addressed by using results from the operational, real-time, global Navy Ocean Layered Model(NLOM) running at the naval Oceanographic Office(NAVOCEANO) and SeaWIFS imagery for the Sping Intermonsoon of 2001. The NLOM model, which is run at 1/16th degree resolution, has an embedded mixed layer and assimilates altimeter and MCSST observations, is in excellent agreement with SeaWIFS ocean color imagery in revealing a filament along the Oman coast in mid-April of 2001. The model reveals that the filament was generated by the interaction of two counter-rotating eddies with the coastal circulation during an upwelling-favorable wind event. SeaWIFS imagery has been processed to uncouple the bio-optical properties within the filament infrastructure. We illustrate the distribution of chlorophyll, backscattering at 555 nm and absorption from colored dissolved organic matter (CDOM). Backscattering defines how coastal particles are located within the filament and how they are distributed offshore and settle below the satellite observations. CDOM absorption defines the degradation of organic matter and how is distributed and disbursed offshore. The implications of such intermonsoon filaments to the bio-physical response during the intense SW monsoon are discussed.

OS11R-03 0910h

Translocation of diapausing Calanoides carinatus in the Mesopelagic/Deep Layers in the Arabian Sea: Modeling Lagrangian Particle Drift in an Isopycnic Ocean Model.

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We use the Miami Isopycnic Coordinate Ocean Model (MICOM), configured for the Arabian Sea, to track particles as they drift in isopycnic layers corresponding to 500-1000m depths. The Lagrangian particles are assumed to represent populations of the copepod Calanoides carinatus, an indiginous species of the Arabian Sea that includes a diapausing stage as part of its life cycle, usually the last juvenile stage (fifth copepodite stage). It is hypothesized that the oligotrophic conditions, following the productive Southwest Monsoon season, may trigger the onset of diapause in this species that overwinters in the deep layers. The overwintering period is thought to begin in August-September and end in May, when the new generation takes advantage of increased diatom production associated with seasonal upwelling.

Model drifter trajectories are numerically solved at the same time step (15 min.) as MICOM (online simulations) using a forth-order Runga-Kutta algorithm. Particle trajectories consist of a deterministic component derived from the MICOM velocity fields and a random component that simulates turbulent flow. The particles themselves represent populations of C. carinatus that are in a state of nonfeeding diapause. Therefore only lipid catabolic expenditure (respiration) is modeled during the overwintering period. The particles are launched in isopycnic layers 6-10 at specified times in August and September off the coast of Somalia. Individuals have a lipid reserve of 50-65% of body dry weight and allowed to drift for an 8-9 month period. At the end of the simulation, the remaining lipid content is calculated and equated to potential egg production. Preliminary results indicate the layer at which particles drift is extremely important in determining the fate of these populations with respect to their emergence from diapause in favorable versus unfavorable conditions.

OS11R-04 0930h

A 4-Dimensional Validation of a Coupled Physical-Biological Model of the Arabian Sea

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The Arabian Sea was selected as one of the JGOFS Process Study sites because of its strong monsoonal forcing and large seasonal oscillations in physical and biogeochemical properties. Data from these studies provide a unique opportunity for testing the response of coupled models under a wide range of oceanic conditions. In this paper we compare horizontal sections and time-series generated by a 3-dimensional, coupled, biological-physical model with observations from the U.S. JGOFS Arabian Sea Process Study. These comparisons include modeled and observed mixed layer depth, chlorophyll concentration, inorganic nitrogen concentrations, zooplankton biomass, and particulate nitrogen export flux. With these comparisons we identify both strengths and weaknesses in the model and we attempt to use the model as a tool to help us understand the observed patterns. The model reproduces most of the large-scale variability in these physical and biogeochemcial quantities, which is driven by the monsoonal forcing cycle. Although chlorophyll concentrations are sometimes overestimated, dissolved inorganic nitrogen concentrations are reproduced quite accurately, and the modeled particulate nitrogen export fluxes are similar to the sediment trap measurements. The modeled and observed zooplankton concentrations compare favorably offshore, but they are significantly underestimated near the coast during the Southwest Monsoon. This may be linked to the model's tendency to overestimate chlorophyll concentrations there as well. Many of the discrepancies between the model and the observations are caused by the presence of mesoscale eddy-like features and chlorophyll-rich filaments which emanate from the coast of Oman. These features cannot be reproduced by the model due to its relatively low horizontal resolution. Our comparisons reveal a clear need for higher resolution simulations and they suggest that a more sophisticated representation of zooplankton grazing maybe required for modeling chlorophyll in the coastal zone.

