are further affected by the seasonal light regime. With the potential for future large scale open ocean iron manipulations, this study provides important seasonal information for the potential alterations in the oceanic sulfur cycle.

OS32L-12 1650h

A multi-element ecosystem model for global biogeochemical cycles

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We have developed an ecosystem model to simulate the dynamics of small and large phytoplankton as they relate to regenerated production, sinking particle export and transport of dissolved organic matter. Regeneration is described as a function of temperature and community structure, competing with the sinking of detrital material through the water column which is described as a function of ballast. Dissolved organic matter production is described as a function of phytoplankton production and nutrient limitation. This model has been calibrated through the generation of a synthesis of euphotic zone data on temperature, chlorophyll biomass, primary production and new production and/or particle export from over 100 sites. Where available, we have also utilized data on size-fractionated phytoplankton biomass and the carbon:chlorophyll ratio of phytoplankton. The resulting model has been incorporated into the Princeton Ocean Biogeochemical Model to diagnose new production, total production, phytoplankton biomass, particle export and dissolved organic matter transport through restoring of surface nitrogen, phosphorous, silicate and alkalinity in the MOM3 general circulation model. Comparison of model results with a synthesis of dissolved organic carbon survey data and satellite-based phytoplankton biomass from ocean color will be presented.

OS32M HC: 318 B Wednesday 1330h

Bentho-Pelagic Coupling at High Latitudes II

Presiding: **H E Hartnett,** Rutgers University**; U Witte,** Max Planck Institute for Marine Microbiology

OS32M-01 1330h INVITED

Benthic Processes in the Bering Strait Region of the Arctic: Temporal/Spatial Variability And Global Change

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Pelagic-benthic coupling can be studied via underlying sediment processes on various time scales. Sediment metabolism can be an indicator of weekly-seasonal carbon depositional regimes, whereas benthic faunal populations can act as multi-year, long-term integrators of a variety of marine processes. Recent environmental changes in the Arctic that are being observed include a seasonal reduction in the extent and duration of sea ice, increased seawater temperature, and changing hydrographic conditions, both spatially and temporally. High latitude ecosystems appear particularly sensitive to climate change, and the shallow, productive nature of the Bering Strait region in the North American Arctic may prove to make it a sentinel indicator for larger-scale regional and global changes.

Recent studies indicate that the Bering Sea is shifting towards an earlier spring transition between ice-covered and ice-free conditions. Coincident changes in the timing, extent, composition and location of annual production (both primary and secondary trophic levels) can have dramatic ramifications on higher trophic level fauna, including those utilized by subsistence hunters in the Arctic. These apex predators include benthic-feeding walrus, bearded seal, gray whale, and diving seaducks. Retrospective analyses of benthic processes in the Bering Strait region since the 1930s indicate a declining trend in carbon deposition and benthic biomass in the region, particularly in the 1990s. Declines in sediment oxygen respiration at individual stations have ranged as high as 73% over the past 15 years. Benthic biomass has declined as much as 89% over a longer time period. The region south of St. Lawrence Island, where we have the longest time-series record, has had both a reduction in bivalve standing stock and a change in dominant species composition. These ecological changes may directly influence the declining populations of a federally-listed (threatened) species, the spectacled eider. The entire world population of this Arctic duck winters in the waters south of St. Lawrence Island, feeding on bivalves on the continental shelf. As part of the NSF-funded Bering Strait Long Term Observatory project, we are maintaining an ecosystem-level study of this system within a global change framework.

URL: http://arctic.bio.utk.edu

OS32M-02 1400h

A Two-Year GIS Comparison for Assessing Ice-Cover Impacts on a Productive Benthic System in the Northern Bering Sea

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During April 1999 and March-April 2001, late winter biological, sediment, and hydrographic measurements were made at 28 stations in an area of historically high benthic biomass in the northern Bering Sea. Benthic macroinvertebrates are an important food source for diving seaducks (e.g., the threatened Spectacled Eider) and marine mammals in this region. This presentation will quantify the influence of seasonal ice cover on water column production and benthic processes during the two late winter cruises, using satellite ice coverage data and GIS mapping tools within the context of a longer, decadal ecosystem study in the region.

