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ABSTRACT BOOK

8[30] *Diagnosing the physical processes that control primary productivity and phytoplankton community structure over the Southern California Bight continental shelf*

Andrew Lucas (NSF International Postdoctoral Fellow), Chris L. Dupont (JCVI), V. Tai (UBC – Victoria), Peter Franks (SIO), John L. Largier (Bodega Marine Lab), and Brian Palenik (SIO)

The waters over the narrow continental shelf of the Southern California Bight (SCB) have elevated primary productivity, chlorophyll concentrations, and a different phytoplankton community than the adjacent open ocean. These persistent gradients are maintained by horizontal nitrate fluxes associated with internal waves of tidal frequency (the internal tide). We calculated the first estimates of the internal tide-driven horizontal fluxes of nitrate, heat, energy, and salinity from high resolution, full water column data gathered by an autonomous wave-powered profiler and a bottom-mounted current meter. We found the magnitude of the vertically integrated horizontal nitrate flux (136.4 g N m-1 d1) was similar to phytoplanktonic nitrate uptake rates over the inner shelf. These observations suggest that horizontal nutrient fluxes must be considered along with the more typically estimated vertical nutrient fluxes, particularly in margin ecosystems or systems with strongly sloping isopycnals (e.g. fronts). Furthermore, the horizontal flux of nitrate was quite variable in time, capable of supporting 0-2800 mg C m-2 d-1 (mean ~774 mg C m-2 d-1) of 'new' primary productivity. The interaction of physical processes at different temporal and spatial scales is responsible for this variability in the internal tide horizontal nitrate flux. These dynamics include: 1) vertical shear in the alongshore currents, 2) local wind forcing, and 3) remote, large-scale variability. Individually, these mechanisms rarely or never explain the phytoplankton community composition and metabolic rate gradients. Instead, large scale, low-frequency forcing exercises control over the "nitrate climate" of the continental shelf, and thus modulates the effectiveness of the internal tide nitrate pump. I will discuss these results and a re-analysis of historical data, which, taken together, suggest opportunities for local ocean observing system data streams that will enhance our ability to predict phytoplankton productivity, community composition, and biomass in the coastal ocean.

8[50] *Physical transport pathways between known source regions for harmful algal blooms and the Pacific Northwest U.S. Coast*

Sarah N. Giddings (Univ. of Washington), Parker MacCready (UW), Kristen A. Davis (UW), Neil S. Banas (UW), and Barbara M. Hickey (UW)

As part of a joint hydrodynamic and ecosystem modeling project to understand the generation and transport of harmful algal blooms (HABs) in the Pacific Northwest we present realistic hindcast simulations of the Salish Sea and the nearshore coastal ocean along the Washington and Oregon shelf. The ROMS simulation is an extension of models generated for the ECOHAB and RISE projects. A broader domain and enhanced resolution on the shelf and in the bottom boundary layer improve simulation of estuarine/shelf exchange processes and allow for investigation of physical transport pathways important to transport of HABs. The simulation was forced with realistic bathymetry, tides, climatology, river forcing, and open boundary conditions. Here we present results from a year long simulation in 2005. We use a combination of particle tracking and model dye releases to determine transport pathways between known source regions for harmful algal blooms, such as the Juan de Fuca Eddy and Heceta Bank, and the coast. As previous studies have shown, specific wind forcing events preferentially enhance retention within these potential source regions as well as allow for transport between these regions and the coast. We perform a numerical experiment in which we remove buoyancy forcing from the major rivers in the domain to investigate the importance of both the Columbia River plume and Juan de Fuca Strait exchange flow on these physical transport pathways.

9[10] *Spatio-temporal variability in cross-shelf exchange across Monterey Bay, CA*

Brock Woodson (Stanford University)

Cross-shelf exchange is driven by a range of processes including tides, winds, and internal motions associated with continental slopes and canyons. All of these contributors play important roles in the circulation patterns on the mid and inner shelf of Monterey Bay. In the northern bay, cross-shelf exchange is influenced by upwelling favorable diurnal winds during spring and summer, and by wave-driven return flows during winter. Upwelling in the northern bay is feasible at diurnal scales due to the presence of strong positive vorticity associated with regional-scale upwelling. In the upper and southern bay, cross-shelf exchange is due to cold-water bores that propagate out of the Monterey Submarine Canyon. The source of variability in the arrival of these bores on the mid and inner shelf is likely due to complex surface-internal tidal interactions that can lead to cold waters cresting the canyon or shelf edge. Each of these processes provides a link between outer and inner shelf dynamics and supplies nutrients to nearshore kelp forest and intertidal ecosystems.

9[30] *High- to low- frequency variability of moored temperature, currents, and dissolved oxygen on central Oregon's mid-shelf to inner-shelf and intertidal regions*

Kate Adams (Oregon State Univ.) and Jack Barth (OSU)

Contrasts between inner- and mid-shelf dynamics drive cross-shelf variations of nutrient and water mass gradients and transport on the shelf. These contrasts are of central importance in the productive central-Oregon coastal upwelling environment where physical drivers such as wind-driven upwelling and relaxation, diurnal sea breeze and tidal mixing vary across the shelf, setting the stage for biogeochemical responses. Temperature, current and dissolved oxygen measurements from moorings deployed in 2010 off the central-Oregon coast are analyzed to explore the relationship between mid-shelf (70 m) and inner-shelf (15 m) dynamics and the observed effect on dissolved oxygen, an influencing factor and product of biogeochemical processes on the shelf. Preliminary results from progressive vector diagrams of the moored current records show along-shelf cumulative displacements on the order of 200 km to the south for the inner-shelf moorings and 50 km to the north for the mid-shelf site, thus painting a picture of a more wind-driven inner-shelf and retentive mid-shelf. Variability of frequency content in temperature, current and dissolved oxygen records at each site is compared using power spectral densities and harmonic regression analyses to explore the percent variance explained by drivers such as tides, diurnal sea breeze and low-frequency wind events, etc. We also explore the relationships across frequency bands between inner-shelf temperature records and temperature measurements from a nearby rocky intertidal zone. Understanding how inner-shelf water properties relate to those observed in the rocky intertidal will be important as recent studies try to unravel the oceanic and local biogeochemical influences on intertidal measurements of important biogeochemical parameters like pH.

9[50] *Turbulent mixing and exchange with interior waters on sloping boundaries*

Eric Kunze (APL, Univ. of Washington), Erika McPhee-Shaw (Moss Landing Marine Lab), Katie Morrice (Moss Landing Marine Lab), James B. Girton (APL, UW) and Samantha R. Terker (APL, UW)

Microstructure measurements along the axes of Monterey and Soquel Canyons reveal 200-300 m thick well-stratified turbulent near-bottom layers with average turbulent kinetic energy dissipation rates ~4 × 10^–8 W/kg and eddy diffusivities ~16 × 10^–4 m^2/s to thalweg depths of 1200 m. Turbulent dissipation rates are an order-of-magnitude lower in the overlying waters

while buoyancy frequencies are only 25% higher. Well-mixed bottom boundary layers are an order of magnitude thinner than the stratified turbulent near-bottom layer. Since well-stratified turbulent layers are commonly observed above slopes, arguments that mixing efficiency should be reduced on sloping boundaries are incorrect. Canyon turbulence may contribute as much diapycnal transport to the world ocean as interior mixing. A vertical advective-diffusive balance is used to infer diapycnal velocities and transports, predicting upslope flows of 10-100 m/day. Upcanyon transports are not uniform. Resulting upslope convergences will drive exchange between the turbulent layer and the more quiescent interior. Predicted depths of detrainment and entrainment are consistent with observed depths of intermediate nepheloid and clear layers. These data demonstrate that turbulent mixing dynamics on sloping topography is fundamentally 2- or 3-D in the ocean so cannot be accurately described by 1-D models.

10^{30} *Sub-regional ocean color variability in the California Current System*

Nate Mantua (Univ. of Washington) and Todd Mitchell (UW, JISAO)

Eleven years of NASA SeaWiFS 5-day mean chlorophyll anomalies within ~500km of the coast from the Queen Charlotte Islands to Baja are analyzed with rotated principal component (RPC) analysis. Five-day means were calculated for the entire SeaWifs record, 8 September 1997 to 11 December 2010, with instrument failures taking up almost 2 years of measurement time. Because the processes that produce chlorophyll variability in individual sub-regions most likely produce variability that overlaps spatially with neighboring sub-regions, ecologically meaningful patterns are poorly captured with unrotated empirical orthogonal function (EOF) analysis. RPC analysis with varimax rotation takes a subset of EOFs as inputs, and outputs spatially simpler patterns that are not required to be orthogonal while preserving temporal orthogonality. The leading RPCs capture, in a common framework, the temporal and spatial variability along the mouth of the Straight of Juan de Fuca, the southern Oregon - northern California coast, the Gulf of Farallones, and other ecologically distinct sub-regions along the Pacific coast. We document the contribution of atmospheric (wind) forcing, and also the SST patterns associated with the regional-scale patterns of chlorophyll variability. To the extent that surface chlorophyll is an important measure of the coastal ecosystem, documenting patterns of variability in this unique data record provides a useful challenge to our understanding and modeling abilities.