OS11R-05 0950h

The Arabian Sea Model Testbed: an Intercomparison of Data Assimilative Ecosystem Models

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The central Arabian Sea is an ideal testbed for assessing the capabilities of oceanic ecosystem models, since the full range of pelagic environments occur in response to the annual monsoon cycle. The associated atmospheric forcing results in a biannual mixed layer deepening which triggers significant phytoplankton blooms during both the winter and summer monsoons, whereas during the intermonsoons the system shifts to an oligotrophic state. In this study, we carry out simulations using three distinct marine ecosystem models with varying levels of complexity, including a four-component model with diatom-like phytoplankton growth, a five-component model emphasizing the microbial loop, and an eight-component model containing multiple plankton size classes. The models are applied within a consistent one-dimensional framework at the site of the WHOI mooring (15.5N, 61.5E), using physical forcing extracted from a 3-D physical circulation model solution of the Arabian Sea. Chlorophyll a and nitrate data from Station S7 (16N, 62E) and sediment trap data from WHOI mooring MS-4 (15.33N, 61.5E) are assimilated using the adjoint method. In this technique model-data misfits are minimized by adjusting model parameters such as sinking velocities, growth rates, assimilation efficiencies and mortality rates. After objectively optimizing each model in this manner, we quantitatively compare the performance of the different models to determine which specific formulations are most appropriate. That is, we systematically ascertain which model formulations best represent the fundamental underlying biogeochemical processes and capture the magnitude and variability of observed biogeochemical quantities. We conclude with a discussion of the strengths and weaknesses of the various model formulations, recommendations for possible improvements, and suggestions for additional observations that would facilitate future development of pelagic ecosystem models of the Arabian Sea

OS11R-06 1010h

Simulation and Observation of Seasonal to Interannual Variability in the Arabian Sea Ecosystem

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A coupled bio-physical ocean general circulation model is employed to study the seasonal variability of the Indian Ocean ecosystem. The ecosystem portion of the model consists of a 9-component formulation that includes two size classes each of phytoplankton, zooplankton and detritus, as well as three nutrients (nitrate, ammonium and iron). The simulation's ecosystem component is validated against in-situ data obtained during the US JGOFS Arabian Sea Expedition, the NODC seasonal nitrate climatology and basin scale observations of surface chlorophyll a provided by SeaWiFS. A model/SeaWiFS comparison of basin scale chlorophyll a over the tropical Indian Ocean will be presented. A detailed examination of the seasonal cycle in the Arabian Sea will illustrate the model's performance in this region, which is a biogeochemical modeling challenge because of the wide-ranging spatio-temporal variability of its pelagic environment. We will also present some results of our recent research on the physical mechanisms that caused the interannual variation in the magnitude of wintertime phytoplankton blooms in the central Arabian Sea apparent in the SeaWiFS data. We present evidence that this interannual ecosystem variability observed in the Arabian Sea was the result of remote forcing that was affected by the 1997 manifestation of the Indian Ocean Zonal Mode.

OS11S HC: 316 A Monday 0830h

Coral Reef Habitats: New Insights From Integrated Coastal Science I

Presiding: **M Field,** University of California, Santa Cruz**; P Jokiel,** University of Hawaii at Manoa

OS11S-01 0835h

Monitoring Change in Coral Colonies by Changing Physical Environments

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To determine the effect of degrading or improving water quality on coral reefs, we have set up an experiment as part of a broader investigation of coral in which we are determining the effects of sediment and nutrient stress on living coral cover.

We selected sites on the shelf off Mayagez, Puerto Rico where four sites of coral reefs are impacted by terrigenous sediment and/or nutrient influx, and one clean water site. To measure recovery of individual coral removed from stress conditions and the effect of stress conditions on healthy corals, we transplanted corals from stressed environments into the clean water environment. These transplants were onto concrete slabs to avoid local bottom effects. Coral from the clean area were also transplanted as controls. We transplanted coral from the clean environment into stressed conditions at the other sites to observe the effects on these coral. Alizerin red was used to mark the coral at the time of transplant. Fourteen species of coral were transplanted.

Photographs are being taken bi-monthly to observe changes. At the end of the study, growth rates will be measured. The study is scheduled to run for two years, but we have already seen that: Coral are more resistant than expected when subjected to nutrient or sediment stress The colonies either died within the first month, or continued to survive. Stressed coral moved into the clean environment have shown little change except Montastraea cavernosa colonies that are actively budding between older polyps

URL: http://cima.uprm.edu/morelock/mayaguez.htm

OS11S-02 0850h

A Multi-disciplinary Program to Assess, Monitor, Map and Protect the Coral Reef Ecosystems of the U.S. Pacific Islands.