The years of 1999 and 2001 were very different in terms of ice extent and concentration. From mid-January to the end of April 1999 the ice concentration was at least nine-tenths for the entire study region. This uniformity of ice during the winter of 1999 may explain the lack of any correlation between ice coverage and any water column or benthic parameters, during our subsequent April sampling. In contrast, the ice concentration and extent during 2001 was greatly reduced over the Bering Sea. A spatially and temporally integrated measure of ice concentration prior to late winter sampling was significantly correlated with water column chlorophyll *a* measured during the cruise (Spearmans ρ=-0.415, p=0.35). Integrated chl *a* concentrations ranged from 3.1 to 52.2 (μg m^{-2}), low by comparison to maximum spring production events (e.g. during May 1994 integrated chl *a* ranged from 21.1 to over 1000 (μg m^{-2}). These data indicate a relationship between low winter ice coverage and temporal acceleration of water column production, which would be a likely scenario with global change. During both 1999 and 2001 benthic biomass (g C m^{-2}) was significantly correlated with late winter measurements of sediment chlorophyll *a* (Spearmans ρ=0.504, p=0.01; Spearmans ρ=0.330, p=0.05). These data support the conclusion that late spring production events and subsequent advection of carbon within the study area are important for deposition and use of carbon in this region over an annual cycle.

URL: http://arctic.bio.utk.edu

OS32M-03 1415h

The short- and medium-term fate of fresh organic carbon in deep-sea sediments

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The deep-ocean floor is one of the major marine reservoirs in the global carbon cycle and the transfer of carbon through the ocean plays a key role in controlling atmospheric CO2 concentrations. Estimates of deep-sea carbon fluxes are usually derived from surface water properties. However, a variety of factors conspire to limit the accuracy of these estimates and there are many advantages in assessing deep ocean fluxes through seafloor studies (Jahnke 1996). For logistic as well as financial reasons, however, these measurements can only be performed at a few spots. Thus, although it is evident that there are temporal changes of SCOC in many areas of the deep-sea it still remains difficult to pinpoint the steering factors triggering the benthic response and predict its speed and amplitude from POC flux measurements. The descriptive approaches to this question have so far been hampered by logistic difficulties and the unpredictability of seasonal sedimentation events (Pfannkuche et al., 1999). To overcome these difficulties, we choose an in-situ experimental approach in our study: a series of in-situ enrichment experiments were performed that were designed to clarify the short- and medium-term fate of fresh algal carbon arriving at deep-sea sediments. A food pulse, consisting of diatoms labeled with 15N and 13C, was simulated in benthic chambers deployed for periods of days to weeks during a 2 months lander campaign at abyssal depth (4800 m) in the NE Atlantic. Additional experiments were carried out at the Norwegian coast at 1300 m. The stable isotopes served as tracers in order to follow the transport into the sediment and uptake, incorporation and remineralization of the algal material by the different functional benthic groups of organisms. In addition, chitin was added to study the degradation pathway of this most abundant polysaccharide in the marine environment. As bacteria are the primary agents of the early diagenesis of organic matter in deep-sea sediments, particular attention was paid to microbial degradation and incorporation of organic matter. Macrofauna was in focus as large organims can be keystone players for the rapid subduction of organic matter into the sediment (Levin et al., 1997). In well-oxygenated marine sediments the sediment community oxygen consumption (SCOC) is generally considered to be an adequate measure of the total benthic mineralization of organic carbon (BCR). Oxygen is either consumed directly in the heterotrophic degradation of organic matter by microorganisms and animals, or consumed by the often microbially mediated reoxidation of upward diffusing, reduced solutes. The experiments revealed an instantaneous reaction of the abyssal benthos in total: SCOC doubled within 2.5 days and the high activity level was maintained throughout the 8.5 and 20 day experiments. *13C values of polychaetes rose from background values of 17 to 19 to values up to +2200 within days, demonstrating the fast incorporation of 13C algal material. The entrainment of label into deeper sediment layers and the incorporation into bacteria biomarker was fast in the Norwegian-coast sediments, but a considerable time lag was recorded in the PAP pointing to a pronounced difference in the response pattern of slope and abyssal plain communities to a food pulse.

OS32M-04 1430h

Reproductive Investment in *Mysis mixta* and *Acanthostephia malmgreni* in the Hyperbenthos of Conception Bay, Newfoundland

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Two hyperbenthic crustaceans, the mysid *Mysis mixta* and the amphipod *Acanthostephia malmgreni*, were sampled in Conception Bay, Newfoundland from October 1998 to November 2000 to determine their reproductive patterns. Due to their high abundance and year-round presence, these species are thought to play important energetic roles in the food web of Conception Bay. The amount and form of energy invested into reproduction by crustaceans can depend on numerous factors including the life cycle type, the number of reproductive events per year, seasonal food input, diet, and seasonal temperature profiles. These factors, in addition to reproductive traits of both species, are compared with seasonal reproductive costs. Costs in the form of lipid investment (LI, % of female lipid) are calculated using lipid profiles of brooding females compared with their embryos.

