[1]Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, 205 N. Mathews Ave., Urbana, IL 61801, United States

[2]Center for Aquatic Ecology, Illinois Natural History Survey, 704 N. Schrader, Havana, IL 62644, United States

[3]Department of Ecology and Evolution, State University of New York at Stony Brook, Stony Brook, NY 11794, United States

[4]Department of Urban and Regional Planning, University of Illinois at Urbana-Champaign, 607 E. Peabody Dr., Champaign, IL 61820, United States

[5]Illinois Water Resources Center, University of Illinois at Urbana-Champaign, Urbana, IL 61801, United States

Predicting the spread and establishment of zebra mussel populations in rivers requires an understanding of both the biological processes and the physical transport. We developed a model for the Illinois River that combines the hydrodynamics with the biology of the zebra mussel. Growth, mortality, and settlement rates are taken from field observations. Advection and longitudinal dispersion are estimated from dye studies conducted by the U. S. Geological Survey, while the trapping effect of dead zones is represented with a simple exchange model. For various river discharges and larval cohort properties the combined model predicts settlement patterns, including the location, spread, peak abundance, and population size. Implications for control of the zebra mussel in rivers with dispersal barriers will also be discussed.

URL: http://www.staff.uiuc.edu/∼rehmann

### OS41K-06 1035h

### The Dynamic Response of the Large Intertidal Bull Kelp *Durvillaea antarctica* (Chamisso) Heriot to waves and the tide.

Catriona L Hurd[1] (64 03 479 7571; hurd@planta.otago.ac.nz)

Craig L Stevens[2] (64 04 386 0300; c.stevens@niwa.cri.nz)

Murray J Smith[2] (m.smith@niwa.cri.nz)

Deane Harder[1] (deane@gmx.de)

[1]Botany Department, University of Otago, PO Box 56, Dunedin 9001, New Zealand

[2]National Institute for Water and Atmospheric Research , Greta Point, PO Box 14-901 Kilbirnie, Wellington 6003, New Zealand

Seaweed habitats and morphological development are strongly affected by wave forces. Novel measurements were made of the force dynamics of the large intertidal macroalga *Durvillaea antarctica* under the influence of wave action. Synchronized video, a pressure sensor and a resistance wave gauge provided data describing the wave field. The response of seaweed to waves was gauged using instrumentation mounted directly on the seaweed, including accelerometers and displacement and force transducers. These field measurements were used to estimate forces and bending moments acting at the holdfast, where failure is most likely to occur. For waves of the order of 0.5 m high, we measured maximum forces on the stipe of around 300 N and blade accelerations that exceeded 30 m $s^{-2}$. During large wave events, inferred bending moments at the base of the stipe reached average values of around 140 N $m^{-1}$. There was a decoupling between the blade response and the force experienced at the stipe base. Furthermore, changes in water depth throughout the tidal cycle had a systematic effect on blade accelerations and moments at the holdfast.

### OS41K-07 1050h

### Hydrodynamics and foraging in streams: substrate effects on behavioral decisions

Paul A. Moore[1,2] (pmoore@bgnet.bgsu.edu)

[1]Laboratory for Sensory Ecology, Department of Biological Sciences Bowling Green State University, Bowling Green, OH 43403, United States

[2]J.P. Scott Center for Neuroscience, Mind Behavior, Bowling Green State University, Bowling Green, OH 43403, United States

Many animals use chemical signals to acquire information about habitats. Each habitat has a unique hydrodynamic environment that is dependent upon the structure of that habitat. Differences in the hydrodynamics (i.e. turbulence) of an environment will be reflected in the fine-scale structure of chemical signals. The structure of this information is dependent upon specific features within a habitat, and the information in signals can be habitat specific. We quantified the spatial and temporal information in an aquatic odor plume in three different artificial stream habitats with different substrate types by measuring turbulent odor plumes with an electrochemical detection system and the orientation behavior of the crayfish, Orconectes rusticus. Our results imply that the information obtained from chemical signals may be limited in some habitats. These constraints on information may affect how organisms perform chemically mediated behaviors. A detailed analysis of orientation behavior supports the theory that crayfish orient differently to food sources in streams with different substrates. These results show that the hydrodynamics associated with chemical signal structure can greatly influence the temporal properties of orientation to food sources.

### OS41K-08 1105h

### Force Production During Pereiopod Power Strokes in Calanus finmarchicus

Petra H Lenz[1] (1 808 956 8003; petra@pbrc.hawaii.edu)

Daniel K Hartline[1] (1 808 956 8003; danh@pbrc.hawaii.edu)

Amy E Hower[1]

[1]Pacific Biomedical Research Center, University of Hawaii Manoa , 1993 East-West Rd., Honolulu, HI 96822, United States

To achieve the dramatic escape speeds of 300 to 1000 body lengths per second, copepods generate one of the higher rates of muscular energy output in the animal kingdom. We investigated the details of this behavior in tethered *Calanus finmarchicus*. Pereiopod movements during the power strokes were monitored using high-speed video, while simultaneously measuring force production. At 8 to 9 °C, the power strokes for each pair of pereiopods registered as a separate force peaks, with the greatest force being produced by the 4th and 3rd pair. Within 3.5 ms of initiation of the power stroke of the 4th pereiopod pair, the copepods generated forces of 50 to 60 dynes. The power and return strokes of the 4 pairs of pereiopods were completed within 10 to 11 ms. At 14 to 15 °C, forces of 100 dynes were produced and the entire sequence of pereiopod power strokes was shortened by ca. 3 ms. During the power strokes, force production was maximized by the large surface area produced by the extension of the segments and setae of the pereiopods. During the return stroke, the pereiopods and the setae collapsed minimizing surface area thus generating only a weak reverse force.