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In addressing the two fundamental themes of The National Action Plan to Conserve Coral Reefs to understand coral reef ecosystems and reduce adverse human impacts, the NOAA Fisheries Honolulu Laboratory established the Coral Reef Ecosystem Investigation to assess, monitor, map, restore and protect the coral reef ecosystems of the U.S. Pacific Islands. This multi-disciplinary program was initiated in partnership and collaboration with our NOAA colleagues, and other Federal, State and Territorial agencies and non-governmental organizations. Preliminary results of the assessment, monitoring and mapping activities conducted during two 30 day research cruises to the U.S. Line (Palmyra and Kingman Atolls and Jarvis Island) and Phoenix Islands (Howland and Baker Islands) and two 30 day research cruises to the Northwestern Hawaiian Islands in 2000 and 2001 are presented. These activities include rapid ecological assessments of fish, corals, algae and invertebrates, towed diver digital video habitat and fish surveys, QTC acoustic seabed classification surveys, towed video and still camera surveys, and in-situ and satellite remote sensing observations of oceanographic conditions. The in-situ oceanographic observations include closely-spaced conductivity-temperature-depth-chlorophyll casts, acoustic Doppler current profiler surveys, long-term moored oceanographic buoys, surface velocity drifters, and APEX diurnally migrating profiling drifters. Integrating these multi-disciplinary observations into a common GIS data base will allow improved understanding of the complex relationships between biotic and abiotic components of these diverse ecosystems. Over time, these observation systems will help describe the natural variability of these complex ecosystems and better enable scientists and resource managers to distinguish between and natural and anthropogenic changes.

OS11S-03 0905h

Development of an Ocean Atlas and Applications to Studying and Monitoring Coral Reef Ecosystems in the Pacific Basin

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Information pertaining to the structure and dynamics of the ocean is essential to understand marine ecosystem dynamics and to interpret the dynamics of living marine resources within the context of the ecosystem, habitat, and large-scale environmental patterns. We are currently developing an ocean atlas that integrates a wide array of remote sensing and in situ oceanic data, providing a suite of products essential for understanding the spatial and temporal variability of the key aspects of the physical environment.

While the atlas is being produced primarily as a tool for the management of pelagic and insular fisheries in the Central and Western Pacific Basin, the derived products have also proved invaluable in the studies of coral reef ecosystems. Knowledge of oceanic transport, ocean temperature, and ocean productivity have played key roles in each aspect of a coral reef ecosystem monitoring program in the Northwestern Hawaiian Islands currently being undertaken by the NOAA Fisheries Honolulu Laboratory. Applications of the atlas products to planning, execution, and analysis of this comprehensive coral reef study are presented, along with some preliminary results from those efforts.

OS11S-04 0920h

CRESPO: A Mission to map the Global Abundance of Live Coral

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CRESPO (Coral Reef Eco-system Spectrophotometric Observatory) is a NASA-funded mission concept to use multispectral imaging from the International Space Station to perform a comprehensive global inventory of live coral. Current quantitative knowledge of coral cover is based on surveys of a a few tens of square kilometers of reef. In the course of a three year mission CRESPO will produce maps of coral cover for over 90% of the 500,000 square kilometers of reef area.

CRESPO is based on the discovery that most coral exhibits a unique spectral signature in the visible region of the spectrum where water is transparent. CRESPO exploits this knowledge with a 6 band multispectral imaging system which can be used to discriminate coral from other reef components and includes bands to carry out essential atmospheric corrections. The CRESPO mapping algorithm has been successfully tested on AVIRIS hyperspectral data convolved to the CRESPO bandpasses.

When flown, CRESPO will return a comprehesive data set on the status of a major marine ecosystem which may be the first such ecosystem to be effected by climate change.