In general, LI of total lipid in *M. mixta* varied seasonally, with maxima of 70 to 73 % occurring early in 1999 and 2000. The high LI periods resulted primarily from increased investment in neutral rather than polar lipid, with triacyglycerol (TAG) representing the majority of neutral and phospholipid (PL) representing the majority of polar lipid. LI of total lipid in *A. malmgreni* averaged 88 % and did not vary seasonally.

Important fatty acids common to both species include 16:0, 18:1ω9, 20:5ω3 and 22:6ω3.

In addition to several reproductive traits, lipid investment data from this study reflect the differing habitat niches and life styles of these two hyperbenthic species. Lipid storage patterns of reproductive females also provide evidence that these species are highly dependent on, and closely linked to, the seasonal phytoplankton flux from the pelagic region. In addition, the enormous reproductive investment, particularly in *A. malmgreni*, results in the introduction of lipid-rich juveniles (3 to 4 mg total lipid per juvenile; 80 to 220 juveniles per brood) into the hyperbenthos of Conception Bay during spawning events that span from December to May. These reproductive events potentially represent a significant food source for benthic and pelagic predators in Conception Bay.

OS32M-05 1445h

The Role of Copepods for Conservation of Carbon in Versus Export From the Photic Zone During a Spring Bloom in Disko Bay, Western Greenland

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The spring bloom in Arctic areas generally constitutes the greater part of the annual primary production and holds potential for export of material from the photic zone. Copepods can accelerate export of phytoplankton through production of faecal pellets, which leave the photic zone. In contrast sloppy feeding and leakage from faecal pellets will conserve energy in the photic zone, thereby being important for fueling the microbial food web.

A one month sampling was carried out during the spring bloom in Disko Bay Western Greenland, June 2001. Every third day in situ primary production, bacterial production, copepod biomass, grazing and egg and pellet production were measured. Vertical fluxes of chlorophyll, carbon, pellets and eggs were estimated from short time deployment of sediment traps. Rates of leaking of DOC from feacal pellets and from sloppy feeding for the dominating Calanus species were determined by laboratory experiments.

The data will be used to discuss the role of marine copepods for conservation of carbon in versus export from the photic zone during spring blooms.

OS32M-06 1500h

Benthic Faunal Biomass in the Western Arctic: Linkage to Overlying Water Column Processes

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The ultimate goal of our research is 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. Benthic organisms integrate elements in the adjacent water column and therefore can be used as indicators of long-term change. We used Geographical Information Systems (GIS) software as a tool to map the biomass and distribution of benthic organisms for comparison to other features (eg. ocean depth, seasonal ice extent, currents, water column chlorophyll, etc.). Benthic data were assembled in an Access relational database and analyzed with the GIS programs ArcView and Arc/Info. A Geostatistical Analyst extension to ArcMap was used to interpolate the data with kriging techniques to produce probability estimates of benthic biomass across the study area. Plotted benthic data reveal areas of high biomass (> 250 g/m^2) north of the Bering Strait in the Chukchi Sea and south of the Bering Strait in Gulf of Anadyr waters. In contrast, benthic biomass along the nearshore Alaskan Beaufort Sea shelf is less than 30 g/m^2 except along the regions of the western Beaufort and east of the Mackenzie River delta. The high benthic biomass in the Bering-Chukchi parallels the abundance of benthic feeding marine mammals in this region compared to the Beaufort Sea. We are conducting further studies to examine the linkages between chlorophyll standing stocks and the productivity of overlying shelf waters with the physical forcing processes that regulate the advection of carbon to these benthic communities.

OS32N HC: 323 B Wednesday 1330h

Biophysical Factors Affecting the Growth and Survival of Aquatic Organisms II

Presiding: **C Hurd,** University of Otago

OS32N-01 1330h INVITED

Seagrass-Induced Transport of Particulate Matter Into Permeable Sediments.

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Water flow plays a fundamental role in seagrass ecology. Most of the work on water flow in seagrass systems has focused on above-ground processes: flux of carbon and nutrients to the leaves, pollination of the flowers, dispersal of the seeds and attenuation of waves and currents by above ground biomass. Due to pressure gradients that develop around seagrass shoots exposed to unidirectional flow, seagrasses can also affect the flux of dissolved and particulate matter between the water column and the permeable sediments they colonize. In a flume experiment, the depth of particle penetration and the number of particles transported from the water column into the seagrass colonized sediments was inversely proportional to particle size. The deepest particle penetration was observed 4 cm upstream of the seagrass shoots where positive pressure causes particles as large as 10 micrometers to penetrate more than 45 mm into the sediment. Blade flapping may also generate pressure gradients that contribute to the transport of particles into the sediment. Seagrasses colonizing permeable sediments, thus, cause particles to be transported into the root zone. This process has the potential to affect the geochemistry of vegetated sediments as well as plant growth.