### OS41K-09 1120h

### The Relationship Between Boundary Layers and Morphology: How Blade Morphology in the Kelp *Eisenia arborea* Modulates Nutrient Flux

Loretta M. Roberson (831-655-6208; loretta@stanford.edu)

Stanford Univeristy, Hopkins Marine Station, Pacific Grove, CA 93950, United States

The kelp *Eisenia arborea* displays two widely different morphologies that are correlated with the local flow environment: in high flow ($>$ 10 cm/s) areas, blades are narrow and flat; in low flow ($<$ 2 cm/s) areas, blades are wide and bullate. It has been suggested that these morphological differences are adaptations to water flow around the blades; bumps in the bullate morph could generate turbulence under low flow conditions when nutrients may be limiting, thereby enhancing mixing at the blade surface, as well as growth and survivorship. To determine if bullate blades showed enhanced transport of nutrients relative to flat blades due to the increased roughness of the surface, boundary-layer water velocities and estimates of nutrient transport rates were measured and calculated for the bullate and flat morphs of *Eisenia*. Using a variety of techniques from dye retention on the blade surface to acoustic Doppler velocimetry, it was found that boundary layer velocities varied substantially between the bullate and flat morphologies, with higher levels of turbulence and transport over the bullate blades than over the flat. These differences in transport coincide with differences in growth rates of transplants in the field, indicating that small-scale differences in water motion could have a large impact on the ecology and evolution of kelps as well as other marine organisms.

### OS41K-10 1135h

### Hydrodynamic consequences of buoyancy and flexural stiffness in benthic algae

Hannah L Stewart ((510) 643-9048; hstewart@socrates.berkeley.edu)

Hannah L. Stewart, University of California, Berkeley, CA 94720, United States

Benthic organisms can maintain upright postures by having high flexural stiffness (EI) or by being buoyant. An upright position in the water column can increase mass transfer and light interception but may also expose sessile organisms to greater hydrodynamic forces. This study compared how buoyancy and EI affect hydrodynamic forces and flow velocity at the surface of the tropical alga *Turbinaria ornata*. Thalli of *T. ornata* from wave-exposed fore reef environments (FR) lack air bladders and are negatively buoyant, but have higher flexural stiffness than *T. ornata* from calm lagoon environments (LG). LG algae have air bladders that produce buoyant forces of ∼0.27 N/thallus. Simultaneous measurements of water velocity, horizontal force and algal motion were recorded for pairs of thalli positioned side by side in the field at a site exposed to moderate wave action. For these experiments LG algae were cut to the same length as FR algae to remove the effect of size. To compare thalli held upright by EI to those held upright by buoyancy, LG algae with air bladders were run simultaneously with FR algae. Stiff FR algae did not experience substantial deflection of the thallus therefore water velocities relative to their surfaces were higher than on more flexible LG algae, which moved with the flow. Mean peak hydrodynamic forces on FR algae were 3x higher than on LG algae. To test the effect of EI alone, LG algae that had the air in their bladders replaced with water were run with FR algae. FR algae experienced mean peak horizontal forces slightly higher than LG algae with filled bladders. The buoyancy of LG algae reduced horizontal force by adding an upward component to the total force, producing a net resultant force vector at an intermediate angle. Although the horizontal forces on buoyant LG algae thalli were substantially lower than on FR thalli, the net resultant forces on LR algae due to buoyancy and hydrodynamic force were not significantly different than horizontal forces on FR thalli. Thus, while hydrodynamic forces are greater on stiff algae that do not move with ambient flow, net resultant force on more flexible thalli due to buoyancy and hydrodynamic loads can be similar.

## OS41L HC: 316 A Thursday 0830h

### Physical, Chemical, and Biological Processes Associated With Active Submarine Volcanism in the Pacific III

*Presiding:* **D Butterfield,** JISAO/U. Washington/PMEL/NOAA**; W Chadwick,** CIMRS/Oregon St. U./PMEL/NOAA

THU

### OS41L-01 0835h

### NeMO: A Long-term Study Site on Axial Volcano on the Juan de Fuca Ridge

Robert W Embley (541-867-0275; embley@pmel.noaa.gov)

NOAA/PMEL, Hatfield Marine Science Center, 2115 SE OSU Drive, Newport, OR 97365, United States

The eruption of Axial Volcano on the Juan de Fuca Ridge in 1998 came at an opportune time following an increased level of seafloor investigations and monitoring at the site that marked the beginning of the NeMO (New Millennium Observatory) program. An earlier exploratory phase of investigation in the 1980s included multibeam, sidescan and deep-towed camera surveys as well as numerous geologic, chemical and biologic samples taken during Alvin and Pisces IV dives. These baseline maps and samples provide data on the geologic, chemical and biologic systems within and near the summit of the volcano prior to the eruption. Seafloor pressure gauges, acoustic range meters and water column temperature arrays that had been placed there the year before monitored the 1998 dike injection and eruption. These instruments recorded intriguing data on the deformation and thermal effects of the eruption. Since the 1998 event, four expeditions have returned to the summit area to collect samples for chemical and biological time-series studies, recover and deploy monitoring instruments, and conduct detailed mapping of the eruptive centers and major hydrothermal sites. These studies have begun to yield a better understanding of the geologic controls on the locations of hydrothermal systems and a more comprehensive view of the short-term behavior of an active submarine volcano system. The hydrothermal systems on the summit of Axial appear to be controlled by one of two mechanisms. First, longer-lived vents containing high temperature chimneys and mature diffuse venting sites are located near faults along the caldera rim, particularly where rift zones intersect the rim. For example, several newly discovered vents at the southern end of the caldera appear to be associated with a buried

portion of the caldera rim. A second style of venting is apparently associated with individual dike intrusions along the rift zones. For example, many of the vents found at the eruption site in the southeast corner of the caldera after the event in 1998 have already ceased venting. Also, venting with similar character was observed by deep-tow photography and submersible dives in the southeast caldera in the 1980s. The 1998 lava flows are chemically indistinguishable from adjacent lavas and have become increasingly difficult to distinguish by physical character because of the many young lava flows in the caldera. These data and observations suggest that Axial Volcano is currently in an active phase and may have magmatic events on a decadal timescale. Monitoring should continue to yield rich data sets to study the behavior of submarine volcanoes.