10^{50} *Nearshore larval retention among years and between regions of varying upwelling intensity*

Jennifer L. Fisher (NOAA, Cooperative Institute for Marine Resource Studies), William T. Peterson (NOAA, Northwest Fisheries Science Center), and Steven G. Morgan (Bodega Marine Lab)

The ability of miniscule larvae to control their fate and replenish populations in dynamic marine environments has been a long-running topic of debate of central importance for managing resources and understanding the ecology and evolution of life in the sea. In upwelling regions, larvae are considered to be highly susceptible to offshore transport that increases dispersal, limits onshore recruitment, and reduces the intensity of community interactions. We examined the cross-shelf distribution of larval crustaceans at two stations located 1 and 5 miles from shore off central Oregon, USA for eight years in a region characterized by intermittent upwelling and high recruitment. These years exhibited differences in oceanographic forcing including the phase of the Pacific Decadal Oscillation (PDO), upwelling intensity and the timing of the spring transition. We show that most species of crustaceans are retained nearshore across years regardless of changing oceanographic conditions. In contrast, *Emerita analoga*, is present only during years when the PDO is in the positive phase. There is also a positive relationship between the presence of this species and the timing of the spring transition, suggesting that larvae are transported into our study area from southern locales. Finally, we compare the cross-shelf

patterns in this region of intermittent upwelling to those observed off northern California, USA, a location characterized by strong upwelling and recruitment limitation.

11[10] *Coastal velocity gradients reduce dispersal distances and enhance self-replenishment of coastal populations*

Kerry Nickols (Bodega Marine Lab, UC Davis), Wilson J. White (UNC Wilmington), John L. Largier (Bodega Marine Lab, UCD), and Brian Gaylord (Bodega Marine Lab, UCD)

Incorporating spatial heterogeneities in flow into larval transport models can have large effects on predicted dynamics of marine populations. While flow structures associated with large features have been explored (e.g., island wakes, headlands), little is known about the implications of more pervasive smaller-scale flow features within the inner shelf where coastal larvae start and end their lives. We use a 2-dimensional particle tracking model to explore the effects of reduced flow speeds observed near the coast (the Coastal Boundary Layer; CBL) on dispersal of organisms that are in the water column from days-weeks. For all sites, incorporating CBLs in the model decreases the mean dispersal distance. This effect is most profound for sites with gentler bathymetric slopes (broader CBL), specifically when the time spent in the CBL is comparable or larger than the pelagic larval duration (PLD). In addition to reduced mean dispersal, the 95th percentile dispersal distances are also reduced for all sites and across a range of PLDs. The total number of settlers is not different with or without a CBL, however, the proportion of settlers that settle within 10 km of the release site ('self-replenishment') is dramatically larger when including a CBL. In either scenario (with or without a CBL), the majority of successful settlers spend >75% of their PLD within 3 km from shore for all sites and all PLDs. In addition, no particles that spend <50% of their PLD within 3 km from shore contribute to self-replenishment, for either scenario (all sites, all PLDs). This further demonstrates the advantages of staying close to shore for the success of larval organisms, while also emphasizing the importance to coastal connectivity and population dynamics of the reduced velocities that have been observed throughout coastal California

11[30] *How do convergent and divergent fronts structure the cross-shore gradients of physical, chemical, and ecosystem properties in Monterey Bay?*

Sergey Frolov (MBARI) and James Bellingham (MBARI)

Surface currents, as measured by HF-Radar, can indicate areas of strong convergent and divergent flow (flow-fronts). Previous studies showed that these flow-fronts often overlap with strong gradients in sea surface temperature and can correspond to areas of increased foraging by marine predators. However, little is known how these flow-fronts structure the distribution of physical, chemical, and biological properties throughout the water column. In this study, we use extensive database of HF-Radar measurements and AUV transacts in Monterey Bay to describe statistics of water column properties co-incident with observed flow-fronts. We found that two persistent fronts form along the entrance of the bay: a convergent front on the west of the entrance to the bay and a divergent front to the east. We also found that both convergent and divergent fronts play equal role in separating water masses with different physical, chemical, and biological properties. Drawing on examples of the AUV transacts, we illustrate three typical scenarios:

1) A convergent front that facilitates mixing of offshore water masses in to productive water of the inner-bay,

2) Aggregation of biological material in a convergent front, and

3) Divergent fronts acting as barriers to distribution of biological tracers in otherwise laterally well-mixed waters.

We use the confirmed relationships between radar-detected fronts and water column properties to direct adaptive sampling of the frontal processes with a combination of autonomous and traditional sampling assets.

11[50] *Amplification of hypoxic and acidic events by La Niña conditions on the continental shelf off California*

SungHyun Nam (Scripps Institution of Oceanography), Hey-Jin Kim (SIO), and Uwe Send (SIO)

Low-oxygen and low-pH events are an increasing concern and threat in the Eastern Pacific coastal waters, and can be lethal for benthic and demersal organisms on the continental shelf. The normal seasonal cycle includes uplifting of isopycnals during upwelling in spring, which brings low-oxygen and low-pH water onto the shelf. Five years of continuous observations of subsurface dissolved oxygen off Southern California, reveal large additional oxygen deficiencies relative to the seasonal cycle during the latest La Niña event. While some changes in oxygen related to the isopycnal suppression/uplifting during El Niño/La Niña are not unexpected, the observed oxygen changes are 2-3 times larger than what can be explained by crossshore exchanges. In late summer 2010, oxygen levels at mid-depth of the water column reached values of 1.5ml/L, which is much lower than normal oxygen levels at this time of the seasons, 4-5ml/L. The extra uplifting of isopycnals related to the La Niña event can explain oxygen reductions only to roughly 3.5ml/L. We find that the additional oxygen decrease beyond that is strongly correlated with decreased primary production and strengthened poleward flows by the California Undercurrent. The combined actions of these three processes created a La Niña-caused oxygen decrease as large and as long as the normal seasonal minimum during upwelling period in spring, but later in the year. With a different timing of a La Niña, the seasonal oxygen minimum and the La Niña anomaly could overlap to potentially create hypoxic events of previously not observed magnitude.

4:00 *A region of hypoxia on the British Columbia Shelf*

Bill Crawford (Institute of Ocean Sciences Fisheries and Oceans Canada)

Low oxygen concentrations are characteristic of bottom waters off southwest Vancouver Island, British Columbia. However, in recent years the dissolved oxygen concentration in mid-shelf bottom waters has dropped to less than 1 millilitre per litre (~40 micromolar), with lowest concentrations in late summer of 2006 and 2009. Oxygen concentrations in these two years were the lowest observed in more than 30 years of observations. This region lies within the Juan de Fuca Eddy, a relatively stationary feature which rotates cyclonically in spring and summer. Observations of this eddy reveal that deep water upwelling is enhanced in this region due to the proximity of the Juan de Fuca canyon. We suspect these recent declines are due mainly to lower oxygen concentrations in deeper water that upwells onto the shelf in spring and summer, and to a lesser extent on stronger upwelling winds off Vancouver Island in the past decade.

4:20 *The NPGO and regional variation in Coho salmon growth: 47° N to 54° N*

Brian Beckman (NWFSC, NOAA), Marc Trudel (PBS, DFO), Cheryl Morgan (CIMRS, OSU), Deb Harstad (SAFS, UW), and Larissa Rohrbach (SAFS, UW)

The relative growth rate of juvenile salmon can be indexed by measures of the hormone insulin-like growth factor 1 (IGF1). IGF1 levels have been measured in coho salmon in June off the Oregon/Washington coast since 2000. This 11-year time series has revealed significant inter-annual differences in growth and that growth rate is significantly correlated to a zooplankton index of salmon food. Thus IGF1 can provide insight into inter-annual differences in pelagic productivity. Moreover, June IGF1 level is significantly related to adult coho salmon return: IGF1 predicts subsequent survival. IGF1 provides a useful assessment of biological oceanographic conditions.

Since 2007 assessments of juvenile coho salmon IGF1 have been extended north from the Washington Coast to SE Alaska, including much of the BC Coast. In some years there are strong latitudinal trends in IGF1 level (lower in the Washington, higher in the Queen Charlotte Islands), in other years there is little latitudinal difference in IGF1 level. We have developed an index of these latitudinal differences in coho salmon growth: the WaQCI IGF1 index. A positive WaQCI denotes a strong latitudinal difference and a weak or negative WaQCI denotes little latitudinal variation. The WaQCI IGF1 index is significantly related to NPGO in both April and May ($r = -0.97$, $p = 0.04$; $r = -0.99$, $p = 0.01$). The local oceanographic processes that might mechanistically underlie this relation will be explored in this talk by a salmon physiologist. It is expected that this might generate some interesting and useful discussion.

