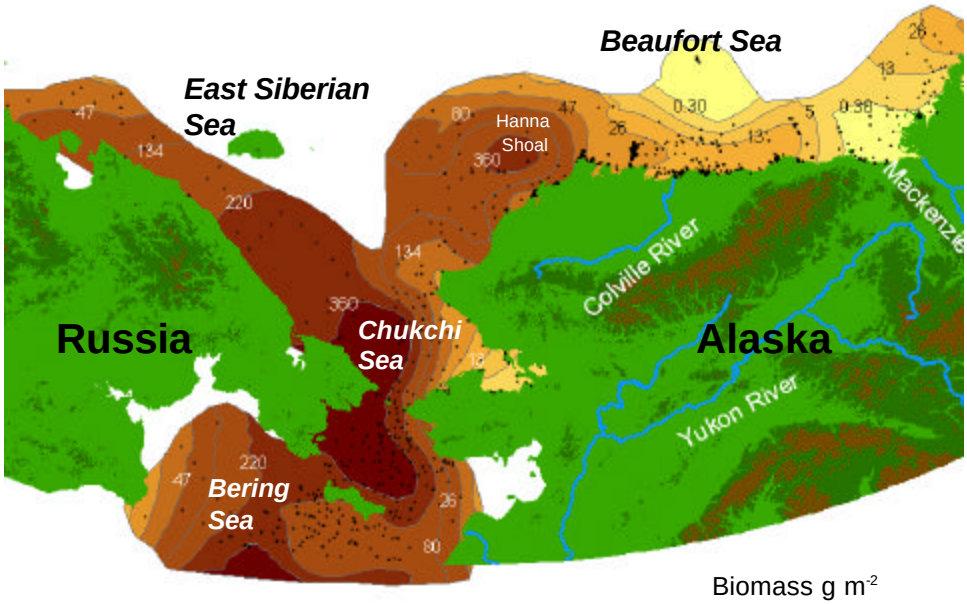

Figure 2. Benthic biomass concentrations (g m^{-2}) mapped in the study area. The darker the brown, the higher the biomass value.

The mapped biomass clearly showed that the benthic biomass in the Beaufort Sea was distinct from that of the other seas in the study area. The mean benthic biomass for the Beaufort Sea was 33g m^{-2}, which is significantly lower than the means of 370, 225, and 167g m^{-2} for the Bering, East Siberian, and Chukchi Seas, respectively (Figure 2). After initial development of a geostatistical model based on the complete dataset, it was determined that variability in Beaufort Sea biomass values was overwhelmed by the much higher values in other parts of the study area. The Beaufort Sea benthos data was removed and modeled separately to better predict the finer spatial distribution patterns within this area (Figure 3).

Several interesting features were defined using geostatistical techniques. The mapped benthic data show an area of very low benthic biomass in the vicinity of Mackenzie Bay (Figures 2, 3). In contrast, the biomass contours in the Beaufort Sea model show local high levels of benthic biomass near the mouth of the Colville River (Figure 3). Another significant observation is the extremely high benthic biomass in the Hanna Shoal region off the northwest coast of Alaska with a predicted mean benthic biomass greater than 360g m^{-2} (Figure 2). A large area including the

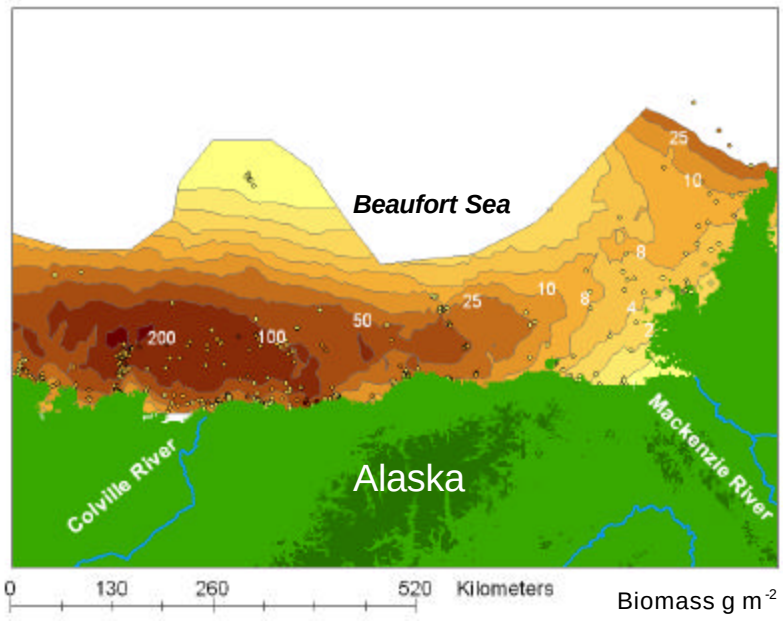

Figure 3. Benthic biomass concentrations (g m^{-2}) mapped in the Beaufort Sea. The darker the brown, the higher the biomass value.

western portion of the northern Bering Sea, Bering Strait, and Chukchi Sea also have high biomass values. We suspect that elevated values of benthic biomass reflect high rates of primary production or an abundance of advected carbon that falls directly to the seabed. Bowhead whales are frequently observed grazing on zooplankton in this region.

Chlorophyll a

Measurements of integrated chlorophyll *a* data were retrieved and modeled to examine the linkages between water column productivity and benthic faunal biomass. Each station was analyzed to assure there was an adequate representation of chlorophyll over the total depth. A Visual Basic program was written to integrate the chlorophyll values taken at many depths at each station into a single representative station value.