**OS41L-02 0850h**

### Emplacement processes of two 1998 lava flows with contrasting morphology, inferred from high-resolution bathymetry and bottom observations at Axial Seamount, Juan de Fuca Ridge

William W Chadwick[1] (541-867-0179; chadwick@pmel.noaa.gov)

Robert W Embley[2] (541-867-0275; embley@pmel.noaa.gov)

Susan G Merle[1] (541-867-0173; merle@pmel.noaa.gov)

[1]Oregon State University/NOAA, Hatfield Marine Science Center, 2115 SE OSU Drive, Newport, OR 97365, United States

[2]NOAA/PMEL, Hatfield Marine Science Center, 2115 SE OSU Drive, Newport, OR 97365, United States

In 1998, Axial Seamount (an active volcano on the Juan de Fuca Ridge and the location of the NeMO seafloor observatory) erupted two lava flows along 9 km of its upper south rift zone. Both lava flows have the same composition and have comparable volumes (about 7 million cubic meters), but they have distinctly different lava morphologies which reflect their different emplacement histories. High-resolution bathymetric maps from scanning sonar data and bottom observations made from a remotely operated vehicle show the following differences. The northern of the two lava flows was erupted in the SE part of the summit caldera on gentle slopes and has a sheet morphology with extensive areas of collapse in its interior. The northern flow is 5.5 km long, 500 m wide, and less than 5 m thick in most places, reflecting brief but intense lava effusion along a long (2-3 km) eruptive fissure. Data from an instrument that was caught in the northern lava flow during the eruption show that the flow rapidly inflated and then drained out within a time span of only 2 hours. In contrast, the southern lava flow (located 5 km south of the caldera) has mainly a pillow morphology, probably reflecting a slower effusion rate and a longer eruption duration. Nevertheless, the southern flow has isolated pits and troughs of collapse terrain, showing that locally fluid lava ponded and drained out, mainly near the eruptive fissure. The southern lava flow is wider across-axis than along-axis. It was erupted from a 1.4 km long fissure, but most of the flow volume came out of the middle 500 m of the fissure. After lava emerged from the crest of the rift zone it flowed up to 1 km down the steep east flank of the ridge where it accumulated to a thickness of up to 26 m. The larger average thickness of the southern pillow flow allows it to have about the same volume as the northern flow, even though the southern flow is about 3 times smaller in area. Where the eruptive fissure is visible at the southern edge of the flow it is about1.5 m wide, which represents the amount of seafloor spreading during this event. The contrasting morphology of the two lava flows erupted in 1998 at Axial Volcano is due to differences in local eruption conditions. The northern sheet flow was produced during a brief outburst along a relatively long eruptive fissure with a very high effusion rate delivering lava onto flat terrain, whereas the southern pillow flow formed by a more prolonged output at a lower effusion rate from a more centralized eruptive vent at the crest of a steep-sided ridge.

**OS41L-03 0905h**

### Mixing, Reaction and Microbial Activity in Sub-seafloor Hydrothermal Upflow Zones: Evidence From Diffuse Flow Outcrops Across the 1998 Axial Volcano Sea-floor Eruption Area

David A Butterfield[1] (206-526-6722; butterfield@pmel.noaa.gov); Kevin K Roe[1] (roe@pmel.noaa.gov); Marvin D Lilley[2] (lilley@ocean.washington.edu); John A Baross[2] (jbaross@u.washington.edu); Julie A Huber[2] (huberja@ocean.washington.edu); Robert W Embley[3] (embley@pmel.noaa.gov)

[1]Joint Institute for the Study of the Atmosphere and Oceans, University of Washington NOAA Pacific Marine Env. Lab 7600 Sand Point Way NE, Seattle, WA 98115, United States

[2]University of Washington, School of Oceanography Box 357940, Seattle, WA 98195, United States

[3]National Oceanic Atmospheric Administration, Pacific Marine Environmental Laboratory 2115 OSU Drive, Newport, OR 97365, United States

In order to understand the impact of diffuse venting on chemical fluxes, plume composition, and microbial activity, we have conducted systematic hydrothermal fluid and particle sampling and analysis of a range of seafloor vents on or near the January, 1998, lava flow at the summit of Axial Volcano on the Juan de Fuca ridge. The location of diffuse vents near the summit of Axial Volcano appears to be controlled by diking and the major structural features of the volcano, the caldera boundary fault and the rift zones. The systematics of the chemical composition indicate that diffuse fluids at Axial Volcano and elsewhere have a high-temperature ($> 350^{\circ}$C) reaction-zone component and a lower-temperature, presumably shallow reaction-zone component. There is evidence that hot reaction zone fluids mix with lower-temperature reaction zone fluids in the upflow zone, leading to variations in fluid chemistry with temperature that can't be explained by mixing a single end-member with ambient seawater. The low-temperature reactions inferred to take place include production of methane and particulate elemental sulfur, removal of hydrogen sulfide and metals, and rock hydrolysis resulting in increased alkalinity. High concentrations of $CO_2$ from magmatic degassing may be important in promoting low-temperature hydrolysis reactions. Methane production, culturable hyperthermophiles, non-oceanic phylogenetic signatures, and increasing cell counts in low-temperature fluids indicate microbial activity below the seafloor. The chemical signals found in hydrothermal plumes following seafloor volcanic eruptions are distinct from the plumes found above non-eruptive hydrothermal systems. Low-temperature ($< 100^{\circ}$C) diffuse venting is widespread following volcanic eruptions. There is a class of low-temperature ($< 25^{\circ}$C) fluids with high Fe/Mn and Fe/heat ratios and low $H_2S$/Fe that have been poorly sampled in the past, but may contribute substantially to post-eruptive water column plumes, including hydrothermal "event" plumes.