4:40 *Oceanographic influences on the growth of coho (Oncorhynchus kisutch) and chinook (O. tshawytscha) salmon along the coast of British Columbia, Canada*

Bridget Ferriss (NWFSC, NOAA), Brian Beckman (NWFSC, NOAA), and Mark Trudel (PBS, DFO)

Somatic growth in marine fish is influenced by environmental conditions and prey availability, providing insights into both individual fitness and their surrounding environment. Relative growth can be measured by levels of insulin-like growth hormone 1 (IGF1) in plasma, which represents growth over an approximate one week period prior to sampling. We collected IGF1 samples from 1661 coho (*Oncorhynchus kisutch*) and 1040 chinook (*O. tshawytscha*) salmon along the coast of British Columbia, Canada in June of 2007, 2008, 2009 and 2010. We examined trends in growth relative to station-specific oceanographic data (e.g., sea surface temperature,

chlorophyll a, nutrient concentrations, and zooplankton abundance) as well as larger scale climate indices and remotely sensed sea surface temperature and ocean color. We will present preliminary results describing spatial variation in the growth of coho and chinook salmon as it relates to physical and biological oceanographic characteristics, exploring the mechanistic drivers behind these patterns. Environmental influences on growth will also be examined in light of inter-specific differences in life history and diet. Understanding the relationships between salmon growth and their environment will improve our ability to forecast their fitness at a population level. This research is part of a larger study exploring the attributes of IGF1 as an indicator of environmental conditions.

5:00 *Seasonal and inter-annual variability in copepod species composition and egg production related to climate and upwelling dynamics in the northern California Current*

Jay O. Peterson (Cooperative Institute of Marine Resources Studies, OSU), William T. Peterson (NOAA Fisheries), and Cheryl Morgan (Cooperative Institute of Marine Resources Studies, OSU)

The copepods *Calanus marshallae* and *C. pacificus* are major components of the zooplankton assemblage in the northern California Current (NCC) seasonal upwelling system. These two species are often associated with different water masses, with *C. marshallae* primarily a boreal, neritic species and *C. pacificus* a sub-tropical, offshore species. Hence, their presence along the Oregon shelf is indicative of the advection of different water masses onto the shelf. Using a 15 year (1996 – 2010) dataset of bi-weekly measurements of cross-shelf hydrography, species life-history stage abundance, and egg production rate, we examine the variability in these parameters in relation to upwelling dynamics (local forcing) and shifts in climate as indexed by the Pacific Decadal Oscillation (PDO) and Multivariate ENSO Index (MEI). Generally, positive phases of the PDO and MEI are coincident with higher abundances and proportions of *C. pacificus* over the shelf, whereas negative phases favor *C. marshallae*. The timing of first appearance of an assemblage of boreal, neritic copepods that includes *C. marshallae* indicates a 'biological transition' from winter to summer, and can lag the physical upwelling transition anywhere from days to months. Egg production rates average 26.7 eggs per female, but vary considerably both inter-annually and seasonally. Here, we investigate how basin-scale and local-scale forcing influence secondary production in an upwelling system.

5:20 *Relationships among interannual climate variability, latitude of the North Pacific Current bifurcation, and nutrient supply to the California Current*

Ryan R. Rykaczewski (Hatfield Marine Science Center, NWFSC, NOAA), William J. Sydeman (Farallon Institute for Advanced Ecosystem Research), Bill T. Peterson (Hatfield Marine Science Center, NWFSC, NOAA), and John P. Dunne (Geophysical Fluid Dynamics Laboratory, NOAA)

Interannual variability in the latitude of the North Pacific Current and its bifurcation along the west coast of North America is significantly correlated with a number biological time series in the California Current over the 2002-2006 period—Poleward shifts in the position of the North Pacific Current are associated with increased biomass and productivity of several zooplankton, bird, and fish species. Increased advective transport of nutrients and/or zooplankton from the subarctic domain has been proposed as the mechanism that controls these relationships. Here, we use a large-scale ocean biogeochemistry model forced by atmospheric fluxes over the 1948-2007 period to 1) explore how the position of the North Pacific Current bifurcation has varied in relation to well-known modes of variability in the region (PDO, ENSO, and NPGO), 2) investigate how the latitude of the bifurcation influences nutrient flux to the California Current, and 3) consider the relationship between bifurcation latitude and other influential ecosystem processes (e.g., upwelling and equatorward transport) in the California Current. Preliminary

analysis suggests a significant negative relationship between the bifurcation latitude and PDO and ENSO indices over the time period.

540 *The Ocean Observatories Initiative's Endurance Array: Preliminary results and future research opportunities*

Michael F. Vardaro (Oregon State University) and Jonathan Fram (OSU)

The Ocean Observatories Initiative (OOI) program, funded by the National Science Foundation, will measure physical, chemical, geological, and biological parameters via a networked series of sensors in the Atlantic, Pacific, and polar oceans. Oregon State University is coordinating development and operation of the Endurance Array, which will consist of three ocean observatory sites (at 25, 80, and 600 m water depth) located off Newport, OR, and three sites at similar depths off Grays Harbor, WA. The Newport Line will also be connected to an undersea fiber optic cable network that was recently connected to the shore station in Pacific City, OR.

A prototype inshore (25 m) mooring and a prototype cabled benthic experiment platform were deployed this year. We will present the preliminary data from those tests, as well as explore how the OOI sensor network can be used to study changes in cross-shelf processes over a range of temporal scales. The OOI sensors will be able to capture local impacts from short-term events such as the arrival of hypoxic water masses, algal blooms, and seasonal storms as well as long-term changes in riverine output, variation in productivity and POC flux levels, CO_2 sequestration, ocean acidification, and food web dynamics. The OOI network is also a unique, expandable platform that is intended for use by the larger scientific community, outside of the OOI implementing organizations. The Endurance Array infrastructure represents an opportunity to conduct novel seafloor and pelagic experiments and observations over the projected 25-year lifespan of the project.

Physical, Chemical, and Biological Connections between Coastal Zones (The Inner, Middle, Outer Shelf and Continental Slope)

Contrasting HAB-susceptible upwelling shadows: the influence of latitude and resonant atmosphere/ocean interactions

Andrew Lucas (NSF International postdoctoral fellow), Raphe Kudela (UCSC), Grant Pitcher (MCM/DAFF, Univ. of Cape Town, South Africa), and Trevor Probyn (MCM/DAFF, Univ. of Cape Town, South Africa)

The inner portion of St. Helena Bay, South Africa, is a retentive zone downwind of a major Eastern Boundary Current upwelling center. This region is afflicted with episodic, major HAB events, resulting in both shellfish toxicity and anoxia-induced rock lobster mortalities. A cross-shore array of wave-powered profilers and bottom current meters show that strong inertial wave activity, driven by the nearly resonant diurnal sea breeze, controls the vertical and horizontal distribution of the HAB forming phytoplankton. The concentrating mechanism resulting from these near-coastal (and therefore modally and temporally complex) inertial waves seems particularly effective for highly motile species. That is, highly motile species cross isopycnals undergoing horizontal and vertical excursions, thus maintain a consistent distribution relative to depth and minimize their cross-shore advection. The data collected in South Africa can be contrasted to a similar time series collected in Monterey Bay where vertical migration is of first order importance to the distribution of the phytoplankton with depth. We hypothesize that the contrast between these "upwelling shadow" regions is in part due to their respective latitudes and the relative efficiency of the transfer of energy from diurnally variable winds to the surface ocean.

The tattered curtain hypothesis revisited

Cheryl Harrison (UC Santa Cruz), Dave Siegel (UC Santa Barbara), and Satoshi Mitarai (OIST)

Benthic larval settlement dynamics along the US West Coast are often thought to be driven by relaxation of upwelling winds. In this scenario the upwelling front, broken up by squirts and filaments, acts as a "tattered curtain", retaining coastally released material and transporting it back to the coast during wind relaxation. Other studies take the approach that settlement is more stochastic and driven by transport in and around coastal eddies. We test these two hypotheses in a coupled ocean/particle-tracking model of an idealized eastern boundary current forced by realistic winds. We find that neither of the previous ideas hold for this system on their own, but instead there is a combination of both processes. Settlement patterns are predominantly driven by retention of larvae in an upwelling jet, modulated by coastally trapped waves and interrupted by squirts. This jet is broken up and moved offshore by extended strong upwelling, reducing coastal retention. Spatially discrete, dense packets of coastal material are entrained in the jet and result in locally large pulses of settlement. Lagrangian coherent structures are used to characterize the two transport boundaries associated with jet, one consistent with the upwelling front, and one inshore of this. Findings here are consistent with observed recruitment patterns along the Oregon coast, suggesting the upwelling jet impacts coastal retention in that region.

