as for the upper 500 m. The El-Nio (1990-1995) events can be clearly seen in the POC sections, characterized by low values of POC in the upper ocean layer.

OS41B-17 0830h POSTER

Using preformed nitrate to infer recent changes in DOM remineralization in the upper thermocline of the subtropical North Pacific

Jeffrey T Abell[1] (206-543-7521; jabell@ocean.washington.edu)

Steve Emerson[1] (semerson@ocean.washington.edu)

Richard Keil[1] (rickkeil@ocean.washington.edu)

[1]University of Washington, School of Oceanography Box 355351, Seattle, WA 98195, United States

The preformed nitrate distribution in the subtropical North Pacific is characterized by a negative anomaly between the winter mixed layer and 25.4 σ_Θ. Its presence indicates that nitrogen remineralization in the upper thermocline deviates significantly from Redfield stoichiometry. It has been suggested that this anomaly is created during nitrate uptake by vertically migrating diatom mats, nitrate uptake by respiring bacteria, or degradation of nitrogen-poor dissolved organic matter (DOM). Here we present quantitative evidence that degradation of DOM with a high C:N ratio is primarily responsible for this feature. We develop a simple isopycnal model to predict preformed nitrate using apparent oxygen utilization (AOU), dissolved organic carbon (DOC), and dissolved organic nitrogen (DON) data. Model results agree well with the actual preformed nitrate distribution and show that the intensity of the anomaly is proportional to the magnitude of DOC remineralization and the DOC:DON remineralization ratio. From historical records of preformed nitrate along a common transect in the subtropical North Pacific, we infer that either the magnitude or the C:N ratio of DOC remineralization in the upper thermocline has increased by a factor of three in the last few decades.

OS41C HC: Hall III Thursday 0830h

Physics and Biology of Antarctic Continental Shelf Waters I

Presiding: **E E Hofmann,** Old Dominion University**; E J Murphy,** British Antarctic Survey

OS41C-18 0830h POSTER

Wave-Ice Interaction during Ice Growth: The Formation of Pancake Ice

Stephen Ackley[1] (210 341 6556; sackley@pol.net)

Hayley H Shen[1] (3152686614; hhshen@clarkson.edu)

M Dai[1] (mdai@clarkson.edu)

Y Yuan[1] (yyuan@clarkson.edu)

[1]Clarkson University, Civil and Env Engr Dept, Potsdam, NY 13699, United States

Field investigations of Antarctic sea ice have shown, by its fine grained frazil ice structure and surface topography features, that ice growth in the presence of waves accounts for a major fraction of the initial ice cover in the Antarctic regions. Pancake ice has been observed to grow in the presence of waves, on the few cruises that have been in the vicinity of the ice edge when the ice growth is occurring. Modeling of ice cover growth and correct parameterization of ice cover thickness, therefore mandates better understanding and quantification of the wave and ice interaction during ice growth in the presence of waves. However, the timing of cruises, to make appropriate wave and ice measurements to coincide with rapid ice cover growth and expansion (over hours to a day or two), is difficult and perhaps prohibitively risky when the success probability is small. To better understand the phenomenology of wave-ice interaction and provide some basis for quantifying the joint effects of waves and ice growth, we have undertaken laboratory studies of the growth of ice in wave fields and how the presence of ice subsequently dampens the wave field. The laboratory experiments, conducted under controlled thermal and wave conditions have allowed us to control the wave parameters and observe the ice growth from initial crystal formation to the final presence of a solid sheet of ice.

Two laboratory campaigns were conducted, both at the Cold Regions Laboratory in Hanover, NH, USA. The first experiments were in an outdoor basin (20m x8m x2m) using salt water in ambient winter conditions. The second experiments were conducted in a 35 m x 1.3m x 0.6m hydraulic flume in a cold room at the same facility. The flume used urea doped water which, when frozen gives a sea ice simulant of slightly different mechanical properties (more brittle) when frozen into a thin sheet. A paddle driven by an electric motor was used to generate a wave field in both facilities. We found that pancake ice formed in the two facilities were similar in most important respects. Ice growth into pancakes formed by the initial packing of frazil crystals into larger discs by aggregation of crystals and subsequently into larger pancakes by the fusing together of the initial pancakes. The onset of disc and pancake formation as well as the subsequent size of the pancakes were highly dependent on the wave frequency and amplitude, along with an apparently critical cooling rate necessary to allow surface freezing and hardening of the pancakes so that they could survive collisions with other floes in the wave field. Initial comparisons with a numerical model developed using interparticle interactions with a discrete element simulation were qualitatively similar. Parameters relating the growth of the pancake ice to initial wave frequency and amplitude and subsequent ice effects on wave decay were both determined.

OS41C-19 0830h POSTER

Circulation and Mixing on the Western Antarctic Peninsula Shelf: A Component of Southern Ocean GLOBEC

Susan L. Howard[1] ((206) 726-0501; howard@esr.org)

Laurence Padman[1] ((541) 753-6695; padman@esr.org)

Robin D. Muench[1] (rmuench@esr.org)

John T. Gunn[1] ((206) 726-0501; gunn@esr.org)

[1]Earth and Space Research, 1910 Fairview Ave. East, Suite 102, Seattle, WA 98102-3620, United States

The Southern Ocean Global Ecosystem Dynamics (S.O. GLOBEC) program is studying the continental shelf region in the vicinity of Marguerite Bay, on the western side of the Antarctic Peninsula, to determine the factors that contribute to Antarctic krill survival over winter. So far, 5 research cruises have collected data from the survey region between March and September 2001. We will use data from the vessel-mounted acoustic Doppler current profilers (ADCPs) on each cruise to describe the mean, mesoscale and tidal velocity fields of this region. We find a strong (~15-25 cm/s) coastal current flowing southward along Adelaide Island and into Marguerite Bay, then continuing southward along Alexander and Charcot Islands. The ADCP data also indicates strong currents at the continental shelf break, with speeds up to 40 cm/s. However, their magnitude and direction vary significantly, possibly in response to incursions of the Antarctic Circumpolar Current or diurnal tidal topographic vorticity waves that are predicted in this region. The ADCP data, combined with hydrographic data from CTD stations, is used to investigate the small-scale processes that drive the flux of heat from intrusions of upper circumpolar deep water into the surface mixed layer and to the sea surface or base of the sea ice. Strong velocity shears occur at the top of the permanent pycnocline in several locations. This shear often results in low gradient Richardson numbers, signifying that turbulent mixing is likely. We examine the spatial extent of the mixing and identify some of the probable sources.