**OS41L-04 0920h**

### A 15-Year Time Series of Vent Fluid Gas Chemistry at Axial Seamount, Juan de Fuca Ridge

John Lupton[1] (541-867-0198; lupton@pmel.noaa.gov)

Marv Lilley[2] (206-543-0859; lilley@ocean.washington.edu)

David Butterfield[3] (206-526-6722; butterfield@pmel.noaa.gov)

Robert Embley[1] (541-867-0275; embley@pmel.noaa.gov)

Leigh Evans[1]

[1]NOAA Pacific Marine Environmental Laboratory, Hatfield Marine Science Center, Newport, OR 97365, United States

[2]School of Oceanography, University of Washington, Seattle, WA 98195, United States

[3]NOAA Pacific Marine Environmental Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115, United States

In 1985, hydrothermal venting on Axial Seamount was discovered and sampled for the first time at the CASM site at the northern end of the caldera [CASM, Nature 313, 212-214, 1985], and in the following year the much larger Ashes hydrothermal field was discovered and sampled in the southwestern part of the caldera [ASHES Expedition, EOS 67(44), 1027, 1986]. Since it was first sampled in 1986, the Ashes field has been visited and sampled 7 additional times (in 1987, 1988, 1995, 1998, 1999, 2000 and 2001). The Ashes field has continued to be a focus of study the fluids exhibit wide diversity in their chemical and physical characteristics, in part due to the phase-separation occurring in the subsurface [Massoth et al., 1989; Butterfield et al., 1990]. Following the 1998 volcanic eruption within the Axial Seamount caldera [Embley et al., 1999], a new hydrothermal vent field was discovered and sampled in the southeastern portion of the caldera. As the study of hydrothermal systems has progressed, it has become apparent that the Axial Seamount vents are among the most gas-rich hydrothermal systems found anywhere in the world ocean. For example, the fluids issuing from Virgin Mound vent in the Ashes field have 285 mM/kg of $CO_2$ and 11 $\mu$M/kg of helium, an order of magnitude higher than typical MOR hydrothermal fluids which contain $<$20 mM/kg $CO_2$ and $<$1 $\mu$M/kg helium. The vents in the southeastern caldera have similar elevated $CO_2$ and helium concentrations. Although hydrothermal venting has been studied on large portions of the mid-ocean ridge system, the only sites with magmatic gas concentrations comparable to Axial Seamount are the 9$^{\circ}$N region of the EPR, Loihi Seamount on the southeastern flank of Hawaii, and a newly-discovered site at 32$^{\circ}$S on the EPR.

**OS41L-05 0935h**

### Temporal Changes in Microbial Diversity and Chemistry at a Diffuse Flow Vent on Axial Volcano, Juan de Fuca Ridge

Julie A Huber[1] (206-543-4911; huberja@ocean.washington.edu)

David A Butterfield[2] (butterfield@pmel.noaa.gov)

John A Baross[1] (jbaross@u.washington.edu)

[1]School of Oceanography, University of Washington Box 357940, Seattle, WA 98195, United States

[2]Joint Institute for the Study of Atmosphere and Ocean, University of Washington, Seattle, WA 98195, United States

The temporal variation in archaeal and bacterial diversity in vent fluids from a mid-ocean ridge subseafloor habitat in the Northeast Pacific was examined using PCR-amplified 16S rRNA gene sequence analysis and Most Probable Number (MPN) cultivation techniques. We performed molecular phylogenetic and chemical analyses on diffuse flow vent fluids from one site at Axial Volcano shortly after the 1998 eruption and again in 1999 and 2000. The microbial population was divided into particle-attached (greater than 3 $\mu$m) and free-living fractions to test the hypothesis that subseafloor microorganisms are adapted for a lifestyle that involves attachment to solid surfaces and biofilm formation. A background seawater sample was also examined to delineate between entrained seawater microbes and the indigenous subseafloor microbial community. The indigenous subseafloor archaeal community consisted of Methanococcales including sequences that closely resembled hyperthermophilic species as well as many uncultured Euryarchaeota some of which have been identified in other vent environments. The bacterial subseafloor community included high temperature members, mesophilic sulfide and methane oxidizers, and many uncultured Epsilon-Proteobacteria similar to those found at other hydrothermal vents. MPNs and counts indicate that while culturable hyperthermophiles represent less than 1 percent of the total microbial community, the subseafloor at new eruption sites supports a hyperthermophilic microbial community. There has been a gradual shift away from a vapor-dominated fluid, characterized by an increase in chlorinity, and a decrease in the hydrogen sulfide content and the overall heat and fluid flux over the period of our observations. These changes are consistent with post-eruptive fluid evolution models. A preliminary model is presented that relates microbial diversity to temperature, chemical characteristics of diffuse flow fluids and the degree of mixing with seawater.