OS11S-05 0935h INVITED

Reefs as Habitats or Habitats for Reefs: Global-Scale Coral Reef Biogeography

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Coral reef organisms tend to exhibit very wide geographic distributions. Reefs in the structural sense are necessarily features with histories of centuries to millennia. This large-scale perspective is difficult to incorporate into consideration of present concerns about the death and degradation of reef communities, at local sites and on time scales of days to decades. We suggest that a critical approach is to regard coral reef communities as assemblages of organisms having habitat requirements that transcend the concept of the reef community itself as a unique habitat. This approach permits definition of habitat for reef organisms that extends beyond existing reefs, and allows a broader and more integrated definition of suitable – or vulnerable regions that may play a role in the preservation of reef biota. Although global-scale analyses are constrained by the availability and resolution of global-scale data sets, geospatial statistical approaches combined with geographic information systems (GIS) can yield useful insights into controls over reef organism distribution and how these may change over time. We apply geospatial clustering in combination with GIS analysis to identifying potential reef habitat based on existing reef distributions, and to classifying clusters of habitats based on their probable stability. Although not a substitute for detailed local assessments, such analyses provide a basis for incorporating larger-scale considerations of biogeographic controls and environmental change into reef habitat assessments at the national or local scale.

OS11S-06 1010h

Where Do Coral Reefs Feel the Heat ? A Global Analysis of HotSpot Frequencies and the Consequences for Tropical Marine Biodiversity Conservation Planning

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The large-scale mortality of corals associated with the 1998 ENSO event bears witness that mass bleaching related to climate change events is now one of the most severe threats facing tropical coral reefs. As with other major threats, such as blast fishing and pollution, repeated mass bleaching is liable to lead to a loss of diversity and local extinction of more vulnerable species on impacted coral reefs. Conservation efforts that aim to preserve areas of outstanding tropical marine biodiversity, should therefore add bleaching susceptibility as an important factor to consider in the selection of new sites for long-term protection.

The analyses reported here are the first attempt to identify areas of coral reef that are most and least likely to be susceptible to long-term impact from large-scale bleaching events. Using a 16 year time series of high resolution (9 kilometer) NOAA AVHRR sea surface temperature anomaly data, ocean temperature anomaly (HotSpot) maps were prepared by analyzing five day (pentad) averages of the sea surface temperature (SST) data, compared to a Maximum Pentad Mean Climatology. To verify the model that these anomalies represent potential climate change impact events, a Geographical Information System (GIS) was used to compare HotSpot frequencies for individual years with field records of bleaching events from the World Conservation Monitoring Center (WCMC). A 16 year HotSpot frequency map was then generated, and reviewed to compare the global distribution of coral reefs with the overall frequency of HotSpot events. Initial results indicate that this approach will be a powerful new analytical tool to assist conservation planning. Although few reefs escape anomalous temperature events, there is a wide range of variation in frequencies experienced. For example, the Northern Hawaii Islands rank relatively low, whereas Palau ranks relatively high, which seems to match their bleaching histories. However complex patterns are the norm, and occur at a variety of scales, especially in coastal and shelf areas. Careful groundtruthing and study of the corresponding oceanographic features are still necessary in order to fully understand the resolving power and accuracy of this approach.

OS11S-07 1025h

Dynamics of Suspended Sediment in a Marginal Reef Environment: Teluk Banten, West Java, Indonesia

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Teluk Banten, West Java, represents a shallow coastal embayment harbouring a coral reef ecosystem subject to turbid conditions. At two selected reef islets, hydrodynamic and sedimentary processes were investigated to explain fluctuation in turbidity levels. The study is part of the Teluk Banten Research Program, a joint Indonesian-Dutch program on Integrated Coastal Zone Management, within the framework of the Global Change Program of the Royal Netherlands Academy of Sciences (KNAW). Arrays of in-situ calibrated Optical Backscatter (OBS) sensors were deployed to measure suspended sediment concentration (SSC) in lines transverse to the reef slopes. Along the same lines, two Electromagnetic Flowmeters with attached pressure sensor registered local wave and current conditions. Remote from the reefs under investigation, an Acoustic Doppler Current Profiler (ADCP) was mounted on a wooden fishing platform to monitor current velocity in the far field. From the same platform, vertical profiles of SSC were obtained hourly from OBS observations. The periods of deployment at each of the two islets encompassed three weeks during the wet season. In addition,

two ADCP surveys were conducted with a small fishing boat, navigating transects of 500 m perpendicular to the reef islets. The ADCP echo-intensity correlated strongly with SSC. Therefore, the ADCP surveys yielded a quasi-synoptic view of spatial SSC patterns around the reef islets. Pronounced buoyant river plumes reached the islets only sporadically. Generally, water masses that passed by the reefs at distance were less turbid than the submarine environments surrounding the corals. Wave action was largest at the reef crests, where coral growth was most abundant and little sediment was available for resuspension. At the reef toes, large amounts of sediment were available for resuspension and tidal currents raised clouds of sediment, which expanded at the time of peak current velocity and settled down afterwards. Turbidity levels at the reef slopes were hence primarily affected by current-induced shear stresses. Sediment accumulation was largest in the lee of the islets, where wakes formed and associated current velocities were small.