URL: http://www.esr.org/globec_index.html

OS41C-20 0830h POSTER

Drifter Measurements of Near-Surface Flow over the West Antarctic Peninsula Shelf During Austral Summer – Fall, 2001

Richard Limeburner[1] (508-289-2539; rlimeburner@whoi.edu)

Robert C. Beardsley[1] (508-289-2536; rbeardsley@whoi.edu)

W. Brechner Owens[1] (508-289-2811; bowens@whoi.edu)

[1]Woods Hole Oceanographic Institution, Physical Oceanography, MS #21, Woods Hole, MA 02543, United States

As part of the U.S. Southern Ocean GLOBEC program, we deployed 14 satellite-tracked drifters near Marguerite Bay on the West Antarctic Peninsula shelf during March–May, 2001 to investigate the regional near-surface circulation. The drifters were WOCE SVP instruments with drogues centered at 15 m and equipped with cold weather batteries and ice strengthened buoy hulls since this area becomes ice covered in austral winter (June to December). The drifter tracks show (1) a moderate (10–20 cm/s) cyclonic circulation around Marguerite Bay with broad inflow in the northern side near Adelaide Island and a narrower outflow and greater variability in the southern side near Alexander Island, (2) weak (<10 cm/s) flow at midshelf, and (3) strong (>20 cm/s) alongshelf flow toward the northeast over the outer shelf and shelf break. The Marguerite Bay circulation was not closed; most drifters entering the bay left the bay, and a few apparently become stuck in the ice during August. Closed eddies were surprisingly absent in Marguerite Bay except for one instance of weak near-inertial oscillations that decayed within two days and small eddies (diameter ~10–20 km, rotation period ~3–5 days) near Rymill Bay. The weak mid-shelf surface drifter velocities were surprising due to the strong winds observed during the deployment cruises. The slow drifter speeds during large wind stress events may be due to the deep surface mixed layer (~50 m), resulting in quite weak Ekman currents. Lagrangian time and space scales of 1.8–3 days and 18–27 km were calculated from the autocorrelation functions for the drifter velocity components.

OS41C-21 0830h POSTER

Observations of Sea Ice Properties in the Marguerite Bay Region during Spring

Bruce Elder[1] (belder@crrel.usace.army.mil)

Sharon Stammerjohn[2] (sharons@ldeo.columbia.edu)

Keran Claffey[1] (kclaffey@crrel.usace.army.mil)

Donald Perovich[1] (perovich@crrel.usace.army.mil)

Raymond Smith[3] (ray@icess.ucsb.edu)

[1]ERDC-Cold Regions Research and Engineering Laboratory, 72 Lyme Road, Hanover, NH 03755

[2]Lamont-Doherty Earth Observatory, P.O. Box 1000 61 Route 9W, Palisades, NY 10964

[3]Institute for Computational Earth System Science, University of California, Santa Barbara, Santa Barbara, CA 93106

During the spring 2001 cruise of the South Globec experiment, we sampled ice physical and optical properties in the Marguerite Bay area of the Palmer Penisula. At 12 sites, ice thickness was measured every meter along 10- to 120-m-long survey lines. The combined mean ice thickness for these surveys was 62 cm, with a median of 43 cm and a maximum thickness of 280 cm. Snow depths ranged from 1 cm to 57 cm, averaging 16 cm. At 45 percent of the thickness holes, a combination of deep snow and thin ice resulted in negative freeboard. A stratigraphic analysis of ice thin sections showed that more than half of the ice cover was granular and that virtually all of the upper 20 cm of the ice was granular. There are indications that snow-ice formation at the surface contributed significantly to ice formation. At most sites the base of the snow cover was wet and saline. The average ice salinity was 7 psu, with the largest salinities, of approximately 10 psu, found near the surface. Ice temperatures were warm resulting in large brine volumes. The thicker ice showed evidence of extensive rafting and ridging. Visible albedos were in the 0.9-0.95 range for snow-covered ice and 0.5 - 0.6 range for bare ice. Maximum transmittances were between 400 and 500 nm. For 30-cm thick ice with 7 cm of snow, peak transmittances were only 2 to 3%. Removing the snowcover increased transmittance by an order of magnitude to almost 30%.

OS41C-22 0830h POSTER

Vertical Fine Structure Beneath the Ice of the Western Antarctic Peninsula Shelf in Austral Winter, 2001

Jason Hyatt[1] (508-289-2815; jhyatt@whoi.edu)

Robert C Beardsley[1] (508-289-2536; rbeardsley@whoi.edu)

John M Klinck[2] (757-683-6005; klinck@ccpo.odu.edu)

Eileen E Hofmann[2] (757-683-5334; hofmann@ccpo.odu.edu)

[1]Department of Physical Oceanography, Woods Hole Oceanographic Institute, 360 Woods Hole Rd, MS 21, Woods Hole, MA 02543, United States

[2]Center for Coastal Physical Oceanography, Old Dominion University, Crittenton Hall, Norfolk, VA 23529, United States

As part of the U.S. Southern Ocean GLOBEC program, a broad-scale CTD survey was conducted in Marguerite Bay and the adjacent West Antarctic Peninsula shelf during austral winter (July 22 to August 31, 2001). With sea-ice covering most of the study area and eliminating almost all surface wave motion, the R/VIB Nathaniel B. Palmer provided a very stable platform, allowing high-quality CTD data to be collected without significant wave-induced contamination. Many of

the CTD profiles exhibit a steppy structure in the main pycnocline. These steps are thin in the vertical, of the order of a few meters, and are separated by stratified layers that ranged in thickness from a few to tens of meters.

In this region, very cold winter surface water overlays warmer, more saline Antarctic Circumpolar Deep Water, such that both temperature and salinity increase with depth. The structure of these steps will be described in detail, and some possible causes will be presented.

OS41C-23 0830h POSTER

Surface Forcing Over the West Antarctic Peninsula Shelf During Austral Summer–Fall, 2001

Robert C. Beardsley[1] (508-289-2536; rbeardsley@whoi.edu)

Richard Limeburner[1] (508-289-2539; rlimeburner@whoi.edu)

Michael J. Caruso[1] (508-289-2901; mcaruso@whoi.edu)

Jason Hyatt[1] (508-289-2814; jhyatt@whoi.edu)

[1]Woods Hole Oceanographic Institution, Physical Oceanography, MS#21, Woods Hole, MA 02543, United States

As part of the U.S. Southern Ocean GLOBEC program, meteorological measurements were made aboard the R/V *Gould* and R/VIB *Palmer* during cruises in and near Marguerite Bay on the West Antarctic Peninsula shelf from April through May, 2001. These measurements included wind speed and direction, air temperature, relative humidity, barometric pressure, seasurface temperature, and downward short- and longwave radiation. The surface wind stress and heat flux were then computed using bulk formula.

This region of the West Antarctic Peninsula shelf experiences large seasonal changes in surface forcing. Passing low pressure systems become more frequent and stronger from summer into winter, when gale-force winds occur on average every ∼2.5–3 days. Cloud cover becomes much more persistent, further reducing the shortwave heat flux as the sun approaches winter solstice. Air temperatures drop to below freezing and seasurface temperatures reach freezing and ice formation occurs. Despite increased winds from summer into winter, sensible and latent heat losses become less important in the net surface heat flux as longwave cooling becomes the dominant component over open water before ice formation.

OS41C-24 0830h POSTER

Seasonal and long-term studies of the nearshore Antarctic marine ecosystem

Andrew Clarke[1] (+44 1223 221591; andrew.clarke@bas.ac.uk)

Eugene J Murphy[1] (+44 1223 221614; e.murphy@bas.ac.uk)

Mike Meredith[1] (+44 1223 221614; m.meredith@bas.ac.uk)

[1]British Antarctic Survey, High Cross Madingley Road, Cambridge CB3 0ET, United Kingdom

The high latitude of Antarctica means that many environmental variables exhibit a strong seasonality. This is manifest as an intense seasonality of primary production, particularly in nearshore waters, which is propagated through to the highest levels of the foodweb. One consequence of this seasonality is that winter data are essential for a complete understanding of ecosystem processes, but such data are difficult and expensive to obtain in polar regions. Here we report data from two long-term programmes of nearshore oceanographic monitoring in Antarctica. The first is a record of fast-ice duration in the South Orkney islands, which at over 90 years is the longest continual environmental time-series for any site in Antarctica. This record reveals a secular change in seasonal ice dynamics in the mid-20th century, and provided evidence for the regional influence of El Nino and the first indications for the Antarctic Circumpolar Wave. The second is a record of temperature, salinity and chlorophyll for northern Marguerite Bay. This reveals strong interannual variability, with the 2000/01 austral summer being distinctly unusual in the warmth of the surface waters. The year-round data provided by shore stations is important in complementing the more detailed work undertaken offshore by research vessels. They are also important in supplementing the surface measures available from satellites; the latter data are available only during cloud-free periods and cannot measure the subsurface layers where some significant physical and biological processes occur.