Currents and Suspended Sediment in the Near-Bottom Stratified Turbulent Layer of the Monterey Submarine Canyon

Erika McPhee-Shaw (Moss Landing Marine Labs, SJSU), Katie Morrice (MLML, SJSU), Eric Kunze (Applied Physics Lab, UW), James Girton (Applied Physics Lab, UW), and Samantha Terker (Applied Physics Lab, UW)

In August – October 2008 observations from the Monterey Submarine Canyon we found persistent features of elevated turbulence extending a few hundred meters above the seafloor everywhere along the canyon axis between 1700 and 600 m (Kunze et al, 2011). These layers remained stratified despite relatively energetic mixing. Here we use shipboard profiles and mooring time series of currents, temperature, density, and light transmission to examine the dynamics of suspended sediment and water masses within these stratified turbulent layers. Along-canyon advection appeared to control suspended particulates. Variance in all constituents was dominated by semidiurnal fluctuations, however, lower

frequency variability also played an important role: At a mid-canyon site 1100-m deep, 3- to 7-day long events of elevated background suspended particulate concentration were characterized by warmer temperatures and energetic semidiurnal currents. Repeated profiles within a 12-hour period at various sites showed individual overturn and benthic “lift off” features subsequently displaced upward by onshore flow of deep waters closer to the seafloor. With these data we start to build a conceptual picture of how vertical straining and lateral dispersal might build up stratified bottom nepheloid layers and contribute to onshore-offshore exchange at continental slopes and canyons.

Sub-regional ocean color variability in the California Current System

Piero L. F. Mazzini (Oregon State University), Craig M. Risien (OSU), Jack A. Barth (OSU) and Ocean Observing Colleagues

From mid-May to July 2011, extreme runoff in the Columbia River ranged from 14,000 to 16,000 m3/s, more than two standard deviations above the mean for this 1.5-month period. The extreme runoff was the result of melting of the anomalously high snowpack associated with the 2010-2011 La Niña. Snowpack reached values above 180% of the mean for some regions along the Columbia River basin. The effects of this increased freshwater discharge could be observed off Newport, Oregon, approximately 180 km south of the Columbia River mouth. Low-salinity pulses were observed at the NH-10 mooring, located 10 miles offshore of Newport in 80 m of water. Pulses where salinity dropped as low as 22 (9 units below the climatological value for this period) lasted for a couple days and were not significantly correlated with time variations in the river discharge. Salinities at a mooring in the inner shelf (25 m of water) showed salinities as low as 24, conforming that these freshwater pulses reach the coast. Analysis of the wind stress, surface currents derived from HF-radar, temperature and salinity transects from underwater gliders, and satellite images from the RRS (Remote sensing reflectance) at 555 nm MODIS channel on NASA's Aqua satellite, shows that the on-offshore location of the plume front is not controlled by the discharge, but rather is driven mainly by Ekman dynamics. However, the increased river discharge changed the fresh water content and therefore the thickness of the plume, allowing the high drops in salinity to occur. HF-radar derived surface velocities help track the freshwater plume along the Oregon coast. We calculate the equivalent freshwater content off Newport based on the glider transects and show how that compares with previous years.

Declining oxygen in the Northeast Pacific

Stephen D. Pierce (Oregon State University), John A. Barth (OSU), R. Kipp Shearman (OSU), and Anatoli Y. Erofeev (OSU)

Climate models predict a decrease in oceanic dissolved oxygen and a thickening of the oxygen minimum zone, associated with globalwarming. Comprehensive observational analyses of oxygen decline are challenging, given generally sparse historical data. The Newport Hydrographic (NH) Line off central Oregon is one of the few locations in the Northeast Pacific with long oxygen records. Good quality data are available here primarily in two time blocks: 1960-71 and 1998-present. Shipboard measurements have been supplemented in recent years (2006-present) with data from autonomous underwater gliders. Oxygen declines significantly over this 50-year period across the entire NH line. In addition to decrease in the vicinity of the oxygen minimum depth (~800 m), oxygen decreases across a range of density surfaces σ_θ = 26-27 within the thermocline, in the depth range 100-550 m. A core of decreasing oxygen (0.7 ± 0.2 μmol/kg/y) is also found over the upper slope at 150-200 m depths, within the region of average northward flow associated with the poleward undercurrent. During the summer upwelling season, the largest decline is observed near-bottom on the shelf: the dissolved oxygen of upwelled water, already low, is further reduced by shelf processes, leading to near-bottom hypoxia (< 60 μmol/kg) on the Oregon shelf.

EPOC 2011 - Wednesday, October 12 - Poster Session Abstracts

Advances in Ecosystem Modeling in the Northeast Pacific

Harnessing your GPU for interactive immersive Individual-Based Modeling

Albert J. Hermann (JISAO, Univ. of Washington) and Christopher W. Moore (JISAO, UW)

Spatially-explicit individual-based modeling can be a powerful tool for the exploration of how changes in coastal circulation affect fish recruitment, and 3D viewing of the results leads to new insights regarding the effects of behavior on spatial path. One limit to the usefulness of this (or any) modeling approach is the latency between submission of a run and examination of the results. Powerful yet inexpensive parallel computing technologies, based on the hundreds of cores available in modern graphics cards (GPU), have been shown to increase the performance of suitably adapted code by a factor of 100x. This suggests a way forward to achieve interactive submission/examination of IBMs, even on a laptop computer. Here we demonstrate the use of this technology with a spatially explicit IBM prototype, based on pre-stored circulation model output for the Bering Sea. Results will be presented using the stereo-immersive capabilities of the graphics card, for 3D animation.

The role of coupled physical-biological models for HAB prediction in California

Clarissa R. Anderson (UC Santa Cruz), Raphael M. Kudela (UCSC), Igor Shulman (NRL Stennis Space Center), Bradley Penta (NRL Stennis Space Center), Yi Chao (Jet Propulsion Laboratory), David A. Siegel (UCSB), and Claudia Benitez-Nelson (Univ. of South Carolina)

The use of optical signals to detect harmful algal blooms has proven successful for a variety of species and regions but shown limited application for remotely sensing toxic blooms on the U.S. west coast where the diatom *Pseudo-nitzschia* is a common HAB-former. Statistical models that incorporate satellite data are useful for detection and tracking of blooms but show reduced skill in remote detection of toxin production. The latter generally requires knowledge of in situ nutrient distributions to constrain our inference of bloom physiological state. Regional ocean models accurately predict physical parameters for forcing statistical models of HAB probability and, when coupled to ecosystem models, provide simulations of chemical and biological fields that are critical for estimates of toxin production. Initial testing of previously developed statistical models parameterized with coupled physical-biological numerical model output shows promise but cannot currently replace environmental data. Regional tuning or coupled development of statistical models and numerical output may greatly aid in improving predictive skill and may be the way forward for development of short-term (weekly) forecasts and decadal analyses of forcing functions driving blooms and toxin production.

General Contributions

Community bloom dynamics and related toxins along the Oregon coast

Anita McCulloch (Cooperative Institute of Marine Resources Studies, OSU/NWFSC), Michelle Wood, Bill T. Peterson (NWFSC, NOAA), Angelicque E. White (COAS, Oregon State Univ.), M. Hunter (Oregon Dept. of Fish & Wildlife), Zachary Forster (Oregon Dept. of Fish & Wildlife), D. Smith (Oregon Department of Agriculture), Morgaine McKibben (COAS, Oregon State Univ.) and Peter Strutton (Inst. for Marine and Antarctic Studies, University of Tasmania)

Blooms of harmful algae, including *Pseudo-nitzschia*, and *Alexandrium*, and associated phycotoxins, such as domoic acid and saxitoxin, often occur along the Oregon coast and threaten wildlife and recreationally important shellfish. In 2007, a monitoring and event response project (MOCHA - Monitoring of Oregon's Coastal Harmful Algae) was established to better understand the ecological mechanisms underlying the occurrence of HABs and minimize their impact on coastal communities. The dominant bloom genera and community bloom dynamics vary both spatially and temporally. Yet, little information is known about why certain genera are dominant over others. We examined the phytoplankton community distributions and nearshore toxin data over a two year period (2009 – 2010) focusing on the dominant bloom genera and associated toxin. Dinoflagellates dominated the bloom dynamics in 2009 while diatoms, specifically *Pseudo-nitzschia*, dominated coastal waters in 2010. In 2009, *Alexandrium* were the dominant genera with elevated saxitoxin concentrations as high as 900 mg/100g from August to November. Saxitoxin levels were highest and occurred slightly earlier in northern Oregon compared to central and southern Oregon. *Pseudo-nitzschia* cell counts reached elevated levels from May to early August. However, domoic acid concentrations did not exceed detection limits. The bloom transitioned to an *Akashiwo sanguinea* bloom in late 2009 (August – November) resulting in thousands of seabird deaths. During 2010, Pseudo-nitzschia was the dominant bloom genera with domoic acid levels exceeding detection limits from June to August. Future efforts will address the contrasting oceanographic conditions between 2009 and 2010.