**OS41L-06 0950h**

### Bacterial Community Structure and Phylogenetic Diversity of Hydrothermal Vents at Axial Volcano, Juan de Fuca Ridge

Craig L Moyer[1] (360-650-7935; cmoyer@hydro.biol.wwu.edu)

Karen S Lynch[1] (KLynch@ICOS.com)

[1]Western Washington University, Biology Department, MS 9160, Bellingham, WA 98225, United States

The community structure and phylogenetic diversity of bacterial communities were determined from four hydrothermal vent sites at Axial Volcano, Juan de Fuca Ridge. Genomic DNA was extracted from sampled microbial communities and amplified using SSU rDNA primers specific to the domain Bacteria. PCR products were then used to generate clone libraries from each

sample. Amplified ribosomal DNA restriction analysis or ARDRA was performed on individual SSU rDNA clones to determine the dominant operational taxonomic units (OTUs). Fifteen bacterial OTUs were identified from the 249 clones screened. Overall, organismal diversity in all samples examined was relatively high as determined by rarefaction. Phylogenetic analyses were performed to determine the genetic relatedness of the representative phylotypes. Three of the sample sites were located in the caldera's recent 1998 lava flow (Marker 33 Vent, Snow Blower and Easy Vent), while the other site (North Rift) was on an old lava flow north of the caldera. Marker 33 Vent microbial mats were dominated by members of the epsilon-Proteobacteria (17.2%) and delta-Proteobacteria (8.6%). The flocejecta collected from the Snow Blower Vent contained representatives from the epsilon-Proteobacteria (25.1%) and Green Non-Sulfur Bacteria (12.5%), possibly originating from the deep subsurface. The Easy Vent bacterial mat community was dominated by members of the epsilon-Proteobacteria (14.3%) and gamma-Proteobacteria (5.4%). The distal microbial mat from North Rift was dominated by members of the Flexibacter-Cytophaga-Bacteroides division (43%), possibly representing additional trophic level interactions. Six bacterial OTUs were detected two or more times among multiple new lava vent sites and were exclusive to OTUs detected at the older North Rift site. The organismal and phylogenetic diversity of the epsilon-Proteobacteria found among the new lava vent sites was exceptional, indicating the ecology of these microorganisms plays a significant role at hydrothermal vents especially after recent eruptive events.

### OS41L-07 1025h

## Hydrothermal Assemblages on the Southern Portion of the Juan de Fuca Ridge: Axial Seamount, North Cleft, and CoAxial Vent Communities

Maia Tsurumi[1] (1-250-721-8858; mtsurumi@uvic.ca)

Verena Tunnicliffe[1] (1-250-721-7135; verenat@uvic.ca)

[1]Department of Biology, University of Victoria, P.O. Box 3020, Victoria, BC V8W 3N5, Canada

The environmental conditions of a vent field or ridge segment are often attributed to physical features such as the shape and size of the underlying magma chamber, spreading rates, axis-depth, and source rock composition. Independent geophysical activity and structure of ridge segments lead to the expectation of chemical and thus biological differences among vent communities. We test this prediction, that vent assemblages on different segments are distinguishable, with data from the southern portion of the Juan de Fuca Ridge. How does the vent community on Axial Seamount, a submarine volcano, compare to vent assemblages on other segments of the Juan de Fuca Ridge? Communities on all three segments are statistically similar. The limpet *Lepetodrilus fucensis* is the dominant species in distribution and abundance throughout the region. The most abundant species are also the most well-distributed and most species have dispersed along the 150 km area of the study. While no spatial differences among communities are found, there is temporal separation of samples. Senescent assemblages can be distinguished from active vent assemblages. Senescent samples are lower in density, more variable in species composition, have higher species richness, contain more obligate vent species, and are more even in rank-abundance. As for active vent samples, *Lepetodrilus fucensis* is the dominant species.

### OS41L-08 1040h

## Species Patterns of Established and Post-eruption Vent Assemblages on Axial Volcano, Juan de Fuca Ridge

Jean Elisabeth Marcus (1-250-721-8858; jmarcus@uvic.ca)

University of Victoria, Department of Biology, University of Victoria PO BOX 3020, STN CSC, Victoria, BC V8W 3N5, Canada

Community ecology of vents on Axial Volcano, Juan de Fuca Ridge is discussed with respect to: 1) species associations of mature tubeworm bush assemblages; and 2) post-eruptive temporal change in community structure.

Species occurrences from 16 diffuse vents were evaluated with a null model analysis. Results indicate that species are distributed over sites non-randomly, and that some species pairs co-occur more or less than expected by chance. This analysis implies that our sampling methods are able to detect pattern with a robust statistical test, and that mature tubeworm bush assemblages at Axial are structured.

In this context, the Axial Volcano eruption of January 1998 is discussed. Established animal communities were destroyed by the lava flow and new vents were created. Vent assemblages were sampled in the summers of 1998, 1999 and 2000. Preliminary analyses of the post-eruption data reveal several interesting trends. First, fauna quickly colonized new vents: of the 55 species known from Axial, 27 (49%) had reached the new vents by 7 months and 42 (76%) by 18 months. Second, initial colonization was spatially variable. Some vents were dominated by the tubeworm Ridgeia piscesae, others by polychaetes and one vent by snails. Causes of this variability are unknown. Possible factors include vent differences in temperature, chemistry, area, distance to source populations, and chance recruitment events. Third, the limpet Lepetodrilus fucensis, present at most vents in low numbers in 1998 and 1999, dramatically increased its abundance at all vents from 1999 to 2000. Last, although initial differences between vents seem to influence assemblage structure in the following year, most assemblages by 30 months post-eruption group with mature vents sampled on pre-eruption lava (cluster analysis). The post-eruption data, along with the null model analysis of fauna from mature vents, suggests that Axial Volcano vent assemblages are structured in part by non-random forces.