OS41C-25 0830h POSTER

Seasonal Variability in an Antarctic Ecosystem at Deception Island

Yueng-Djern Lenn[1] (858 822 5831; ylenn@ucsd.edu); Teresa Chereskin[1] (tchereskin@ucsd.edu); Ken Smith[1] (ksmith@ucsd.edu); Robert Glatts[1] (rglatts@ucsd.edu); Roberta Baldwin[1] (rbaldwin@ucsd.edu); Anne Sturz[2] (asturz@acusd.edu)

[1]Scripps Institution of Oceanography, 9500 Gilman Dr, La Jolla, CA 92093-0230, United States

[2]University of San Diego, 5998 Alcala Park, San Diego, CA 92110-2492, United States

On seasonal time scales Southern Ocean ice cover is one of the largest signals in the global ocean. This extreme seasonal variability causes large fluctuations in primary production and pelagic and benthic populations. From March 1999 to November 2000, the annual cycle of the ecosystem at Port Foster, Deception Island was studied with long-term moorings and a series of 5 cruises. Deception Island has a central drowned caldera which communicates with the open ocean through a shallow, narrow opening to Bransfield Strait called Neptune's Bellows. This site was chosen for its sheltered environment, free from icebergs, but representative of Antarctic continental shelf waters.

The entire water column (160 m) was monitored at a mid-bay site with 3 thermistor moorings. An upward-looking Acoustic Doppler Profiler was deployed from February to November 2000. A camera and anemometer, located on the northern ridge, were used to monitor winds and ice cover. We observed a clear seasonal signal in both temperature and currents. The erosion of the summertime stratification was characterized by a deepening of the thermocline and high velocity shear across the base of the mixed layer. In winter, the entire column was well-mixed to just above freezing. Frequency spectra of the currents indicate that the M2 tide dominates and is anti-clockwise polarized below 70 m. Above 70 m there is no apparent polarization of the K1 and M2 tides, and the K1 tide becomes dominant nearer the surface. Both tidal signals also appear in the temperature data. At this latitude the inertial period is about 13.5 hours and could not be resolved from the M2 tide. Preliminary analysis indicates that the winds were highly variable in both direction and amplitude. A nonzero mean current profile at mid-bay suggests that there is a persistent circulation within Port Foster which may enhance exchange with Bransfield Strait. The depth-dependent signals in the M2 and K1 tides lead us to hypothesize that the barotropic tide pulses at Neptune's Bellows, exciting a baroclinic response in Port Foster. A diurnal signal is present in the ADP backscatter amplitude, consistent with diel migration of zooplankton and clearly reflects the changing length of day during the austral winter.

OS41C-26 0830h POSTER

Physical Forcing of Phytoplankton Community Structure in Continental Shelf Waters of the Western Antarctic Peninsula

Barbara B. Prezelin[1] (805-893-2879; barbara@lifesci.ucsb.edu)

Eileen E. Hofmann[2] (757-683-5334; hofmann@ccpo.odu.edu)

John M. Klinck[2] (757-683-6005; klinck@ccpo.odu.edu)

[1]University of California, Santa Barbara, Marine Science Institute, Department of Ecology, Evolution and Marine Biology, Santa Barbara, CA 93106, United States

[2]Old Dominion University, CCPO, Crittenton Hall, Norfolk, VA 23529, United States

A previous study of the western Antarctic Peninsula (WAP) continental shelf that was based upon a multidisciplinary data set collected during austral summer of January 1993 identified a mechanism previously unrecognized that sets up a physical and chemical structure that supports enhanced biological production. This biological production occurs when the southern boundary of the Antarctic Circumpolar Current (ACC) flows along the shelf edge and produces onshelf intrusions of nutrient-rich Upper Circumpolar Deep Water (UCDW), thereby allowing site-specific diatom-dominated phytoplankton communities to develop. The enhanced biological production potentially affects all components of the marine food web in this region. In this analysis, we extend the area and seasons studied through similar analyses of multidisciplinary data sets collected on four additional cruises that cover all seasons. We find that this newly recognized forcing is active in other regions of the WAP shelf where similar conditions are found, is episodic, and is forced by non-seasonal physical processes. The meander frequency of the ACC has consequences for the timing and location of UCDW intrusions. When multiple intrusions are observed, each event may be in a different stage. Further, the occurrence of an event in one area does not necessarily imply that similar events are ongoing in other areas along the WAP shelf. While these UCDW upwelling events originate along the outer shelf, they have a signature that extends into the inner shelf region because of the deep topography with allows the inner shelf to be connected to the outer shelf. The frontal boundary between the intruded water and the shelf water is variable in location because of the episodic nature of the onshelf intrusions, being moved further inshore when one of these events is occurring. The frontal boundaries are characterized by distinct phytoplankton communities whose distribution along the circulation structure is identifiable by the unique presence of a chemotaxonomic marker (Chlorophyll b) in the near surface waters. These observations show clearly that the phytoplankton community structure on the WAP shelf is determined by physical forcing. Moreover, variability in this physical forcing, such as may occur via climate change, can potentially affect the overall biological production of the WAP continental shelf system.

OS41C-27 0830h POSTER

The Southern Ocean Global Ocean Ecosystem Dynamics Program: Results from the First Field Season

Eileen E Hofmann (757-683-5334; hofmann@ccpo.odu.edu)

Old Dominion University, CCPO Crittenton Hall, Norfolk, VA 23529, United States

The Global Ocean Ecosystem Dynamics (GLOBEC) Program has a primary goal understanding marine population variability in response to environmental variability. From the early stages of GLOBEC planning, the Southern Oceanwas selected as a research site for addressing this goal. The focus of the SO GLOBEC research efforts is on understanding the physical and biological factors that contribute to enhanced Antarctic krill (*Euphausia superba*) growth, reproduction, recruitment, and survivorship throughout the year. This focus also includes the predators and competitors of Antarctic krill, such as penguins, seals, cetaceans, fish, and other zooplankton. The Southern Ocean GLOBEC (SO GLOBEC) field program began in 2001 with cruises by Australia (January-February), Germany (April-May), and the United States (April-June and July-September), which were focused on the Antarctic region near 70°E and the west Antarctic Peninsula region. The SO GLOBEC cruises are multidisciplinary and include components to measure circulation, hydrography, water column and sea ice primary production, krill distribution and abundance, krill physiology, fish ecology, penguin, seal and cetacean distribution and abundance, and krill predator diets. Similar sampling in the national field programs provides a basis for making comparisons between environments that differ in sea ice cover, hydrographic structure, and biological characteristics. As part of the United States field program, an array of current meters was deployed on the west Antarctic Peninsula continental shelf for a period of one year, which represents the first long-term *in situ* measurements of current velocity for this region. The German and United States 2001 field activities have an emphasis on austral winter processes because of the recently recognized importance of sea ice in determining growth and recruitment of Antarctic krill. These programs provided some of the first comprehensive austral winter measurements that are designed to investigate the structure and function of the Antarctic marine food web. As such they, will provide a basis for understanding the effect of climate variability in the Antarctic. This poster provides an overview of the SO GLOBEC program as well as preliminary results from the first year of field activities of this program.