A map of the integrated chlorophyll values shows a large area of elevated values similar to the area of high biomass that includes the western portion of the northern Bering Sea, Bering Strait, and Chukchi Sea (Figure 4). The Beaufort Sea in general had lower chlorophyll values than the other mapped regions although an interesting area of elevated chlorophyll readings is observed in an area adjacent to Barter Island. Upwelling events bringing offshore waters onto the shelf were reported in this area by both G.L. Hufford and D.G. Mountain in 1974.

2. Temporal Trends

The entire benthic biomass data set was analyzed by the location, year, and month of collection in an attempt to identify stations that had been revisited over time. The only location within the study area with repeated sampling over a span of several years was in the vicinity of St. Lawrence Island in the Bering Sea.

Two 200 km by 200 km regions were identified in which a significant number (n = 20) of benthic measurements existed from different decades (Figure 5). One area was just north of St. Lawrence Island and the other just south. For each location, the raw samples were divided into their respective decades. The southern region contained measurements from the 1970's and the 1990's and the northern region contained measurements from the 1970's and 1980's.

Using ordinary kriging, benthic biomass was interpolated for each time period within each region. Area averaging of the interpolated biomass surface (block kriging) for each decade at each of the two locations provided evidence of a long-term (decadal) upward trend for the

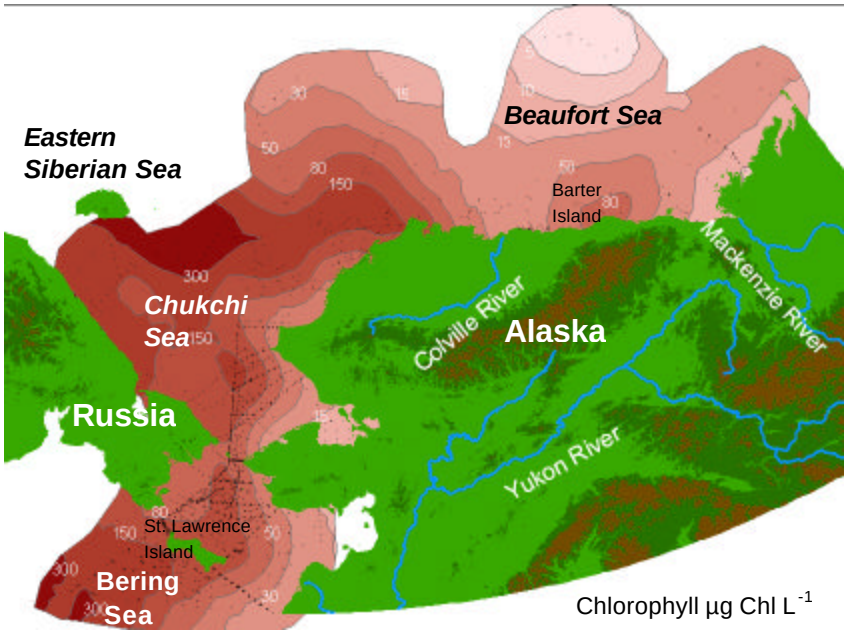

Figure 4. Chlorophyll *a* concentrations (µg L^{-1}) mapped in the study area. The darker the brown, the higher the chlorophyll value.

southern region and no evidence of a long-term trend for the northern region. The ability to detect temporal trends in the benthic data, however, was weakened by insufficient repetition of data at specific stations.

3. Other Associations

In addition to the benthic biomass samples, additional datasets were collected that might relate to benthic biomass and provide additional information to improve interpolation results. The additional data sets were chlorophyll *a* integrated over water column depth, water temperature, and depth at sampling locations. Scatterplots of all combinations of benthic biomass with the other three variables were made for each scale (sample, 1 km, 50 km, and 100 km). The scatterplots showed little to no correlation between benthic biomass and integrated chlorophyll *a*, depth, or temperature (correlation coefficients for all three were less than 0.4).

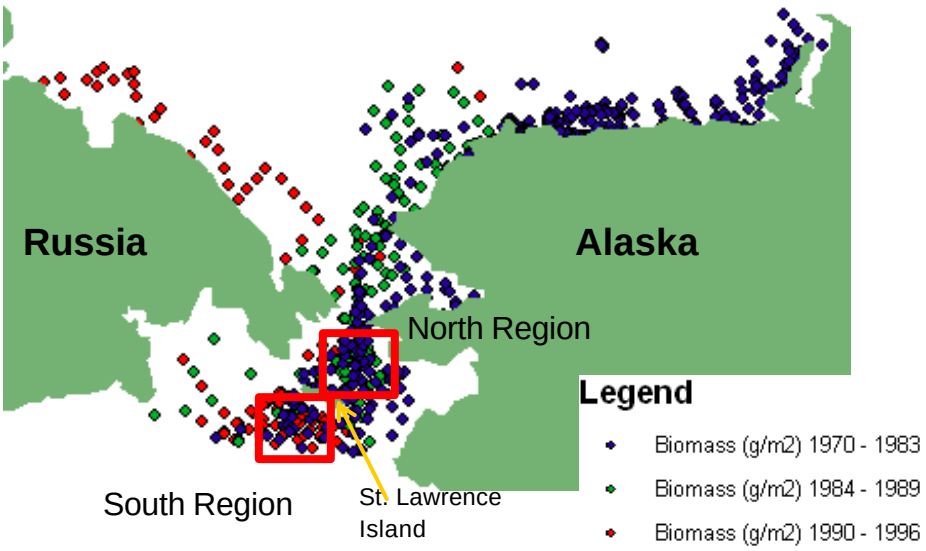

Figure 5. Biomass data were compared between the 1970's and 1980's (north of St. Lawrence Island) and between the 1970's and 1990's (south of St. Lawrence Island). Significant temporal trends were not detected in either area.