### OS41L-09 1055h

## Evidence for Autotrophic Ammonia Oxidation in Hydrothermal Vents Environments: the Use of Molecular Biological Approaches

Phyllis Lam[1] (808-956-7816; plam@soest.hawaii.edu)

James P. Cowen[1] (808-956-7124; jcowen@soest.hawaii.edu)

Andreas Teske[2] (508-289-2305; ateske@whoi.edu)

Ronald Jones[3] (305-348-6472; serc@fiu.edu)

[1]Department of Oceanography, University of Hawaii at Manoa, 1000 Pope Road, Honolulu, HI 96822, United States

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

[3]Southeast Environmental Research Center, Florida International University, University Park, OE 148, Miami, FL 33199, United States

Populations of autotrophic ammonia-oxidizing bacteria were detected in the hydrothermal vents environment using molecular biological techniques. In spite of the abundance of ammonium in the hydrothermal fluids of sedimented and certain sediment-scarce mid-ocean ridges, it has rarely been examined as an energy-yielding substrate for autotrophic organic carbon production in the vent environment. The fact that autotrophic ammonia-oxidizers cluster into two monophyletic groups within *Proteobacteria* on the phylogenetic tree emphasizes the usefulness of various 16S rRNA-based techniques to hunt for these microorganisms. Fluorescence *in situ* hybridization (FISH), using fluorescently-labeled 16S rRNA-targeted oligonucleotide probes, has been employed to detect and enumerate these microbes in the neutrally buoyant plumes of Endeavour Segment, Juan de Fuca Ridge. The ammonia-oxidizers numbered $10^3$ - $10^4$ cells $ml^{-1}$ within the plume, equivalent to 1-30% of the total microbial abundance based on DAPI-stained cell counts. Their numbers were strongly and positively correlated with *specific* autotrophic ammonium removal rates (up to 1.34 $d^{-1}$), which could be translated to an organic carbon flux equal to 50-700 % of the surface-derived organic carbon that rained down to plume core depths. Other molecular tools employed include PCR-based techniques using primer pairs targeting the 16S rRNA genes as well as the functional gene *amoA*. In both cases, $\beta$-proteobacterial ammonia-oxidizers have been detected in the hydrothermal sediments of Guaymas Basin, Gulf of California. Subsequent DNA sequencing showed that most fell into the genus *Nitrosospira*. In addition, PCR with *amoA*-targeted primers have discovered sequences of $\gamma$-proteobacterial ammonia-oxidizers. The presence of these ammonia-oxidizing bacteria provides indirect evidence of autotrophic ammonia oxidation in the hydrothermal vent environments. As the first step in nitrification, not only is ammonia oxidation key to nitrogen cycling, but it also represents an autotrophic metabolic pathway that has often been understudied in the hydrothermal vent environments, and in the consideration of subseafloor biosphere.

### OS41L-10 1110h

## Hydroacoustic Detection of a Seafloor Spreading Episode at the Middle Valley Segment, Northern Juan de Fuca Ridge, September 2001

Robert P. Dziak[1] (541-867-0175; dziak@pmel.noaa.gov)

Christopher G. Fox[2] (54-867-0276; fox@pmel.noaa.gov)

[1]Oregon State University/NOAA, Hatfield Marine Science Center 2115 SE OSU Drive, Newport, OR 97365, United States

[2]NOAA/PMEL, Hatfield Marine Science Center 2115 SE OSU Drive, Newport, OR 97365, United States

On September 6, 2001 a swarm of >14,000 earthquakes began along the intersection between the northern-most segment of the Juan de Fuca Ridge (Middle Valley) and the Sovanco Fracture Zone (SFZ). The earthquakes were detected by the NOAA/PMEL T-phase Real-Time Monitoring System which reviews data from the U.S. Navy SOSUS in the North Pacific. The Middle Valley earthquake swarm lasted for ~25 days, however the vast majority of seismicity occurred within the first 12 days of the swarm. Also during the first 12 days, the earthquakes migrated 30 km southward along the eastern wall of the Middle Valley at a rate of ~0.04 m $s^{-1}$. The land seismic network operated by the Pacific Geoscience Center (Geological Survey, Canada) was able to estimate the locations and focal mechanisms of 26 of the earthquakes ($3.6 < M_L < 5.1$). The mechanisms indicate a combination of normal and strike-slip motion reflecting the complex stress field formed by the northern Juan de Fuca, SFZ, and Nootka Fault triple junction. A response effort was undertaken aboard the Canadian R/V Tully (M. Lilley, Chief Sci) and arrived onsite 25 days after initiation of activity. Although the propagation of seismicity terminated near a site with several high-temperature vents and ODP drill holes, a thorough set of CTD casts along axis of Middle Valley found no significant evidence of a hydrothermal plume. Analysis of the Middle Valley hydroacoustic data indicate that most of the characteristics of the earlier plume-producing, extrusive events were present in this episode, including a vigorous earthquake swarm (over 50 earthquakes/hr during the first day), a duration of more an 10 days, no initial mainshock, and a significant migration of earthquake locations along the rift zone. Depth estimates (rise-times), used to identify shallow (seafloor eruption) earthquakes, are not yet available. The primary hydroacoustic differences of this event are (1) no consistent background level of volcanic tremor and (2) the migration rate was 4-5 times slower than previous dike injection episodes. The geophysical differences of this event to previous eruption episodes are (1) the earthquake swarm initiated along the adjacent transform fault rather than the ridge axis, and (2) the Middle Valley rift zone is covered by a thick layer of sediment. It is anticipated that pressure sensors within the ODP drill holes (to be recovered next summer) will detect pore-fluid changes induced by the earthquake swarm.