OS41C-28 0830h POSTER

Studies on Ammonia in the Antarctic Ocean

Yulia M Serebrennikova[1] (727-553-1646; yulias@seas.marine.usf.edu)

Kent A Fanning[1] (727-553-1594; kaf@marine.usf.edu)

[1]College of Marine Science University of South Florida , 140 Seventh Avenue South, St. Petersburg, FL 33701, United States

Ammonia in most of the ocean is principally a surface-water phenomenon since dissolved ammonia concentrations are largely undetectable below the mixed layer. The rapid utilization of ammonia by phytoplankton is invoked to explain the fact that mixed-layer ammonia levels are also frequently very low. We chose to study ammonia in the Antarctic Ocean, where possibly the highest surface ammonia concentrations occur outside of specialized environments or polluted areas. Field data from the GLOBEC study in and near Marguerite Bay on the western side of the Palmer Peninsula during the austral winter of 2001 are compared to archived data from the JGOFS study in the Ross Sea in 1996-98.

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The highest ammonia concentrations we measured were found in the upper 50 meters on the GLOBEC cruises: NBP-0103 (April-May) and NBP-0104 (July-August). Values up to 4 μM were detected during the April-May cruise before the austral winter and up to 2 μM during the July-August cruise at the height of the austral winter. Concentrations below the mixed layer at 50-100 meters approached zero. The highest values were close to the peninsular coastline, with lower concentrations offshore followed by slightly increasing values further offshore. There was no obvious relationship between ammonia distributions and primary and secondary production, at least on the April-May cruise. Surface chlorophyll distribution showed a north-south trend during the study while ammonia had an onshore-offshore gradient. Zooplankton, such as krill, were abundant in the high-ammonia zones but the greatest zooplankton abundance was below the mixed layer. Data from microzooplankton studies are not yet available. On the assumption that phytoplankton ammonia uptake is minimal during the austral winter, a possible explanation for the approximately 2 μM decline in ammonia concentration between the two GLOBEC cruises is the wintertime bacterial oxidation of ammonia remineralized from a summer phytoplankton population. However supporting bacterioplankton data are not available.

An interesting relationship between ammonia and nitrate in the upper water column was evident during both GLOBEC cruises. A decrease in nitrate concentration toward the shore of the Palmer Peninsula is in linear proportion to an increase in ammonia concentration. JGOFS data from the Ross Sea do not show such a relationship for the most of the JGOFS cruises that took place during austral summer, although ammonia concentrations as high as 3 μM were detected. However one JGOFS cruise conducted at the same season (April) as the GLOBEC NBP-0103 cruise does in fact show the linear nitrate-ammonia relationship of the GLOBEC cruises. The prevalence of this relationship will be tested in the next austral winter during the second year of GLOBEC cruises to the Marguerite-Bay region.

A plot of ammonia versus salinity for the GLOBEC cruises was linear. This fact suggests that, if the mixed layer was principally a two-point mixing regime, physical processes were dominating the ammonia distribution before and during the austral winter. Relationships between ammonia and salinity are not well known for the most of the ocean, but the one found here implies that ammonia might prove useful as a surface tracer in the austral winter. However, this implication would have to be reconciled with the decline in ammonia concentrations found between the two GLOBEC cruises since, as mentioned, nonconservative biochemical processes may be producing the decline.

OS41C-29 0830h POSTER

Wintertime Production Rates, Size Distribution, and Abundance of Sea Ice Bacteria West of the Antarctic Peninsula

Frank J. Stewart[1] (1-775-674-7539; fstewart@dri.edu)

Christian H. Fritsen[2] (1-775-673-7487; cfritsen@dri.edu)

[1]Desert Research Institute Division of Earth and Ecosystem Sciences University of Nevada, Reno, Desert Research Institute 2215 Raggio Pkwy., Reno, NV 89512, United States

[2]Desert Research Institute Division of Earth and Ecosystem Sciences, Desert Research Institute 2215 Raggio Pkwy., Reno, NV 89512, United States

The extent to which microorganisms in Antarctic sea ice support pelagic organisms overwintering below the ice is not known but is believed to be dependent in part on heterotrophic bacteria and the cycling of carbon through the microbial food web. Samples were collected along a grid spanning the continental shelf within and around Marguerite Bay during late July and August 2001. Sea ice coverage was greater than 90 percent at all sample sites. Bacterial biomass, size distribution, and activity and autotrophic biomass (as chlorophyll a) were measured for consolidated sea ice, surface water, and brine habitats. Bacteria and algal biomass in sea ice and brine samples were generally low relative to published values for Antarctic sea ice in the spring and summer. Biovolume measurements showed a distinct trend toward large cells (0.15-0.2 um^3 $cell^{-1}$) in sea ice and brine relative to surface water (0.1-0.5 um^3 $cell^{-1}$). Bacterial growth was detectable and variable across habitats. These trends coincide with a year having a relatively late onset of ice formation in the study area. The transfer of energy and materials from sea ice microbial communities to the water column may have increased significance in years when a late-forming ice cover restricts the period during which krill can graze on organic matter released from the under surface of the ice.

OS41C-30 0830h POSTER

Stable Isotope Structure of West Antarctic Peninsula Continental Shelf Plankton Communities II: Comparison with Georges Bank, N.W. Atlantic

Jennifer W Whiteis[1] (607-255-5449; jww10@cornell.edu)

Karen Fisher[1] (607-255-5449; kef10@cornell.edu)

David Rosenfield[1] (607-255-5449; dar30@cornell.edu)

[1]Department of Earth Atmospheric Sciences Cornell Univeristy, 2154 Snee Hall, Ithaca, NY 14853, United States

Stable isotope structure of the zooplankton communities observed during Southern Ocean GLOBEC show a number of similarities to the zooplankton shelf regions observed are highly variable environments with different assemblages of zooplankton species, a number of similarities stand out in overall patterns. Broadly defined zooplankton groups tend to have characteristic positions when arranged in order of δN and δC values (ratio of heavy to light isotopes of each element). δN values are expected to yield information about the flow of nutrients from herbivores, which tend to be have lower δN values indicating relatively higher proportions of N-14 relative to N-15, to higher trophic levels. δC values are expected to reflect a wider rangeof environmental conditions. Samples from MOCNESS (Multiple Opening Closing Net and Environmental Sensing System) tows were obtained from GLOBEC cruises at over 100 stations. Hydrographic regimes observed ranged from the Southern Flank of Georges Bank, under the influence of a Gulf Stream Ring, to ice covered Antarctic waters. Stable isotope composition for all samples was determined on a Finnegan Delta Plus mass spectrometer and a Carlo Erba NC2500 Elemental Analyzer at the COSIL facility at Boyce Thompson Institute, on the Cornell Univeristy Campus. Pteropods, copepods, euphuasiids, amphipods, chaetognaths, and fish larvae were analyzed for each region. Replicate samples of animals sorted to species at sea were run to determine the amount of within species variation relative to between species variation. The extent of spatial and temporal variability in community isotope structure, relative to the variation within each group, shows potential for use of stable isotopes as indicators of community structure.