URL: http://coast.geog.uu.nl/banten.htm

OS11S-08 1040h

Patterns and Impact of Sedimentation on a Fringing Coral Reef, Molokai, Hawaii

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The south coast of Molokai hosts a 50-km-long fringing reef harboring a richness and density of coral that are amongst the highest in the Hawaiian Islands; many areas of the reef contain 90 % live coral. The reef consists of a broad (1 km) and shallow (1-1.5 m) reef flat succeeded seaward by extensive spur and groove development to depths of 25 m. Erosion rates of the adjacent weathered volcanic terrain appear to have dramatically increased in historic time due to deforestation, agriculture, overgrazing, and coastal construction. Terrigenous mud is accumulating on the reef flat and along the shoreline, and corals in a number of locations are degraded and necrotic. The inner reef flat is particularly affected; it is typically mantled with 5-15 cm of mud with no significant coral present. Corals are stressed and impoverished in several locations on the inner reef and fore reef (less than 50 % live coral coverage at 10 m depth, compared to ∼90 % elsewhere). These conditions reflect at least in part excessively large sediment loads in the past century and entrapment of fine sediment on the reef flat.

Our studies incorporate mapping sediment deposits, measuring the relevant processes that inject and redistribute sediment to the reef system, and monitoring sedimentation events and their effect on the reef. More than 700 measurements of sediment thickness from 23 transects are augmented by 250 surface sediment samples collected from the fore reef, reef flat, and adjacent watersheds. Analyses of texture and sediment type were used to understand the sources, transport pathways, and sinks for sediment in this reef system. Turbidity and currents are being recorded on the reef flat by instrumented tripods to assess the transport levels and direction.

A 5-15 cm thick layer of terrigenous and carbonate sandy mud covers the majority of the innermost portion of the reef flat and typically pinches out within 150 m of the shoreline on an antecedent reef flat. Terrigenous grains are a sub-dominant component (∼30%) of the sand fraction and a dominant component (>50%) of the silt fraction on the inner reef. Micro-atolls with low percentages of live coral start to appear approximately 350 m offshore concurrent with the decrease in terrestrial material. The thickness of sediment cover becomes more variable further offshore due to variable relief on the antecedent surface. The outer portion of the reef flat is covered with a higher percentage of live coral growing along shore-normal ridges; intervening swales (or grooves) contain thick deposits of rippled sand derived largely from erosion of the antecedent reef flat. Overall, the mean thickness of sediment on the reef flat increases exponentially from east to west, reflecting the dominant net westward transport direction and the increase in available sediment sources. Sensors on an instrumented tripod show that mud is resuspended by trade wind waves during high tides, and that net transport is to the west and offshore towards the zone of impoverished coral.

OS11S-09 1055h

Sediment Resuspension and Transport on a Shallow Fringing Reef: Molokai, Hawaii

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Reefs have been known to flourish in turbid environments around the world, yet excessive loading of terrigenous sediment is recognized to be one of the greatest potential harms to coral reefs. The amount of sediment in suspension and rate of deposition that can be tolerated without degrading the health of a reef environment are not well understood. This study of sediment resuspension, transport and resulting deposition on a shallow fringing reef flat off Molokai, Hawaii shows the importance of the oceanographic processes (trade winds, offshore wave heights) on controlling the amount of sediment observed in a particular environment. At this site, daily resuspension events are observed in response to tidal elevation on the reef flat (offshore wave energy can propagate onto the reef flat during high tides) and wind-driven waves and currents. The magnitude of wind-driven processes depends upon the season, and the interactions between tidal elevation and trade-wind strength. The net flux of sediment on this reef moves west, along the reef flat, in the direction of the prevailing trade winds, and offshore towards a zone of degraded reef health. The offshore flow appears to be constant along the reef flat indicating either large-scale circulation feature on this relatively continuous reef flat, or a near bed return flow compensating for setup on the reef flat due to wind-driven flows.

A correlation between the reef flat resuspension processes and reef crest sediment trap collection rate can be seen indicating that terrestrial sediment resuspended on the reef flat can be transported into deeper water and zones of higher coral abundance, potentially affecting reef health. The measurements show that the variability of sediment resuspension is high and that single measurements of suspended-sediment concentration or sediment trap collection rate are inadequate to describe conditions on a reef flat.