### OS41L-11 1125h

## From Chemical Speciation to Genomic Fingerprints: Identifying the Temporal and Spatial Mechanisms Structuring Communities on the Fast-spreading East Pacific Rise

Timothy M. Shank[1] (508-289-3392; tshank@whoi.edu)

George W. Luther[2] (302-645-4208; luther@udel.edu)

[1]Biology Department Woods Hole Oceanographic Institution, MS 33 Redfield, Woods Hole, MA 02543, United States

[2]College of Marine Studies, University of Delaware, Lewes, DE 19958, United States

For the past 20 years, studies of hydrothermal vent ecosystems have sought to understand the various factors controlling the distribution of species and the forces structuring communities over a variety of temporal and spatial scales. Studies of reproduction, larval biology, dispersal, settlement, symbioses, community composition, and gene flow have been undertaken to examine how vent species colonize new habitats, maintain their populations in existing habitats, and establish and maintain their geographic ranges. However, fundamental questions remain about the specific mechanisms by which vent invertebrate species maintain their populations and geographic ranges through larval dispersal and successful colonization. To address these questions, we employed the use of a recently-deveolped in-situ real time submersible electrochemical analyzer (a solid state electrochemical voltammetric sensor designed by Analytical Instrument Systems, Inc) to characterize fluid chemstry in a variety of diffuse flow habitats along East Pacific Rise. The appreciable formation of soluble iron-sulfide (FeSaq) molecular clusters dramatically reduced the biological availability of free H2S and HS- as nutrients to vent (micro)organisms in higher-temperature, >30°C, habitats (e.g., in the non-endosymbiont-bearing host *Alvinella pompejana* tubes and near their tube openings. In contrast, in lower temperature habitats occupied by the endosymbiont hosting tubeworm, *Riftia pachyptila*, H2S is the dominant sulfide phase. The free H2S and HS- concentration in *Alvinella* habitats is similar to or lower than that measured in *Riftia* fields even though the total sulfide is significantly higher. Further significant differences in oxygen, iron

THU

and sulfur speciation strongly correlate with the distribution of specific taxa within different microhabitats. These findings suggest that the chemical composition of hydrothermal fluids may control the different patterns of colonization and distribution exhibited by symbiont and nonsymbiont-bearing invertebrates. In addition, recent results of Amplified Fragment Length Polymorphism (AFLP) genomic fingerprinting studies indicate that the genetic relationships among recent invertebrate colonizers, including closely-spaced (400 meters) and distant (3000 meters) Riftia populations are consistent with larval dispersal and habitat colonization processes that retain the genetic integrity of individual vent assemblages via the discrete transport and settlement of larval cohorts in chemically suitable microhabitats. Detailed experiments coupling in-situ time-series chemical characterization of vent habitats and fine-scale genomic fingerprinting techniques, through the use of deep-submergence assets and long-term seafloor observatories, are poised to provide novel insights into the specific mechanisms structuring mid-ocean ridge ecosystems.

### OS41L-12 1140h

### Rates of Primary Productivity by two Hydrothermal Vent Vestimentiferan Tubeworms: *Riftia pachyptila* and *Tevnia jerichonana*

Peter Riad Girguis[1] (831-775-1826; girguis@mbari.org)

James Childress[2] (805-893-3203; childres@lifesci.ucsb.edu)

[1]Peter Riad Girguis, MBARI 7700 Sandholdt Road, Moss Landing, CA 95039, United States

[2]James Childress, University of California Santa Barbara Marine Science Institute, Santa Barbara, CA 93106, United States

*Riftia pachyptila* and *Tevnia jerichonana* are hydrothermal vent vestimentiferans that thrive at diffuse flow sites along the East Pacific Rise. Both species are symbiotic with carbon-fixing autotrophic bacteria. During shipboard high-pressure respirometry experiments, individuals of both species were maintained in a range of conditions found in situ. During these experiments, primary productivity rates were calculated from the net inorganic carbon uptake rates. Both *Riftia pachyptila* and *Tevnia jerichonana* have net inorganic carbon uptake rates (hereafter referred to as "primary productivity rates") that are comparable to the highest recorded rates of bacterial, algal and plant primary productivity in marine environments. Averaged net productivity rates of *Riftia pachyptila* were also comparable to the net productivity rates of communities such as mangrove swamps and coastal upwelling zones. While net microbial primary productivity at vents has not been well assessed, it is likely that primary productivity by fast-growing vestimentiferans contributes significantly to net primary productivity at hydrothermal vent communities. The ramifications and consequences of vestimentiferan primary productivity on community development and sustenance will be discussed.

URL: http://www.petergirguis.com/

## OS41M HC: 323 C Thursday 0830h

## Biogeoinformatics: Challenges at the Intersection of Biological, Biogeochemical, and Physical Data Over Multiple Scales of Space and Time II

***Presiding:*** **K Stocks,** University of California, San Diego**; C S Jones,** University of California, Santa Barbara

### OS41M-01 0830h

### Patterns Emerging from the LOICZ Biogeochemical Budget and Typology Datasets

Dennis Swaney[1] (dps1@cornell.edu)

Steve Smith[2] (svsmith@soest.hawaii.edu)

Vilma Dupra[2] (vdupra@soest.hawaii.edu)

[1]Boyce Thompson Inst/Cornell University, Tower Rd, Ithaca, NY 14850, United States

[2]SOEST University of Hawaii, 1000 Pope Road, Honolulu, HI 96822, United States

As of November, 2001, the Land Ocean Interactions in the Coastal Zone (LOICZ) project has assembled nutrient budgets for over 170 coastal systems around the world, and, in a parallel effort, a database of over 100 global distributed environmental variables at the 1/2 degree scale. Integrating this information, diverse in both scale and data quality, has posed some formidable challenges. We discuss what we have learned so far about integration and scaling of these data in the search for global and regional patterns.