Coastal variability and Lagrangian circulation in Todos Santos Bay and off Baja California during Spring-Summer 2007

David Rivas (CICATA-IPN, Altamira, Mexico), Rocio Mancilla-Rojas (CICATA-IPN, Altamira, Mexico), Carmen Rivas-Lara (CICATA-IPN, Altamira, Mexico), Ernesto Garcia-Mendoza (CICESE, Ensenada, Mexico), and Antonio Almazan-Becerril (CICY, Cancun, Mexico)

Here we study numerically the circulation in Todos Santos Bay area (31.88°N) and off Baja California during Spring and Summer 2007. This period is particularly interesting after an intense toxic algal bloom occurred in April 2007 in this area, which was most probably caused by enviromental conditions associated with the wind-driven upwelling in the region. We carried out high-resolution, numerical model simulations to study dynamical features along the coast of the northern Baja California (BC) Peninsula and within Todos Santos Bay (TSB), and also to be used in a three-dimensional Lagrangian analysis which provides information about the origin and distribution of the waters present in the Bay during the occurrence of the toxic bloom. The regional dynamics reproduced by the model include the poleward propagation of coastal trapped waves along the BC coast, the so-called Ensenada front, and a persistent cyclonic eddy formed northwest of TSB. The Lagrangian results show that these last two features drive the paths followed by the water parcels found in TSB in Spring 2007. Most of those waters come from locations west of TSB (even beyond the model's domain), stay within the Bay by about one month, and ultimately scatter south-southwestward along the BC coast. The Lagrangian paths also show some connectivity between the waters in TSB and those in Southern California Bight.

<u>Oceanographic Processes in the Coastal Ocean-Estuary Transition Zone</u>

The influence of coastal nutrients on phytoplankton blooms in a low-inflow estuary

Christina Buck (RTC, SFSU), Frances Wilkerson (RTC, SFSU), Alex Parker (RTC, SFSU), and John Largier (Bodega Marine Lab)

Drakes Estero, located in Point Reyes National Seashore, CA, is a shallow low-inflow estuary where harmful algal bloom (HAB) species including *Alexandrium catenella* have been observed. Nutrient supply to the estero is primarily via tidal fluxes from the adjacent ocean, which is an important wind-driven coastal upwelling region. Additional terrestrial nutrients delivered through land runoff from wilderness areas and cattle grazing lands are likely important in winter. The estero is also the site of an oyster aquaculture facility, which may enhance local sources of regenerated nutrients. The influence these varied nutrient sources on phytoplankton communities and primary production is unknown. A study was initiated in May 2010 to measure seasonal and spatial variations in nutrient concentrations, chlorophyll, and primary production and nitrogen uptake as well as to enumerate phytoplankton species. During the low-inflow estuarine season (July-October) a gradient in nutrient concentrations and elemental ratios was observed along the land-to-sea axis of the estero with the landward region exhibiting elevated ammonium and low DIN : PO4, compared to coastal locations that had elevated levels of nitrate and high DIN : PO4 ratio. Phytoplankton blooms were observed at the coastal and middle estero locations, dominated by diatoms during the upwelling season and dinoflagellates during the fall. This study provides a mechanistic look at the how oceanographic processes in the coastal ocean- estuary transition influence the ecology of Drakes Estero.

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General Contributions

8[30] *Development of the Eastern Pacific Ocean Prediction Forum (ePOPf)*

Chris Mooers (Portland State Univ.), Yi Chao (JPL/UCLA), Chris Edwards (UCSC), Ted Strub (OSU), Roger Samelson (OSU), Parker MacCready (UW), Zizang Yang (Coast Survey Development Laboratory/NOS/NOAA), Richard Patchen (CSDL/NOS/NOAA), and Frank Aikman (CSDL/NOS/NOAA)

The intent to form ePOPf was first presented at the 56th EPOC. The concept of ePOPf was further developed at a workshop in SEP10 and summarized at the 57th EPOC. In the interim, the notion of a super-regional model testbed has been further advanced nationally, as spurred by initiatives on the East and Gulf Coasts. Also, the Coast Survey Development Laboratory (CSDL) of the National Ocean Service (NOS) has advanced its plans for a Pacific Coast operational model that will help with downscaling from an operational global ocean model to operational shelf and estuarine models. Such a network of coupled predictive systems will provide opportunities for the R&D community as well for societal applications. However, a community-wide effort will be required to help develop and skill assess the predictive systems. One role of ePOPf is to help foster, facilitate, and coordinate that activity with IOOS, OOI, etc.

8[50] *Intraseasonal variability of coastal winds and ocean conditions along the US Pacific coast in summer*

James Johnstone (JSIAO, Univ of Washington)

The summer climate of the US Pacific coast is dominated by alongshore winds that drive upwelling and productivity in the marine ecosystem. Interannual variability in wind strength and upwelling is considerable, largely driven by seasonal anomalies in the midlatitude atmospheric circulation over the NE Pacific. This study examines shorter-term intraseasonal variability in coastal northerly winds off the Oregon coast at 45°N. Winds are shown to display a statistically significant tendency for strengthening/weakening on a ~20 day time scale. Using buoy, reanalysis, satellite, and land station data, the composite sequence of northerly wind surges is illustrated; particularly notable is a tendency for wind events to begin in central California and migrate northward to the Pacific Northwest. This pattern of northward migration is also evident to varying degrees in coastal SST, chlorophyll, land temperatures, and stratus cloud. The potential for predictability of wind surges and marine responses is also discussed.

9[10] *Subthermocline eddies over the Washington Continental slope as observed by Seaglider, 2003-09*

Noel Pelland (Univ of Washington School of Oceanography), Charles Eriksen (UW),
Craig Lee (Applied Physics Laboratory and School of Oceanography, UW)

A 5.5 year time series of cross-shore Seaglider surveys along two transects in the Washington slope region revealed the presence of multiple subsurface, anticyclonic eddies with core water properties similar to those found in the California Undercurrent ("cuddies"). Gliders achieved 40 anticyclone crossings; closer inspection grouped these into 17 individual eddies (approximately three per year) sampled during the time series. The eddies' size and characteristics -- horizontal radii of 25-30 km, vorticity minima in some cases almost 50% below ambient values, mean propagation velocity (inferred by repeat occupations of multiple eddies) of about 1 cm s^-1 westward -- are on average consistent with Submesoscale Coherent Vortices. The smallest and most intense of these features are likely generated through frictional torque acting on the topographically-trapped undercurrent. A survey of glider profiles near eddy edges found numerous examples of along-isopycnal interleaving between eddy core water and the surrounding subarctic water; a parameterization of effective cross-frontal diffusivity (using typical interleaving scales) compares well with horizontal diffusivity inferred from the observed cross-shore eddy decay. Anomalous transport of salt due to eddy features accounts for a lateral flux of 70x10^9 kg salt yr^-1 from the upper slope region over the time series; this represents 30% of the alongshore loss of salt from the undercurrent as inferred from the poleward freshening observed between the two glider transect locations, and provides a novel quantification of cuddies' role in offshore flux of subsurface waters.

9[30] *Coastal trapped waves and the California Undercurrent*

Thomas Connolly (Univ. of Washington) and Barbara Hickey (UW)

The California Undercurrent strongly influences the distribution of water masses along the coast and regulates the source depth for coastal upwelling. However, physical mechanisms for its generation and seasonal variability are not firmly understood. We explore the hypothesis that the large scale structure of upwelling favorable wind stress along the U.S. west coast, with a maximum off northern California, leads to a poleward alongshore pressure gradient and acceleration of a poleward undercurrent. We use the Navy Coastal Ocean Model of the California Current System (NCOM-CCS) from 30–49N to investigate the structure and variability of the alongshore pressure gradient and the California Undercurrent during 2005. We also employ a linear, time-dependent coastal trapped wave (CTW) model with similar alongshore extent in order to further diagnose sensitivity to both wind forcing and signals generated further south. Time series of alongshore velocity in both models compare favorably with current meter observations in the core of the undercurrent off the coast of British Columbia. In the NCOM-CCS model, the mean pressure gradient force is poleward at 300m depth during summer, although the coastal sea level gradient becomes equatorward north of 45N. Fluctuations of the alongshore pressure gradient balance acceleration within the undercurrent. In the CTW model, seasonal variability of alongshore flow over the British Columbia slope is highly sensitive to the inclusion of San Diego sea level data as a southern boundary condition, which causes more equatorward flow during spring and more poleward flow during late summer.