OS11S-10 1110h

Warm, High-Salinity Plumes in Shelf Waters of the Exuma Cays, Bahamas: A Possible Trigger for Coral Bleaching

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Hydrographic data are used to characterize warm, high-salinity plumes in shelf waters of the Exuma Cays, Bahamas. Results indicate that Great Bahama Bank water transported through channels on the ebb tide to the shelf on the Exuma Sound side of the islands can be up to 3.5^{o}C warmer, 3 psu saltier and 2 kg m^{3} denser than ambient sound water. Vertical temperature and salinity profiles taken off the mouth of the channel suggest that as hyperpycnal bank water exits the channel it sinks to the near-bottom layers as it cascades across the shelf. Entrainment and mixing of plume water with shelf water decreases with depth, so the warmest, saltiest water is found near the bottom. Salinity used as a natural tracer indicates that plume water is diluted by nearly 80% in the upper layers, but only by about 25% near the bottom. Profile data and near-bottom temperature time series from study sites along the shelf indicate that plume water can spread laterally at least four times the width of the tidal pass by the time it reaches the middle shelf, approximately 0.5 km from the mouth of the channel. Since there are over 40 major tidal passes and scores of shallower openings that connect bank and sound water along the island chain, it is likely that warm, high-salinity bank water impacts significant areas of the shelf. These temporary, but periodic, pulses of warm salty water inundate the well-developed fringing reefs found over the shelf and may trigger bleaching of resident zooxanthellate organisms, including corals and sponges.

OS11S-11 1125h

Sand Transport within a Reef Channel off Kailua, Oahu, Hawaii

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Measurements of currents, waves, and bedform movement were made in a well-formed channel that transects a fringing coral reef seaward of Kailua, Hawaii. Measurements of currents, waves, suspended sediment concentrations and bedform migration were obtained during Sept.-Nov., 1996 (56 days), and May-Sept., 1997 (137 days), and June-July, 1998 (53 days). This project was part of a larger study of sedimentary processes in this region. One of the major goals of this study was to estimate sand transport within the channel. The channel meanders across the reef complex from about 5-m depth to about 25-m depth. Its average width is about 100 m; its walls extend about 3 to 5 m above the channel floor. The channel bottom is mantled by medium-sized carbonate sand that has been formed into large, nearly symmetric ripples. Diver observations, video images, and data from a sonic bed elevation sensor showed that during all deployments the sand ripples had wavelengths of 0.5-1.0 m and heights of 6-12 cm. Divers and video images also documented that sand grains on the ripple crests were often resuspended by oscillatory bottom currents. Measurements and video recordings from the 1997 and 1998 deployments showed that ripple sizes and movement were correlated with combined bottom wave and current speeds.

Onshore sand transport occurred during the first deployment in 1996 during periods of weak to moderate Trade Winds. In marked contrast, during the second deployment in mid-July 1997 when the Trade Winds were more intense, sand ripples at the tripod site migrated offshore. Ripple migration speeds were estimated to be about 0.5 m/day. Estimates of offshore sand transport during this period were about 4.7 g/cm/s. A diver survey of the bottom at the tripod location indicated that the well-formed ripples were long-crested, approximately normal to the channel walls, and extended across the entire channel width. Assuming that the estimated transport rate was representative across the entire channel at this depth, the total transport of sand was computed to be about 6.7 x 103 kg/day.

Reef channels can be significant transport pathways for sand within a reef. The rates and direction of transport through these channels are related to several factors including local and regional wind patterns, circulation, tides, wave conditions, sediment characteristics, and channel geometry. Based on our observations in this work, these channels likely play an important role in the exchange of sand between the beach-lagoon complex and the region seaward of the reef. Whether these channels provide an escape route for sand from the beaches or act as a conduit for sand supply to the beach-lagoon complex will depend on the wind and hydrodynamic conditions.

OS11S-12 1140h

Geochemical Records of Bleaching Events in Pacific Coral Reefs

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Over the last two decades coral bleaching events have increased in frequency and severity due to a variety of reasons including increased sea surface temperatures. Documenting coral bleaching events and the associated stressors beyond the period of recent observations by means of a geochemical proxy would increase our understanding of the frequency and long-term effects of bleaching events. Since the δ^{13}C of the coral