OS41C-31 0830h POSTER

Stable Isotope Structure of West Antarctic Peninsula Continental Shelf Plankton Communities I: Particulates and Zooplankton between 65 S and 70S

Karen E Fisher[1] (607 255-5449; kef10@cornell.edu)

Jennifer W Whiteis[1] (607 255-5449; jww10@cornell.edu)

David A Rosenfield[1] (607 255-5449; daverosenfield@hotmail.com)

[1]Cornell University, 2154 Snee Hall Cornell University, Ithaca, NY 14853, United States

The continental shelf area of the Western Antarctic Peninsula observed in 2001 during Southern Ocean GLOBEC extends over 500 kilometers in latitude, and over 200 kilometers from the shelf break to the interior of Marguerite Bay. Conditions at the surface varied considerably along the grid, and between the austral fall (NBP0103) and austral winter (NBP0104) cruises, from open water with pycnoclines 100 meters deep, to sheltered stratified waters capped with ice. Stable isotope observations of particulate (< 300 microns filtered onto precombusted GFC's), and zooplankton samples (1 m MOCNESS) were vacuum freeze- dried, and analyzed in a Finnegan Delta Plus Mass Spectrometer at the Cornell Boyce Thompson Stable Isotope Laboratory (CoBSIL). Particulate material from fall surface samples set the baseline for the analysis. Midshelf stations yielded $\delta N \simeq -1$; stations along the coast in the southern portion of the grid along Alexander and Charcot Islands yielded $\delta N \simeq 5$; and stations along the shelf break on the outer edge of the grid, and in the middle of Marguerite Bay, yielded $\delta N \simeq 1$. Winter surface values on the outer edge of the grid yielded $\delta N \simeq 5$, comparable to inshore values observed in the fall. Conversely, for δC only three fall stations lay outside the cluster of $\delta C \simeq -23$ to -25 values found: the outermost fall shelf stations, $\delta C \simeq -26.7$ and -29.4, and the southern most ice covered station, $\delta C \simeq -25.7$. Both patterns are consistent with the hydrography and circulation encountered. As tracers of varying duration, individual zooplanktors represent snapshots of the flow of nitrogen and carbon from particulates through successive trophic levels. Species, size, and individual variation all impact stable isotope composition. Several zooplankton groups (krill, amphipods, copepods, fish larvae, and pteropods) were analyzed. Consideration of the structure of stable isotope relationships at each location, and changes from fall to winter, shows patterns of variability ranging from individuals to plankton assemblages.

OS41C-32 0830h POSTER

The Development of Standard Condition Indicators for Antarctic Krill

Hyoung-Chul Shin[1] (hcshin@kordi.re.kr)

Stephen Nicol[2] (61 3 62 323324; $stephen_ic@antdiv.gov.au$)

Robert King[2] ($rob_kin@antdiv.gov.au$)

Edwina Hollander[3] (edwinah@postoffice.utas.edu.au)

[1]Polar Sciences Laboratory, KORDI, Ansan PO Box 22, Seoul 425-600, Korea, Republic of

[2]Australian Antarctic Division, Channel Highway, Kingston, Tas 7050, Australia

[3]Institute of Antarctic and Southern Ocean Studies, University of Tasmania, Hobart, Tas 7001, Australia

Recent studies have focussed on the biology of Antarctic krill during winter. Krill have the ability to employ a number of overwintering strategies including: omnivory, carnivory, dependence on ice algae, reduced metabolism and starvation and associated shrinkage. There is no certainty on the environmental conditions that result in krill employing one strategy over another. There are also few simple tests that can be used to determine which behaviour is being relied on by krill at any particular place or time. We have developed a series of simple methods, which have been validated in the laboratory and in the field, to indicate the nutritional condition of krill collected at any season. They are particularly applicable for studies in winter for which there is greatest uncertainty.

The simplest measure that indicates the in situ nutritional condition of krill is the in vitro measurement of the length of the digestive gland relative to the length of the carapace. In animals that have been starved or in animals that have been collected during winter there is markedly reduced digestive gland length for a given size of krill. We propose a condition index based on this relationship. This index reflects relatively short term (< 7 days) food availability.

Longer term food shortage (> 10 days) results in shrinkage in overall length in krill. There is still little consensus on how often this occurs in the wild. Krill that have undergone long periods of shrinkage are distinguishable from krill that have not shrunk by the relationship between the eyeball diameter and the total length. Shrinking krill conserve the eyeball diameter thus shrunk krill have larger relative eyeball size than un-shrunk krill of the same length. This index reflects food shortage over seasonal periods.

Intermediate length nutritional condition can be measured by a number of parameters derived from the instantaneous growth rate methodology. This is an experimental technique that measures growth from a comparison between the size of krill and the size of their newly shed exoskeletons. This technique has shown that in summer, krill are growing at rates of up to 10% per moult and that krill are driven to shrinkage only after 20 days of starvation. In autumn, krill are growing at a reduced rate (< 4% per moult) and they begin to shrink after less than 15 days of starvation. In winter, krill are either not growing or are shrinking at a maximal rate of around 2% per moult. The moult cycle also changes with season. These rates can simply be converted to carbon content and can provide an index of condition over periods of time less than a moult cycle.

These techniques have now been used in field studies and provide a suite of measurements that could be used by krill researchers which would allow comparisons between studies, areas and seasons, and even between different species of krill.

OS41C-33 0830h POSTER

The Role of Lipids in the Life Strategies of the Antarctic Krill

Wilhelm Hagen[1] (49-421-2187145; whagen@uni-bremen.de)

Gerhard Kattner[2] (49-471-48311490; gkattner@awi-bremerhaven.de)

Dorothea Stübing[1] (49-421-2189508; stuebing@uni-bremen.de)

[1]Marine Zoology, University of Bremen, P.O. Box 330440, Bremen 28334, Germany

[2]Alfred Wegener Institute for Polar and Marine Research, P.O. Box 120161, Bremerhaven 27515, Germany

Various developmental stages (larvae to adults) of *Euphausia superba* have been collected during different seasons in the Weddell Sea and off the Antarctic Peninsula to investigate the significance of lipids and fatty

acids in the life cycle of the Antarctic krill. Emphasis was laid upon data from late fall and early spring, hence before and after the supposedly critical winter period. The total lipid data of *E. superba* exhibited pronounced seasonal variations, especially in the immature and adult specimens. Minimum lipid levels were found in late winter/early spring and maximum levels in autumn, primarily due to the accumulation and utilization, respectively of triacylglycerol and phosphatidylcholine. The fatty acid compositions of the younger stages were dominated by 20:5(n-3), 22:6(n-3) and 16:0. These typical phospholipid fatty acids are major biomembrane constituents. The phospholipid composition was similar in the older stages. With increasing storage of triacylglycerols in the lipid-rich immature and adult stages, the fatty acids 14:0, 16:0 and 18:1(n-9) prevailed comprising about two thirds of total triacylglycerol fatty acids. The trophic marker fatty acids 16:1(n-7) and 18:4(n-3) indicating diatom or flagellate ingestion were less abundant. They reflected however the dependence of the larvae on phytoplankton as well as the seasonal changes in algal compositions.

Considering the various overwintering scenarios of krill under discussion, lipid production is effective enough to accumulate large energy reserves for the dark season, but *E. superba* does not exhibit the sophisticated biosynthetic pathways known from other Antarctic euphausiids and copepods. Although important, lipid utilization appears to be just one of several successful strategies of *E. superba* to thrive under the extreme Antarctic conditions.

OS41C-34 0830h POSTER

The Use of a High Powered Strobe Light to Increase the Catch of Antarctic Krill by a 1-m2 MOCNESS.