OS32N-02 1345h

The Role of Instantaneous Turbulent Processes on Broadcast Spawning

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Turbulent flows advect, disperse, and mix any dissolved or suspended quantities of mass (scalars) that are added to the fluid. Benthic invertebrates that utilize broadcast spawning as a reproductive strategy rely on these physical processes to bring released gametes together. This study examines the role of hydrodynamics in the efficiency of the broadcast spawning process (as measured by mean fertilization rates), with an emphasis on how the instantaneous spatial and temporal structure of turbulence might enhance the coalescence of gametes in the flow.

Traditionally, it has been assumed that turbulence acts to inhibit fertilization rates through the rapid dilution of released sperm and ova. This assumption is based on a time-averaged perspective of the turbulent mixing processes. Previous numerical models of broadcast spawning, based on time-averaged models of gamete plumes, result in predicted fertilization rates that are much smaller than those measured in the field. It appears likely that the failure of previous models stems from the fact that these models omit the role of instantaneous hydrodynamic processes.

The instantaneous structure of scalar plumes consists of thin, high-concentration filaments surrounded by regions where the concentration is essentially zero. In a time-averaged sense, this results in low mean concentrations. However, if filaments of sperm and ova should coalesce, high local rates of fertilization would result (based on the product of the overlapping instantaneous concentrations). The time-averaged fertilization rate is not, in general, equal to the product of the time-averaged concentrations. Instead, it is equal to the time-average of the product of the instantaneous concentrations.

This study presents preliminary results which suggest that predictions of mean fertilization rates based on instantaneous processes are significantly higher than those based on mean processes. Hydrodynamic processes that produce statistical coalescence of gamete filaments are identified. The new fertilization rate predictions are likely to be consistent with both the magnitude and temporal variability of the rates measured in the field. Plans for future numerical and experimental investigations of this problem will be discussed.

OS32N-03 1400h

In Situ 3-Dimensional Measurements of the Local Particle Distribution and Turbulence Surrounding Copepods in the Marine Environment

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A submersible holographic system attached to the Johnson Sea Link has recorded about 500 *in situ* holograms of marine particles and organisms in the open ocean (Gulf of Maine, Wilkinson Basin) as deep as 225 meters during horizontal transects and unpowered vertical ascents. The holograms were recorded across bioluminescent thin layers identified by measurements made prior to each dive with a HIDEX bathyphotometer and during each dive with intensified video camera recording of a transect screen. The one liter sample volume of each hologram was located about 1 m above the JSL, between two streamlined fins in order to minimize the disturbance to the sample particle field. The reconstructed field of each hologram provides images with resolution better than 10 microns throughout this volume (3 microns for cylindrical objects). Scanning of each reconstructed field using video microscopy provides the instantaneous three dimensional locations and shapes of the particles in the sample volume. Automated scanning and data analysis procedures have been developed, including methods for spatially filtering the data and eliminating the speckle noise. It takes about 4 hours to analyze a single hologram, a process that distills 35 Gb of image information. The results include focused images of the particles, and measurements of their size, exact location and orientation in space. Classification of the larger, less numerous particles, e.g. distinction between *Calanus finmarchicus* and *Metridia lucens* copepods, is performed manually based on specific features. Smaller particles are classified based on their characteristic shapes. In the holograms recorded during the present study, each reconstructed field typically contains several thousand particles. Analysis of these holograms, which is still in progress, focuses on the distributions of marine snow and fecal pellets, as well as on a comparison of the concentration of 10 - 50 micron particles within the estimated detection range of the calanoid and cyclopoid copepods to that in regions outside this range. Nearest neighbor distances within these classes of particles are derived to quantify the patchiness of the microenvironment. Analyzed double exposure holograms provide a first glimpse of the instantaneous turbulent velocity field surrounding these copepods and their behavior, i.e. swimming velocities and orientation in these fields.

The development of the holocamera and holographic data analysis procedure was sponsored by the National Science Foundation under the Oceanographic Technology Program managed by Larry Clark, under grant OCE-9909170. Funding for the deployment was provided by the Office of Naval Research under the Thin Layers Program managed by Jim Eckman, under contract N00014-00-1-0176.

URL: http://www.me.jhu.edu/~lefd/shc/shc.htm

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