9[50] *The influence of stratification, shelf slope, and wind stress curl on nutrient supply in a coastal upwelling system*

Michael G. Jacox (UC Santa Cruz) and Christopher A. Edwards (UCSC)

Qualitatively, the process by which equatorward winds along oceanic eastern boundaries draw fluid from depth into the euphotic zone is well-known. While the volume flux is set by the surface wind stress, the associated nutrient flux is also influenced by the depth of source waters and by the vertical nutrient profile. It has been shown in an idealized 2-dimensional (cross-shore) study that source depth varies quantitatively with stratification, shelf-slope, and latitude, as these parameters determine the relative proportion of upwelling deriving from the bottom boundary layer and from the interior region above. Nearshore wind stress curl modifies this prescription further by changing the local surface Ekman transport and by altering the cross-shore momentum flux divergence. With the typical oceanic scenario of reduced equatorward winds at the coast and nutrients that increase with depth, these two factors reduce upwelling from the bottom boundary layer and the associated nutrient flux into the coastal euphotic zone, relative to that resulting from constant wind stress forcing.

10^{30} *Modeling the impact of watershed management policies on marine ecosystem services with application to Hood Canal, WA, USA*

Dave Sutherland (NOAA NWFSC, Univ. of Oregon), Choong-Ki Kim (Natural Capital Project, Stanford Univ.), Matthew Marsik (NOAA Fisheries NWFSC), Georgi Spiridonov (NOAA Chesapeake Bay Office/NMFS, Cooperative Oxford Lab), Jodie Toft (NOAA NWFSC, Natural Capital Project, Stanford Univ.), Mary Ruckelshaus (NOAA NWFSC, Natural Capital Project, Stanford Univ.), Anne Guerry (NOAA NWFSC, Natural Capital Project, Stanford Univ.), and Mark Plummer (NOAA NWFSC)

Humans obtain numerous benefits from marine ecosystems, including fish to eat; mitigation of storm damage; nutrient and water cycling and primary production; and cultural, aesthetic and recreational values. However, managing these benefits, or ecosystem services, in the marine world relies on an integrated approach that accounts for both marine and watershed activities. Here we present the results of a set of simple, physically-based, and spatially-explicit models that quantify the effects of terrestrial activities on marine ecosystem services. Specifically, we model the circulation and water quality of Hood Canal, WA, USA, a fjord system in Puget Sound where multiple human uses of the nearshore ecosystem (e.g., shellfish aquaculture, recreational Dungeness crab and shellfish harvest) can be compromised when water quality is poor (e.g., hypoxia, excessive non-point source pollution). Linked to the estuarine water quality model is a terrestrial hydrology model that simulates streamflow and nutrient loading, so land cover and climate changes in watersheds can be reflected in the marine environment. In addition, a shellfish aquaculture model is linked to the water quality model to test the sensitivity of the ecosystem service and its value to both terrestrial and marine activities. The modeling framework is general and will be publicly available, allowing easy comparisons of watershed impacts on marine ecosystem services across multiple scales and regions.

10^{50} *Scales, sources and implications of short-term oxygen and pH variability on the continental shelf off southern California*

Christina A. Frieder (Scripps Institution of Oceanography), SungHyun Nam (SIO), Todd R. Martz (SIO), Uwe Send (SIO), and Lisa A. Levin (SIO)

The Eastern Pacific continental shelves are frequently exposed to low oxygen and pH waters given their proximity to an expansive OMZ. CO2-driven decreases in oxygen and pH are additional threats. We investigated oxygen and pH dynamics with the use of physical and biogeochemical sensors moored at the outer- and inner-shelf along the San Diego coastline. Our goals were to (a) identify the relationship between oxygen and pH, (b) characterize their variability from semidiurnal and diurnal, to event-scales, (c) identify mechanisms responsible for the observed variability, and (d) determine the extent to which benthic organisms are exposed to low-oxygen and/or low-pH events. Results thus far reveal a linear relationship between oxygen and pH (r2=0.94). Temporal variability is greatest at the semidiurnal frequency; at depths associated with the thermocline oxygen and pH can change 50% and 0.3 units, respectively, every six hours. Diurnal variability is predominant at the surface and is due to two components: heating/cooling and production/respiration which act antagonistically. Event-scale current reversals drive changes in oxygen and pH over days to weeks. Equatorward currents cause low-oxygen and pH water masses to intrude shallower. When currents relax, oxygen and pH increase at depth. Not surprisingly, outer-shelf benthic communities experience greater intensity and duration of low-oxygen and low-pH events. Inner-shelf benthic communities were subjected to low-oxygen and low-pH conditions (DO<90 µmol kg-1 or pH<7.75) for infrequent, short durations. This suggests that on the continental shelf there is a continuum of biological processes affected by low-oxygen and pH from outer- to inner-shelf ecosystems.

11[10] *Linking otoliths and oceanography to elucidate environment-growth relationships for early life history stages of rockfishes off Central California*

Kathryn Crane (Humboldt State Univ.), Eric P. Bjorkstedt (Humboldt State Univ., NOAA SWFSC), Robert VanKirk (Humboldt State Univ), Timothy J. Mulligan 1 (Humboldt State Univ), and Stephen Ralston (NOAA SWFSC)

Recruitment strength in most marine fishes is strongly influenced by environmental conditions encountered during early life history (ELH), which has motivated research to develop recruitment indices based on environmental predictors of larval growth and survival. In this study, we quantify variability in growth during early life history for several species of rockfish, and develop quantitative models relating inferred growth rates to measures of physical forcing which serve as a proxy of environmental conditions experienced by individual fish. Individual growth trajectories are based on micro-increment analysis of sagittal otoliths from over 500 individual rockfish captured as pelagic juveniles off central California from 1983 to 2008.We link observed growth patterns to time series of environmental variables using a simulation-based state-space model that explicitly accommodates changes in growth patterns related to developmental stage and autocorrelation in growth rate within individual fish. Our analysis is designed to evaluate whether proxies of local environmental condition (e.g.wind forcing, coastal upwelling and downwelling, sea surface temperature, and sea level anomaly) have instantaneous, lagged or cumulative effects on individuals' growth rates, and whether cumulative variability of environmental parameters better explain variability in ELH growth rates. Initial analysis of otolith growth patterns indicates that sensitivity to environmental conditions is consistently highest between ages roughly corresponding to exhaustion of maternal provisions and the development of robust foraging capabilities and lipid reserves. Results from this work represent a significant advance over previous analyses of environment-growth relationships in rockfishes, and in particular, partition the contribution of extrinsic processes (e.g., food web responses to cumulative environmental forcing) and intrinsic state (energy reserves, size, and foraging history)to observed autocorrelation in otolith growth rates. We also compare our results to simulations of the coastal plankton ecosystem off central California derived from a simple coupled bio-physical model which provides a regional comparison of the integrated effects of environmental variability on ecosystem productivity. Otolith growth data and environment-growth relationships from this work are being used in the development of individual-based models for rockfish early life history stages. Moreover, assuming that conditions favoring larval growth translate into increased survival, our results provide a basis for environment-recruitment indices that may reduce uncertainty and improve performance of existing stock assessment frameworks, and provide insight to mechanisms central to how rockfish populations will respond to climate change.

11[30] *Growing in the flow: Modeling circulation, production, and early life history ecology to develop recruitment indices for rockfishes*

Eric Bjorkstedt (NOAA Fisheries, Southwest Fisheries Science Center)

Recruitment variability to populations of winter-spawning rockfish derives primarily from highly variable survival through the larval stage, presumably as a consequence of environmental and ecological conditions affecting early life history stages. We have developed a modeling framework in which (1) a coupled bio-physical model (CBPM) of the coastal ocean is forced with observed environmental conditions to simulate cross-shelf circulation and dynamics of the planktonic ecosystem during the winter-spring parturition season of rockfishes, and (2) an individual-based model (IBM) for larval and juvenile rockfish is used to simulate larval growth and potential survival as a function of conditions experienced by larvae entering the plankton over the course of the parturition season and across the continental shelf from near the coast to the shelf-break. The CPBM is implemented in the Regional Ocean Modeling System (ROMS) as a 2-D cross-shelf slice of the coastal ocean forced with observed time series of environmental

conditions for the period from 1983 to 2010. Predictions of recruitment success are obtained by integrating the joint probability of (1) survival conditional on birth date, and (2) entering the plankton on a given date and at a given location, where the latter is based on the distribution of spawning over time and the distribution of adult habitat. Simulated growth trajectories compare favorably to growth inferred from micro-increment analysis of otoliths from pelagic juvenile rockfishes. Moreover, time series of recruitment indices derived from the CBPM-IBM exhibit strong coherence with time series of recruitments estimated in stock assessments for several rockfish species. Results from this work demonstrate the potential for IBMs to serve as useful tools for understanding recruitment dynamics in west coast rockfishes and motivate the incorporation of realistic IBMs for rockfish early life history stages into existing three-dimensional particle-tracking ocean circulation models currently used to explore dispersal and connectivity.