Peter H. Wiebe[1] (508-289-2313; pwiebe@whoi.edu)

Carin J. Ashjian[1] (508-289-3457; cashjian@whoi.edu)

Scott M. Gallager[1] (508-289-2783; sgallager@whoi.edu)

Cabell S. Davis[1] (508-289-2333; cdavis@whoi.edu)

Nancy J. Copley[1] (508-289-3204; ncopley@whoi.edu)

[1]Department of Biology, Woods Hole Oceanographic Institution, Woods Hole, MA 02543

Adult Euphausia superba, better known as krill, are strong swimmers and are notoriously difficult to capture with the size of nets typically used by oceanographers. Comparisons of the abundance of krill in a given region based on acoustical techniques, marine mammal and sea bird foraging requirements, and net tow abundance estimates nearly always result in the net estimates being significantly lower than either of the other estimates. The reasons most often given for the net systems poor performance are avoidance of capture by the nets and the extreme patchiness of krill making it difficult to get a good statistical estimate of their abundance. A study was done during the first broad-scale survey cruise of the Southern Ocean GLOBEC Program (NBP0103) in April/May 2001 to evaluate the use of a high powered strobe light (1500 W with a beam fan angle of 30 degrees)with a 3 second flashing rate to reduce the avoidance effect. Three horizontal tows were done in Marguerite Bay (Western Antarctic Peninsula), a region with high numbers and biomass of adult krill. Each tow consisted of a series of paired down and up casts through a set depth interval (e.g., 50-90 m), with each successive net sampling both a down and up cast. The strobe light was set to either "on" or "off" while each net was open. During a tow, four of the eight nets (335 um mesh) sampled with the strobe flashing and four sampled with the strobe off, in a random sequence. Total displacement volume was significantly increased ($p<0.05$) on average by a factor of ~ 1.5 when the strobe light was on. The increased biovolume was due to the enhanced catch (factor of ~ 2) of adult krill in the 15 to 60 mm size range. They accounted for most of the biovolume. There was not an enhanced catch of krill in the 5 to 15 mm size range. In addition, the average size of the krill was not changed substantially by having the strobe light on. These preliminary results suggest that krill avoidance of nets can be overcome by smart counter-measures.

OS41C-35 0830h POSTER

Ctenophore Predation on Larval *Euphausia superba* During Winter Along the Western Antarctic Peninsula

Kerri M. Scolardi[1] (727-553-1208; kscolardi@marine.usf.edu)

Kendra L. Daly[1] (727-553-1041; kdaly@marine.usf.edu)

Scott M. Gallager[2] (508-289-2783; sgallager@whoi.edu)

[1]University of South Florida, College of Marine Science, 140 Seventh Ave. South, St. Petersburg, FL 33701, United States

[2]Department of Biology, Woods Hole Oceanographic Institution, Woods Hole, MA 02543, United States

The Southern Ocean Global Ecosystem Dynamics Program (SO GLOBEC) is a collaborative research effort designed to examine the physical, chemical and biological processes that contribute to the abundance and success of the Antarctic krill, a keystone species in the Southern Ocean. The Western Antarctic Peninsula is a region marked by unusually high Antarctic krill production and is an important habitat for krill predators. Fish, birds, penguins, seals and other marine mammals are known to be important predators of adult Antarctic krill, but little is know about predation on larval krill. Gelatinous zooplankton, which were common in the study area, are potentially an important group of predators of larval krill. During the first US GLOBEC field season in July and August of 2001, diver observations indicated high densities of ctenophores (greater than 1 ctenophore m^{-3}) just under the pack ice (top 10 meters of the water column) where larval krill aggregated. These ctenophores were observed floating relatively stationary in the water with their tentacles fully extended, a method of predation used by ambush predators. In some locations, high ctenophore numbers co-occurred with low larval abundances. Gut analysis of mertensiid ctenophores (n = 30) collected by divers and in net tows showed that 62% of the ctenophores containing recognizable prey in their digestive system had remnants of krill larvae in their guts. However, 57% of the ctenophores sampled did not have recognizable prey item in their guts. Ctenophore and larval krill abundances from ROV images and net tows collected during this field season will be presented. Our preliminary observations from this first winter study suggest that the mertensiid ctenophore may be an important predator on larval krill populations in the WAP and as such may have a significant effect on the abundances and distribution of Antarctic krill in this area.

OS41C-36 0830h POSTER

Mysticete Whale Acoustic Census Within the SoGLOBEC West Antarctic Peninsula (WAP) Region

Sue E Moore[1] (206-526-4021; sue.moore@noaa.gov)

Mark A McDonald[2] (307-742-0753; mmcdon@worldnet.att.net)

Ana Širović[3] (858-534-8210; ana@mpl.ucsd.edu)

Catherine Berchok[4] (cberchok@yahoo.com)

John A Hildebrand[3] (858-534-4069; jah@mpl.ucsd.edu)

[1]National Marine Mammal Laboratory/NOAA, 7600 Sand Point Way, N.E., Seattle, WA 98115, United States

[2]Whaleacoustics.com, 2535 Sky View Lane, Laramie, WY 82070, United States

[3]Scripps Institution of Oceanography, University of California San Diego, 9500 Gilman Drive, MC 0205, La Jolla, CA 92093-0205, United States

[4]Penn State University Graduate Program in Acoustics, 217 Applied Science Bldg, State College, PA 16804, United States

Mysticete whales are top-predators of euphausiids (krill), but whale populations were so severely depleted by commercial whaling during the 20^{th} century that their role in the existing Antarctic ecosystem is unknown. The primary goal of this project is to determine seasonal occurrence and minimum population size of mysticete whales within the WAP study area through year-round detection of their calls. Eight autonomous acoustic recording packages (ARPs) were deployed between 18 March and 13 April 2001 offshore the Antarctic Peninsula to record calls from baleen (mysticete) whales. The ARPs are bottom-moored, with a hydrophone suspended roughly 5 m above the seafloor. Their sample rate is 500 Hz and, with a total hard disk storage capacity of 36 Gbytes, they are capable of a 400 day deployment. Blue whales (*Balaenoptera musculus*) and fin whales (*B. physalus*) produce repetitive low frequency calls ($\sim$20 Hz), which can be reliably identified and detected at ranges of 20-30 km. These species were nearly extirpated during the whaling era, and obtaining an accurate population estimate from visual surveys is virtually impossible. Humpback whales (*Megaptera novaeangliae*) and minke whales (*Balaenoptera acutorostrata*) produce calls at higher frequencies (40-2000 Hz), the lower ends of which are well within the sampling capability of the ARPs. For these two species we anticipate describing seasonal occurrence and minimum population density estimates both from acoustic and visual detections, as they are far more numerous. Whale calls also were detected and recorded via sonobuoy deployments during several SoGLOBEC cruises including: NBP01-03, from 23 April to 6 June, and NBP01-04, from 22 July to 31 August. Recordings made during these cruises can be coordinated in real-time with visual observations and form the basis for identification of calls recorded on the ARPs. The ARPs are scheduled for recovery (and redeployment) in February-March 2002, with the data processing beginning immediately thereafter.