skeletal carbonate is known to be affected by both environmental factors (e.g. insolation and temperature) and physiological factors (e.g. photosynthesis, calcification, and the statues of the symbiotic relationship between corals and zooxanthellae) it is the most promising proxy for reconstructing past bleaching events. Two high resolution (weekly to fortnightly) δ^{13}C, δ^{18}O and Sr/Ca records from 1987-1997 of coral cores recovered from depths of 2m and 12m near the island of Moorea, French Polynesia have been made. In this calibration study, we are testing whether we can detect a signal of coral bleaching and SST, which will then allow us to reconstruct past events. Temperatures calculated using common calibration curves for both δ^{18}O and Sr/Ca reveal seasonal variations matching both satellite and in-situ measured SSTs in the shallow core. In the deep core, Sr/Ca derived temperatures have a muted seasonal cycle reflective of its greater depth, while the δ^{18}O record is ambiguous and may in part reflect changes in upwelling. The δ^{13}C record from the deep coral has a clear seasonal cycle on the order of $1.2^{o}/_{oo}$, reflecting seasonal variations in cloud cover and/or changes in the extent of heterotrophic verses autotrophic feeding. The most noticeable aspects of the δ^{13}C record from the shallow core are two significant decreases of $0.8^{o}/_{oo}$ in 1991 and 1994 when large portions of the reef were bleached. A decrease in the maximum δ^{13}C values after 1994-1995 may be indicative of increased cloud cover. This increased cloud cover may have prevented bleaching of the reef in 1998 when SSTs were above the bleaching threshold. A two year record from a coral that was known to have been bleached on Pandora Reef, Great Barrier Reef, in 1998 supports these results. This core was sampled at weekly resolution, and both the Sr/Ca and δ^{18}O track even small changes in a STT record measured at a nearby island. At the onset of bleaching, the δ^{13}C decreased by $5^{o}/_{oo}$, presumably due to a decrease in photosynthesis associated with a loss of the zooxanthellae during bleaching. These calibrations studies suggest that δ^{13}C, δ^{18}O and Sr/Ca measurements can be used to reconstruct past bleaching events, if corals are sampled at high enough resolution.

OS11T HC: 323 C Monday 0830h

Zooplankton: Feeding, Growth, and Distribution I

OS11T-01 0830h

Feeding Ecology and Potential Predatory Impact of *Tortanus dextrilobatus*, an Invasive Carnivorous Copepod in the San Francisco Estuary

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Tortanus dextrilobatus (Copepoda: Calanoida) is one of at least seven copepods to have successfully invaded San Francisco Bay over the past 25 years. Although it is widespread and at times abundant ($> 10^3$ m^{-3}) in the San Francisco Estuary, the ecological impacts of this invertebrate predator are unknown. The objective of this study was to investigate the functional response of adult female *T. dextrilobatus* predation upon both native (*Acartiura sp.*) and non-native prey (*Oithona davisae* and *Acartiella sp.*). Predator and prey organisms were collected in the field and studied during two seasons (summer and autumn) at ambient temperature (19°C and 14°C) and salinity (13-19 psu) conditions. Twenty-four hour experiments were conducted with a plankton wheel (1 rpm) in a temperature and light controlled room. *T. dextrilobatus* exhibits a saturation type of functional response (characterized by an Ivlev curve) wherein maximum ingestion rates occurred within the range of natural prey densities. These experimentally derived feeding rates were applied to field observations of distribution and abundance (1997-1999) to estimate the potential predatory impact of this carnivorous copepod upon the zooplankton community in the San Francisco Estuary.

OS11T-02 0845h

Egg production, hatching and mortality of *Calanus sinicus* in the Bohai Sea, P. R. China

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Calanus sinicus is an important component of pelagic food chain in the coastal temperate waters of China. Egg production rates were measured in June, September, and December 1998 and April 1999 in the Bohai Sea. The influence of temperature on egg production rates was evaluated in June and December and hatching rates were measured December and April. Population structure was determined from field samples filtered through a 20m net. Egg production rates were maximal in April and minimal in December. The high egg production rate in April may have been due to an abundance of mature females from overwintering stock and the spring phytoplankton bloom. Temperature appears to have a significant influence on egg production rates within the optimum range. Egg production rates showed substantial spatial variation depending upon sample location and this variation was up to an order of magnitude. Egg hatching rates were 97.9% and 23.2% in April and December, respectively. These results were consistent with seasonal variations in abundance. In April, high production and high hatching rates were consistent with the seasonal pattern of high abundances that occurs in May and June. Low abundances in September and December corresponded to low egg production and low hatching rates.