11[50] *Event profiling reveals larval advection and behavior in a recruitment-limited upwelling system*

Steven G. Morgan (Bodega Marine Lab, UC Davis), Jennifer L. Fisher (Bodega Marine Lab, UC Davis, Hatfield Marine Science Center/OSU), Skyli T. McAfee (Bodega Marine Lab, UC Davis, California Ocean Science Trust), John L. Largier (Bodega Marine Lab, UC Davis), and Chris M. Halle (Bodega Marine Lab, UC Davis)

The effectiveness of larval behavior in regulating dispersal and recruitment in a dynamic ocean is of central importance to marine population and community ecology and for conserving and managing resources. A long history of surveying larvae in the plankton and new recruits from the shore indicates that larvae exert considerable control over their movements during prevailing ocean conditions. The advent of ocean observing systems enables complementary targeting of oceanographic events to determine how changes in ocean conditions affect larval transport and recruitment. We capitalized on a long-term record of larval recruitment and a distinctive oceanographic signature to provide a rare glimpse of how changes in ocean conditions affect larval advection, control and recruitment in a in a region of strong upwelling and recruitment limitation. We repeatedly profiled the vertical and horizontal distribution of a larval assemblage and ocean conditions during infrequent relaxations of prevailing equatorward winds near Bodega Bay, California, USA. Water flowing from San Francisco Bay into the ocean was advected poleward by a buoyant coastal boundary current that arrived devoid of larvae, whereupon the resident larval assemblage was restricted to cold saline bottom waters, pushed offshore and diel vertical migrations were suppressed. This revealed the strong effect of changes in oceanographic conditions can have on behaviorally mediated larval distributions and why few species recruit during relaxation events. Targeted profiling of larval assemblages complements widespread monitoring of recruitment from shore and is necessary to determine how changing ocean conditions affect larval distributions, recruitment dynamics and the connectivity of populations.

4[00] *Modeling the effects of decadal-scale climate variability across trophic levels*

Kelly Kearney (Princeton University), Charles Stock (NOAA Geophysical Fluid Dynamics Laboratory), and Jorge Sarmiento (Princeton University)

The Eastern Subarctic Pacific has shown decadal variations in ecosystem state, sometimes characterized as regime shifts, that are correlated to the Pacific Decadal Oscillation and have been documented at several trophic levels, from primary producers to top predators. While correlative links between changes in physical properties and population changes at various levels of the food chain have been demonstrated, the underlying mechanisms of these population shifts remain unclear. Here, we use an end-to-end ecosystem model to investigate the response of an oceanic food web to changes in the physical environment. The end-to-end model fully couples a one- dimensional physical model, a biogeochemical model, and a predator-prey food web model, allowing two-way feedback between all trophic levels. An ensemble approach that accounts for uncertainty in fisheries food web interactions is used to assess the range of potential responses of the ecosystem to climate variability. While this study is focused on the pelagic Subarctic Pacific ecosystem, the modelling methodology is designed to be generic to any ecosystem, and provides one potential framework for investigating ecosystem response to climate variation.

4[20] *Assessing the biodiversity necessary to maximize modeled phytoplankton productivity in the California Current System*

Nicole Goebel (UC Santa Cruz), Chris Edwards (UCSC), Mick Follows (MIT), and John Zehr (UCSC)

Biodiversity plays an important role in ecosystem productivity through the complete use of resources by a number of specialized individuals. Ecosystem modelers are challenged by the computational cost and parameter-tuning required to model many individuals. Ecosystem models that include few individuals may not only underrepresent diversity, but also misrepresent resultant processes such as resource use and productivity. A self-emergent ecosystem model that strives to represent phytoplankton diversity of the California Coastal System is used to test how primary productivity varies with phytoplankton diversity. In a numerical experiment, rates of productivity were calculated for a series of model runs that included monocultures or polycultures of individuals drawn from the top 10 phytoplankton that emerged from a complete model run (n=78 phytoplankton). We find that modeled annual average production is maximized for 4 organisms and will discuss ecological mechanisms that structure the modeled phytoplankton community.

4[40] *Modeling the interaction of different forms of nitrogen, freshwater flow and phytoplankton growth to predict estuarine blooms*

Dick Dugdale (Romberg Tiburon Center, San Francisco State University)

Phytoplankton blooms occurred regularly in spring in northern San Francisco estuary (SFE) but are rare now, in spite of high inorganic nutrient concentrations delivered to the Bay by the Sacramento River. A necessary condition for chlorophyll blooms to occur in northern San Francisco estuary is for phytoplankton uptake of nitrate since it is the largest pool of dissolved inorganic nitrogen. However, anthropogenic ammonium from wastewater treatment plants are hypothesized to prevent access by phytoplankton to nitrate. In addition river flow conditions are important since high flow will dilute the ammonium concentrations enabling blooms but too much flow will reduce residence time and cause phytoplankton washout. To be able to predict the possibility of spring blooms, a simple STELLA model was designed to incorporate the ammonium/nitrate interactions, flow and the available irradiance. The model reproduces the conditions well with two phytoplankton states- one with high productivity (based on nitrate use,

with low ammonium and relatively high flow conditions) and the other low productivity based entirely on ammonium uptake when there is low flow. Using this simple model to better define the N to P pathway in more complex ecosystem models of the SFE is the next step.

5^{00} *Model robustness in estimating larval transport and connectivity in the coastal ocean*

Rachel D. Simons (UC Santa Barbara), David A. Siegel (UCSB), and Kevin Brown (UCSB)

Biophysical models, consisting of ocean circulation models combined with Lagrangian particle tracking, are now widely used for estimating larval transport and connectivity in the coastal ocean. These models, also called individually based models (IBMs), provide new insights into the dynamics of larval connectivity that could not be obtained using empirical methods. This study quantifies how sensitive estimates of larval transport and connectivity are to certain parameters that must be selected prior to the use of all biophysical models. These parameters include the number of particles released, release depth, and advection time. For our study site of the Southern California Bight (SCB), we use a biophysical model of three-dimensional Regional Ocean Modeling System (ROMS) solutions in combination with a particle-tracking model. We quantify the particle distribution after release using a two-dimensional density distribution (DD). The DD is produced for a specified time by summing the number of particles in each cell of the model grid and then dividing by the total number of particles released. Particles are released from 12 nearshore sites throughout the SCB over a range of months and years. The area of each site is approximately 10 km2. DDs are created for the particles released from one site over one month. To test how sensitive the DDs are to a parameter, a series of DDs are produced while systematically changing the value of the parameter. The DDs are then statistically compared to each other using the coefficient of determination (r^2). We found that too few particles released or particles released from different depths can significantly changed spatial patterns of the DDs. We found that to achieve DD robustness, defined as a 95% confidence level that the number of particles are not influencing the DD pattern, a minimum number of particles was required and that this threshold was consistent across all sites, months, and years, but varied depending on how long the particles' were advected. Below this threshold, differences in DDs increased rapidly as the number of particles decreased. When DDs were created by releasing particles from different depths (one release depth per DD), differences between DDs grew steadily as the particles were released farther and farther apart. Averaged over all sites, years, and months, differences in DDs grew by approximately 3% per meter for each meter apart the particles were released.

5^{20} *An ecosystem perspective for quantifying the dynamics of juvenile Chinook salmon (Oncorhynchus tshawytscha) and prey in the central California coastal region*

Brian Wells (NOAA SWFSC), Jarrod A. Santora (Farallon Institute for Advanced Ecosystem Research), John C. Field (NOAA SWFSC), R. Bruce MacFarlane (NOAA SWFSC), Baldo B. Marinovic (UC Santa Cruz), and William J. Sydeman (Farallon Institute for Advanced Ecosystem Research)

We examine physical and biological features in and around the Gulf of the Farallones to understand the dynamics affecting condition and survival of juvenile central California Chinook salmon (*Oncorhynchus tshawytscha*). Specifically, we tested the hypothesis that the interannual variability of abundance and spatial organization fish, crab and krill prey, are related to the development and production of Chinook salmon. When the thermocline was 25m or less, krill distributed farther south and were less abundant in the Gulf of the Farallones and thereby less available to salmon. There is a year lag in the relationship between volume of krill in the diet of juvenile salmon and abundance of krill in midwater trawl samples. Body condition of juvenile Chinook salmon relates to the spatial distribution of adult krill the year before as well as their relative contribution to the diet in the current year. Fulton's K condition (W/L3 × 105) of fish was positively related to the amount of newly recruited *Thysanoessa spinifera* in the fish's diet.