OS41C-37 0830h POSTER

A Model Study of Circulation and Biogeochemical Processes in the Ross Sea

Michael S. Dinniman[1] (757-683-5559; msd@ccpo.odu.edu)

John M. Klinck[1] (757-683-6005; klinck@ccpo.odu.edu)

Walker O. Smith[2] (804-684-7709; wos@vims.edu)

[1]Center for Coastal Physical Oceanography, Old Dominion University Crittenton Hall, Norfolk, VA 23529

[2]Virginia Institute of Marine Science, College of William and Mary, Gloucester Pt., VA 23062

Physical forcing, which includes advective circulation, vertical mixing, and vertical stratification, may be the primary factor producing the observed vertical and horizontal variability in phytoplankton distribution and primary production in the Ross Sea. Related to this, exchange of Circumpolar Deep Water (CDW) onto Antarctic Seas and continental shelves has a large influence on sea ice and biological processes. As part of the US JGOFS Synthesis and Modeling effort, we are investigating circulation and nutrient transport in the Ross Sea with an eddy permitting, regional, 3D, numerical circulation model. The present effort focuses on implementation and testing of the circulation model. Later work will consider more realistic biogeochemical processes and simulations for specific years, to compare directly to observations.

We use the Rutgers/UCLA Regional Ocean Model System (ROMS) with a grid resolution of 5 km horizontally and 24 levels vertically. A gridded bathymetry is derived from ETOPO5. Initial model fields of temperature and salinity are derived from the World Ocean Atlas (WOA98). Initial values of nitrate and silicate come from a newly developed gridded nutrient and chlorophyll monthly climatology for the Ross Sea. Wind stress is from the monthly climatology of ECMWF reanalysis stress. Instead of using a fully dynamic sea-ice model, ice concentrations are specified using the SSM/I climatology and this, along with the COARE bulk flux algorithm, is used to compute the model surface heat and salt fluxes. Vertical mixing in the interior and surface boundary layer is done using the K profile parameter (KPP) vertical mixing scheme (modified for the presence of ice). A radiation boundary condition is used on all the open boundaries along with adaptive nudging (Marchesiello 2000) to monthly climatologies of temperature (WOA98), salinity (WOA98), nutrients (our database) and depth averaged circulation (OCCAM global high resolution circulation model). The effects of the Ross Ice Shelf are modeled by relaxing the temperature and salinity to climatological values along the edge of the shelf. The model circulation compares favorably to general schematics of the flow. Circumpolar Deep Water intrudes onto the shelf in the eastern Ross Sea due to wind and topographic effects. There is westward, wind driven flow along the Ross Ice Shelf and a northward boundary flow occurs along the western Ross Sea. Circulation and nutrient transport are strongly affected by bottom topography. A strong northwestward current, with an associated V-front, flows along the shelf break. Onshore flow occurs at the shelf break over shallower banks while offshore flow occurs in the troughs. Without uptake, the advection and diffusion of nutrients as passive tracers leads to them being retained in the surface layer near Ross Island.

OS41C-38 0830h POSTER

Nutrient Processes in a Regional Model of the Ross Sea

Walker O Smith[1] (804-684-7709; wos@vims.edu)

Micheal S Dinniman[2] (757-683-5559; msd@ccpo.odu.edu)

John M Klinck[2] (757-683-6005; klinck@ccpo.odu.edu)

Eileen E Hofmann[2] (757-683-5334; hofmann@ccpo.odu.edu)

[1]Virginia Institute of Marine Science, College of William and Mary, Gloucester Pt, VA 23062, United States

[2]Center for Coastal Physical Oceanography, Old Dominion University Crittenton Hall, Norfolk, VA 23529, United States

A regional numerical model of the Ross Sea is used to analyze processes by which silicate and nitrate advect and diffuse on the Ross Sea shelf and are removed by phytoplankton. As part of a JGOFS synthesis and modeling project, we consider the path of nutrients

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from the ocean to the subpycnocline waters of the shelf, as well as the vertical flux to the surface layers. Uptake of nutrients is based on the historical distribution of chlorophyll and appears as a sink. Path, timing and nutrient ratios are used as diagnostics.

We use the Rutgers/UCLA Regional Ocean Model System (ROMS) with a grid resolution of 5 km horizontally and 24 levels vertically. A gridded bathymetry is derived from ETOPO5, and initial temperature and salinity are derived from the World Ocean Atlas (WOA98). Both nitrate and silicate are active in the model and initial distributions come from a newly developed, gridded, monthly nutrient and chlorophyll climatology for the Ross Sea that is created from observations from many cruises (mostly from the U.S. Southern Ocean JGOFS program) combined with WOA98 gridded fields. Monthly wind stress is from the ECMWF reanalysis climatology. Ice masked surface heat and salt flux are constructed from the SSM/I and ECMWF reanalysis climatologies using the COARE bulk flux algorithms. Vertical mixing in the interior and surface boundary layer uses the K profile parameter (KPP) scheme. Open boundaries use adaptive nudging (Marchesiello 2000) to monthly climatologies of temperature, salinity, nutrients as well as depth averaged circulation from the OCCAM global circulation model. Effects of the Ross Ice Shelf are imposed through nudging to climatological temperature and salinity in a buffer zone. Nutrients are removed from the near surface at rates that depend on the new gridded chlorophyll concentration as well as model nutrients.

The new biogeochemical climatologies show a strong seasonal variability in parts of the western Ross Sea, where data are available. Residual surface nutrients in summer are likely due to iron limitation. The climatologies can be used to compare individual cruises to long-term mean conditions and therefore quantify large-scale variations of biogeochemically relevant variables.

Model results show that nutrients enter the shelf along the NW shelf break (near Cape Adair) and along the eastern shelf break (Cape Colbeck). Surface nitrate is reduced from 30 to 6 uM in 20 days where the chlorophyll concentration is high, while silicate is reduced from 80 to 30 uM. Subpycnocline nutrients remain near initial levels of 30 and 75 uM, respectively. Surface nutrients in the model will continually decline to zero unless some process, like iron limitation, halts uptake even with nutrients.

OS41C-39 0830h POSTER

Relationships Between Spatial and Temporal Dynamics of two Euphausiid Species and ice and Water Masses in the Ross Sea

Aniello Russo[1,2] (a.russo@unian.it)

Massimo Azzali[2]

Sarine Manoukian[2] (0039-071-2078848; manuk75@hotmail.com)

Giovanna Lanciani[2]

Elio Paschini[2]

[1]Institute of Marine Sciences - University of Ancona, Via Brecce Bianche, Ancona, AN 60131, Italy

[2]Maritime Fishery Research Institute - National Research Council, Largo Fiera della Pesca, Ancona, AN 60125, Italy

The pelagic ecosystem of the Ross Sea is dominated by two similar and probably competing krill species: Euphausia superba (E.s) and Euphausia crystallorophias (E.c). The coexistence of the two populations implies that they have different dynamics in space and time, probably caused by the dynamics of ice and water masses. The paper presents initially the spatial distributions of the two populations, the ice cover and the water masses structure from late spring (Nov.1994) to early (Dec.1997) and full summer (Jan./Feb.2000). Then an attempt to explain the dynamics of the two species through that of ice and water mass is discussed.

Data on krill populations were collected from three large-scale acoustic surveys. They covered the western part of the Ross Sea, between the lat.70° and 77°S and long.164°E and 178°W. The multi-frequency and echo-integration methods were used to discriminate the two species, assess their biomass and determine their spatial distribution. During the acoustic survey of Nov.1994, the Ross Sea was completely covered with ice. The survey of Dec.1997 was conducted in partially ice-covered and relatively rough conditions, while the survey of Jan./Feb.2000 in ice-free waters and in stable weather conditions. During the acoustic surveys the Euphausiids were sampled using a 5m2 Plankton Hamburg Net (HPN) of 500/1000 m. From net samplings the biological parameters of each species were determined. As far as physical oceanography data are concerned, these include CTD casts, XBT launches and continuous surface temperature recordings. Although they were collected during the three cruises, the 2000 Expedition data are the only ones gained synoptically with the echo-survey and then the more integrable from acoustical, biological and physical point of view. Therefore our attention was particularly fixed on this last Expedition, during which 34 CTD stations were performed with a Sea Bird Electronics SBE 911plus probe, measuring temperature, salinity, density and fluorescence from the sea surface to the bottom (or at least 400 m), and 72 Sippican T7 XBT probes were launched, allowing for measurement of temperature from the sea surface to the bottom.