OS11T-03 0900h

Onset of Dormancy in the Copepod *Calanus pacificus* in the Southern California Bight: Timing of Descent, Indicators of Preparation for Dormancy, and Environmental Conditions

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The timing of onset of dormancy in abundant, open-ocean, calanoid copepods such as *Calanus pacificus* affects their population dynamics and availability as prey items of fish and marine mammals and as grazers of phytoplankton. The mechanism of dormancy induction in open-ocean copepods is unknown, and it is therefore impossible to predict how dormancy timing might change as a result of environmental change. Onset of dormancy was examined in field-collected *C. pacificus* to identify the timing of onset of dormancy, to evaluate two potential indicators of preparation for dormancy in surface copepods, and to compare changes in environmental conditions at the surface with changes in the dormant status of copepods. Vertically stratified zooplankton samples were collected between the surface and 1100 m at San Diego Trough on twelve dates between April 2000 and January 2001. The timing of onset of dormancy was inferred from the appearance and build up of fifth copepodite stages (CVs) in deep water, which occurred from June to October 2000. Two potential indicators of preparation for dormancy at the surface, jaw development phase frequency distributions and average ecdysteroid (molting hormone) titers, were examined in deep, dormant CVs and in surface CVs and CIVs (fourth copepodites). Dormant copepods remain in the postmolt jaw development phase. Therefore the proportion of surface CVs in the postmolt phase is expected to increase when surface CVs are preparing for dormancy. Because jaw phase distributions can also change due to environmental factors, CV jaw phase distributions were compared with those of CIVs, which do not become dormant in the Southern California Bight. A higher proportion of postmolt CVs was observed when onset of dormancy was occurring than when onset was not occurring. In contrast, CIV jaw phase distributions did not differ between these dates. Ecdysteroid titer is low in CVs after molting and during dormancy. Therefore average CV ecdysteroid titer is expected to be lower when onset of dormancy is occurring than when onset of dormancy is not occurring. Onset of dormancy was spread over a wide range of dates and occurred mainly during a period of decreasing day length and increasing surface temperature. The two largest increases in deep CV abundance occurred during or shortly after peaks in subsurface chlorophyll concentration.

OS11T-04 0915h

Development Times of *Euphausia Pacifica* Larvae in the Laboratory

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We are working out the population dynamics of euphausiids in the Oregon upwelling zone with the goal of estimating growth, productivity and mortality rates *in situ*. It is first necessary to establish the variability in times to stage and in developmental pathways for a given population of animals before making assumptions that allow for use of field samples to determine these rates. In this study, gravid adult female *Euphausia pacifica* were collected 25 miles off the coast of Newport, OR. These females were transferred to the laboratory where eggs were spawned, hatched, and reared under close observation at 10.5° C. Four cohorts of larvae were monitored daily until they reached the juvenile 1 stage. They were fed to excess with a combination of *Isochrysis sp., Chaetoceros calcitrans, Rhodomonas salina*, and *Heterocapsa triquetra* cells. We plotted the cumulative percent of individuals within each developmental stage and performed arcsine transformations in order to estimate median development times using linear regression.

The first calyptopis stage and the third furcilia stage appear to be bottlenecks in the development of this species. These stages had durations nearly double that of any other stages. Individual cohorts developed at nearly the same rate until the first furcilia stage, after which one cohort began to develop significantly faster. Median time to juvenile 1 ranged from 51.9 to 60.6 days with significant differences among cohorts. Differences in development time among cohorts appear to be closely related to the degree of synchrony in development within a cohort. Our development time results matched well with those found by Ross (1981) for a population taken from Puget Sound, WA, despite other differences in their population dynamics.

OS11T-05 0930h

Velocity and Shear Stress Fields of Krill, Euphausia pacifica

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The movements of planktonic animals influence the cycling of matter and energy by altering the size distribution and abundance of particles and aggregates. In order to test whether animal-generated flow fields disrupt marine snow, we measured the structure of flows created by swimming krill. The velocity field and shear stress around a tethered krill were mapped using digital particle image velocimetry (DPIV). The velocity fields showed the position of the jet generated by the movement of the krills pleopods. Water entrained broadly around the krill is directed into a high-speed jet behind the last set of pleopods. The Reynolds number of the krill-generated jet is 500 based on an average velocity of 5 cm/sec through the central region of the jet of 1 cm width. Maps of the instantaneous flow fields show eddies at the edge of the jet and analyses of the shear stress show maxima at the jet edge. Toroidal vortex rings develop in the shear layer of the jet and propagate downstream. Snow particles entrained into the jet by the induced motion of the vortex rings are subjected to high values of shear stress, potentially capable of aggregate disruption. Detailed observations of the flow field and behavior of the macroplanktonic organism, krill, will enhance our understanding of the role of body size and movement patterns in intermediate Re realms. Studies of fluid flow and animal movements at this scale bridges the research of the biological-physical

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