We demonstrate that minor shifts in larger adult *T. spinifera* distribution can dramatically affect the likelihood that fish entering the ocean the next year will survive to maturation. Specifically, juvenile salmon condition and later adult abundance was dependent on habitat and prey resources in the region of the Farallon Islands the year before juveniles went to sea. Such information may be used to improve forecast models as well as adapt escapement goals in season.

5[40] *A multivariate EOF analysis of modeled vs. observed modes of biophysical variability on the Bering Sea shelf*

Albert J. Hermann (JISAO, UW), Kerim Aydin (Alaska Fisheries Science Center, NOAA/NMFS), Nicholas A. Bond (JISAO, UW) Wei Cheng (JISAO, UW), Enrique N. Curchitser (Rutgers Univ.), Georgina A. Gibson (Univ. of Alaska Fairbanks), Kate Hedstrom (Arctic Region Supercomputing Center), Ivonne Ortiz (Alaska Fisheries Science Center, NOAA/NMFS), Muyin Wang (JISAO, UW), Phyllis J. Stabeno (NOAA/PMEL), Lisa Eisner (Auke Bay Laboratories, NOAA), and Markus Janout (Alfred-Wegener-Institute for Polar and Marine Research)

Coupled physical/biological models can be used to downscale global climate change to the ecology of subarctic regions, and to explore the bottom-up and top-down effects of that change on the spatial structure of subarctic ecosystems - for example, the relative dominance of pelagic vs. benthic food webs in relation to ice cover. Here we utilize a multivariate statistical approach to extract the emergent properties of a coupled physical/biological simulation of the Bering Sea, and explore how these properties compare with the observed system. Specifically, we employ multivariate Empirical Orthogonal Function (EOF) analysis to derive the interannual covariance among physical and biological patterns from our simulation; these are compared with EOFs derived from spatially gridded measurements of the region, collected during the multi-year BASIS and BSIERP field programs. Ultimately this analysis helps to quantify the greater predictability of spatially and trophically averaged properties of the Bering Sea, as compared to univariate time series from a single location.

8^{30} *Modeling slope, shelf, and river plume flow interactions in the coastal ocean*

John J. Osborne (College of Oceanic and Atmospheric Sciences, Oregon State Univ.), Alexander L. Kurapov (COAS, OSU), Gary D. Egbert (COAS, OSU), and P. Michael Kosro (COAS, OSU)

A 1-km resolution coastal ocean model centered on the Oregon coast is utilized to study influences and combined effects of processes driven by winds, tides, and the Columbia River fresh water discharge. The model is based on the Regional Ocean Modeling System (ROMS), forced with realistic boundary conditions, winds, atmospheric heat flux, and 8 dominant tidal constituents (in summer 2002). An area of intensive M2 internal tide generation is found on the slope near Cape Blanco. The internal tide generated interacts with the separated jet, creating sharp frontal areas, and affecting coastal current separation. Despite diurnal tides (both K1 and O1) are generally small along the Oregon shelf, they are found to be intensified around capes, including most notably Cape Blanco (up to 20 cm/s). This model result qualitatively agrees with available ADCP data. Using a numerical tracer release, effects of intensified tides on vertical mixing, dispersion, and cross-shore transport are contrasted with a model solution lacking tidal forcing. The effect is particularly strong during spring diurnal tide periods (when O1 and K1 tides are in phase). The solution with the Columbia River is being analyzed to see the effect of the river plume on stratification and temperature distribution in the vast area southeast of the river mouth, as well as internal tide energetics on the mid-Oregon shelf.

8^{50} *Freshwater inputs and coastal productivity in the Pacific Northwest*

Kristen Davis (Applied Physics Laboratory, UW), Neil Banas (APL, UW)
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The coastal ocean plays a key role in global biogeochemical cycles. In the Pacific Northwest, the coastal waters are strongly influenced by freshwater inputs from the Strait of Juan de Fuca (fed by the Fraser River and the rivers of Puget Sound) and the Columbia River. These rivers act as a conduit for land-derived nutrients and as a facilitator for entraining ocean-derived nutrients into the coastal euphotic zone. Riverine delivery of nutrients to the coastal ocean may play an important role in winter and spring phytoplankton blooms along the Washington and Oregon coasts. In the Strait of Juan de Fuca, freshwater flow influences estuarine exchange, where deep, high-nutrient waters are upwelled from a submarine canyon and entrained into surface waters. Additionally, the Columbia River plume modifies flow on the shelf and can play a significant role in the retention and transport of phytoplankton communities along the coast. Here, we present results from a four-box (NPZD) model of planktonic nutrient cycling coupled to a high-resolution circulation model of the Washington and Oregon coasts developed as part of the PNWTOX (Pacific Northwest Toxins) Project. Specifically, we consider a numerical simulation of the year 2005 forced with realistic bathymetry, tides, and climatology with a special model case in which we turn off the Columbia, Fraser, and Puget Sound rivers to examine the role of freshwater inputs on regional patterns of phytoplankton biomass and productivity. Results from the biophysical model are also compared to physical, chemical, and biological data from two recently completed observational studies – The Ecology and Oceanography of Harmful Algal Blooms in the Pacific Northwest (ECOHAB) and River Influences on Shelf Ecosystems (RISE).

9[10] *Effect of coastal ocean on suspended particle dynamics in a southern California urban estuary during the dry season*

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Physical (tides) end biological (phytoplankton) effect of coastal ocean on suspended particle dynamics in the Ballona Creek Estuary in southern California was demonstrated on the basis of the data collected by a laser scatterometer LISST-100X, throughout the summer of 2008. The bio-fouling observed between instrument servicing were approximated by logistic equation and removed from the raw data. The detrended data matrix on particle size distribution was transformed using Principal Component Analysis (PCA) multivariate statistics. The three leading PCA modes (>92% of total variability) were attributed to different particle size classes: mid-size (71%), small-size (14%), and large-size (7%). Domination of mid-size suspended sediments (TSM) was associated with high phytoplankton biomass in the coastal ocean waters, based on correlation between the first PCA mode and remotely-sensed chlorophyll a concentrations in Santa Monica Bay and diurnal (i.e., associated with phytoplankton growth) variability. Small- and large-size sediments (second and third PCA modes) were dominated by semi-diurnal variability, indicating the role of tidal circulation in forcing horizontal transport and resuspension. The relationship between tides and small- and large-particle TSM was non-linear, indicating high spatial heterogeneity of these particles. The extremes of both small and large-particle TSM were observed during spring ebb tides transporting down-estuary low concentrations of small-size particles and high concentrations of large-size particles.

9[30] *Excessive silicic acid supply leads to increased silicification in coastal diatoms*

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Diatoms dominate primary production in coastal areas. Along the coast of Washington and Oregon, diatom growth is typically limited by nitrate because excess silicic acid is supplied by the Columbia River and upwelled deep water. Although silicic acid concentrations do not control community growth rate, silicic acid concentrations may affect cellular silica content, because diatoms have flexible silicic acid requirements. In this way, variable silicic acid concentrations supplied by the Columbia River could alter community silicification and thus the efficiency of particle export out of the surface. A total of four on-deck incubation experiments were conducted at locations spanning the Washington and Oregon coast in 2009 and 2010. Chlorophyll a concentrations increased equally in seawater amended with nitrate or both silicic acid and nitrate compared to an unamended control. However, biogenic silica concentrations were higher in the bottles amended with both silicic acid and nitrate. To determine whether the observed increase in community silica content was caused increases in the silica content of individual species, three diatom isolates were grown in controlled laboratory conditions that simulated typical coastal nutrient concentrations. All three isolates increased their silica per cell as silicic acid concentrations increased while nitrogen concentrations remained constant. When grown together, biogenic silica also increased with increasing silicic acid concentrations and no major shifts in species composition were observed. These results suggest that the supply of silicic acid to diatom communities controls their cellular silica content, which may influence how efficiently diatom biomass is exported to the deep ocean.

9[50] *Using Lagrangian particle tracking to quantify ocean/estuary exchange rate*

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Lagrangian methods in estuarine physics research are important because they link water mass transport pathways (and materials contained in water parcels), important to estuarine and coastal ecology and water quality, to the underlying dynamics that drives the time dependent circulation in estuaries. Here we use Lagrangian particle tracking methods in numerical simulations of Yaquina Bay estuary to quantify exchange between the estuary and the coastal ocean and its dependence on forcing, such as river discharge, which varies by more than two orders of magnitude on seasonal and storm event time scales. Exchange rate calculated by this method is compared rates based on salt flux estimates (e.g., as estimated from the Total Exchange Flow, TEF, formulation). Transport pathways of water parcels originating from the ocean are also studied and locations where significant water mass transformations occur, through turbulent salt fluxes, are quantified.