The krill density biomass has been mapped on the ice cover. In the last decade of Nov. it develops a noticeable frontier between the two species around lat. 75°S, where the marginal ice zone begins to form. The southern end of the environment (below 75°S) is dominated by E.c, while the Northern part (above 75°S) is dominated by E.s In Dec. the frontier between the two species widens: E.s. moves to North together with ice melting, while E.c moves slightly to South of 75°S. In Jan./Feb. the movement of E.s slows down, until it stabilises above 73°S. In the same period E.c moves North up to 73°S, where it stabilises. The krill density biomass has been plotted on the horizontal and vertical temperature field. Most part of the observed krill swarms is placed in relation to the surface waters. Where the last residual pack ice is present associated to colder surface waters, a separation of swarms has been observed. It would seem that the E.c swarms were connected mainly to the Ross Sea surface waters and E.s swarms were almost exclusively found in Antarctic Surface Waters, both being scantily present in the High Salinity Shelf Water, Circumpolar Deep Water and Warm Core. Deeper swarms were observed mainly close to shelf-break areas where a deeper mixed layer was present.

OS41C-40 0830h POSTER

SO GLOBEC meets APIS: The character of the midwater fish faunas of the eastern Ross Sea and the western Antarctic Peninsula Shelf

Joseph Donnelly[1] (727-553-1648; jdonnelly@marine.usf.edu); Joseph J Torres[1] (727-553-1169; jtorres@marine.usf.edu); Tracey T Sutton[1] (727-553-1189; tsutton@marine.usf.edu); Christina Simoniello[1] (727-553-1648; simo@marine.usf.edu); Michelle Grigsby[1] (727-553-1648; mgrigsby@marine.usf.edu); Joel Bellucci[1] (727-553-1648; joel@cetaceans.com); Scott Burghart[1] (727-553-3970; sburghart@marine.usf.edu); Thomas Bailey[2] (561-231-1489; baileywick@aol.com)

[1]College of Marine Science, University of South Florida, 140 Seventh Avenue South, St. Petersburg, FL 33701, United States

[2]Indian River Community College, Mueller Campus, 6155 College Lane, Vero Beach, FL 32966, United States

The fish fauna of the Southern Ocean is comprised of two elements, an oceanic fauna comprised of midwater fish families found throughout the world ocean and an endemic fauna associated with the shelf and slope of the continent and outlying islands. The pelagic fish fauna of the shelf regions is of considerable interest. Apex predators such as seals and penguins feed in the upper 500 m and include fishes in their diet. In addition, fishes are potentially important predators of krill and zooplankton. The 500 m average depth of the water column associated with the Antarctic continental shelf would not exclude the oceanic species from being present based on depth alone, so on an a priori basis a mix of oceanic and endemic species would be expected, particularly at the shelf break. We examined the pelagic fish communities of the eastern Ross Sea, including the continental shelf region, and compared them to those found on the western Antarctic Peninsula (WAP) shelf. Thirty six midwater trawls were taken in the Ross Sea, including 22 MOCNESS tows, and thirty two MOCNESS trawls were taken on the WAP shelf. We found a profound difference between the two systems. Representatives of the classical midwater fauna, e.g. the myctophids and bathylagids were present in both systems seaward of the shelf break, but there the resemblance ended. The midwater families were found throughout the study region on the WAP shelf, including the fjord regions near the continent. In contrast, the midwater families stopped abruptly at the shelf break in the eastern Ross Sea. The most obvious difference between the two systems is the temperature structure of the water column, which is uniformly cold (approximately -2°C) from surface to bottom in the Ross Sea and warm (approximately 1°C) on the WAP shelf. It is tempting to conclude that temperature is excluding the oceanic species, but other factors are likely to play an important role as well. What is clear is that the character of the pelagic fish fauna between the two regions is quite different.

OS41D HC: Hall III Thursday 0830h

Equatorial Oceanography III

Presiding: **D Moore,** NOAA /PMEL**; D Turk,** International CLIVAR Project Office

OS41D-41 0830h POSTER

Yanai-Kelvin Wave Conversion in the Gulf of Guinea

Allan N Kaufman[2] (1-510-486-7899; ankaufman@lbl.gov)

Bradley A Shadwick[1] (1-510-486-4347; bashadwick@lbl.gov)

[1]Lawrence Berkeley National Laboratory, MS 4/230, Berkeley, CA 94720, United States

[2]University of California, Physics Department, Berkeley, CA 94720-7300, United States

When a Yanai wave-packet, propagating eastward along the Atlantic Equator, enters the Gulf of Guinea, it transfers a fraction of its wave energy to a westward-propagating coastal Kelvin wave. This wave conversion occurs via localized linear resonance between the zonal wavenumbers, which vary zonally because of the nonuniform depth of the thermocline. When the Yanai wave strikes the African coast, it bifurcates into northward and southward coastal Kelvin waves. The northward wave follows the coast and re-enters the resonance region, where the same fraction is transferred back to a new Yanai wave, and so on. The conversion process has been studied analytically [J Fluid Mech 394 (1999) 175-192], by projecting a variational principle onto the local meridional eigenfunctions for fixed-frequency waves. We now report on two-dimensional computations of the full linear equations, for various initial or boundary conditions. We compare the simulation results with the previously obtained analytic formulation.

OS41D-42 0830h POSTER

The cross-equatorial structure of Tropical Instability Waves from a linearized stability analysis of the Pacific

John m Lyman[1] (jlyman@oce.orst.edu)

Dudley Chelton[1] (chelton@oce.orst.edu)

Roland deSzoeke[1] (rdeszoek@oce.orst.edu)

Roger M Samelson[1] (rsamelson@oce.orst.edu)

[1]College of Oceanic and Atmospheric Sciences, Oregon State University, 104 Ocean Admin Building, Corvallis, OR 97331-5503

A linearized 2-mode projection model has been developed to understand observed characteristics of monthly variability in the Equatorial Pacific from TOPEX/POSEIDON measurements of Sea Surface Height (SSH). The 2-mode projection model is obtained from an equatorial beta plane model that has been linearized about a geostrophically balanced mean flow. The state variables from the model are projected on to the first 2 baroclinic vertical eigenfunctions. Because in situ measurements of currents in the equatorial Pacific are not available with adequate spatial and temporal resolution, the mean current structure used in the 2-mode projection model was obtained from the Parallel Ocean Climate Model (POCM). POCM was chosen because the monthly variability in the model SSH fields closely resembles that of TOPEX/POSEIDON in dispersion characteristics and cross-equatorial structure. The sensitivity of the 2-mode projection model to the mean equatorial currents is examined by individually increasing and decreasing the various components of the equatorial current system: the currents south of the equator, the currents north of the equator and north branch of South Equatorial Current (SECN). The eigenvectors and eigenvalues from this range of current structures are able to reproduce many of the characteristics (phase, amplitude, period, wavenumber and meridional structure) observed in TOPEX/POSEDON and POCM. The most surprising result is that the eigenvector amplitudes in the south depend only on the strength of the northern equatorial current system.