### OS41M-02 0855h

### Modeling and Model-Data Comparisons in the Monterey Bay area.

Reginaldo Durazo[1] (rdurazo@vigia.ens.uabc.mx)

Igor Shulman[2] (228-6883403; shulman@coam.usm.edu)

Jeff Paduan[3] (paduan@nps.navy.mil)

Leslie Rosenfeld[3] (lkrosenf@nps.navy.mil)

Steve Ramp[3] (sramp@nps.navy.mil)

[1]UABC-FCM, Ensenada, B.C., Mexico

[2]COMS, USM, Stennis Space Center, MS

[3]NPS, Monterey, CA

The fine-resolution numerical ocean model of the Monterey Bay Area (ICON model) has been developed under the NOPP "An Innovative Coastal-Ocean Observing Network" (ICON) project.

The ICON model's major elements are: the Princeton Ocean Model-based ICON ocean model is coupled to the larger-scale Pacific West Coast (PWC) model; the ICON model is forced with atmospheric products from coarser-resolution NOGAPS and finer-resolution COAMPS Navy atmospheric models; the ICON model assimilates HF radar-derived surface currents and MCSST data.

The focus of this paper is on: influence of coarser- versus finer-resolution atmospheric forcing on the model's predictive skills; impact of open boundary conditions and coupling with larger-scale PWC model on reproducing major hydrographic conditions in the Monterey Bay area; influence of heat fluxes versus MCSST assimilation on the ICON mixed layer depth predictions; impact of the HF radar surface currents assimilation on the ICON model predictions.

Qualitative and quantitative comparisons are made between observations and model predictions for the entire 1999 year as well as for August-September of 2000.

URL: http://coam.usm.edu/ICON

### OS41M-03 0910h

### Meso-Scale Eddies of the Gulf Loop Current as Spawning and Nursery Habitat for Scombrid Fishes

John T Lamkin[1] (305-361-4226; John.Lamkin@noaa.gov)

John J Govoni[2] (252-728-8727; Jeff.govoni@noaa.gov)

Tom D Leming[3] (228-688-1214; Thomas.D.Leming@noaa.gov)

Joanne Lyczkowski-Shultz[4] (228-762-4591; Joanne.Lyzckowski-Shultz@noaa.gov)

[1]Southeast Fisheries Science Center, NOAA, 75 Virginia Beach Dr., Miami, FL 33157

[2]NOAA Beaufort Laboratory, 101 Pivers Island RD., Beaufort, NC 28516

[3]NOAA Mississippi Laboratories Stennis Space Center Facility, Bldg 1103, Room 218, Stennis Space Center, MS 39529

[4]NOAA Mississippi Laboratories, Pascagoula, 3209 frederic Street, Pascagoula, MS 39567

Bluefin tuna, Thunnus thynnus and other scombrids spawn in the Gulf of Mexico in Late April, May, and into early June. The relationship between larval bluefin tuna and thermal fronts has been established through previous studies, while an assessment of eddies and their associated fronts as spawning and nursery habitat has not been undertaken. The coupling of physical, biological, and fisheries oceanography is requisite for the proper assessment and description of these features as spawning and nursery habitat. MESHES, Mesocale Eddy Scombrid Habitat Ecological Study, was designed to identity and describe eddies as spawning and nursery habitat by locating these features and collecting biological and physical data.

In 1995 we began a three year effort to examine cold-core cyclonic eddies in the eastern Gulf of Mexico. A large cold core cyclonic eddy was present in 1996, and 1997, and we present data from these two years. In both 1996, and 1997, a broad area of cold-core circulation was located to the north of the Loop current in the eastern Gulf of Mexico, and was present throughout the year. The eddies were approximately 160 km in diameter. In both years transects passed through the eastern portion of the cyclone, and into the Loop Current. Despite peaks in chlorophyl abundance, and a significant shallowing of the chlorophyl maximum, scombrid larvae were not abundant in the Gyre. Instead they appear to be concentrated in the upper 25 meters the of the interface between the cold-core ring - Loop Current

### OS41M-04 0925h

### Circatidal Activity Rhythms in Ovigerous Blue Crabs *Callinectes sapidus*: Implications for Selective Tidal-Stream Transport

Richard A Tankersley[1] ((321) 674-8195; rtankers@fit.edu)

Richard B Forward[2] ((252) 504-7610; rforward@duke.edu)

Patricia N Pochelon[1] (ppochelon@fit.edu)

[1]Florida Institute of Technology, Department of Biological Sciences 150 W. University Blvd., Melbourne, FL 32901, United States

[2]Duke University Nicholas School of the Environment, Duke Marine Laboratory, Beaufort, NC 28516, United States

Prior to larval release, ovigerous blue crabs *Callinectes sapidus* migrate seaward from low-salinity areas of estuaries to spawn near the entrance. Previous studies found that ovigerous crabs use selective tidal stream-transport (STST) to enhance the rate and efficiency of down-estuary transport. Crabs enter the water column during nocturnal ebb-tides and remain on or near the bottom at all other times. Possible behaviors contributing to this tidal vertical migration pattern are (1) a circatidal swimming rhythm, and (2) behavioral responses to environmental factors. We tested the hypothesis that active upward movement into the water column on ebb tides is the result of an endogenous rhythm in activity. Ovigerous crabs were collected near Beaufort Inlet, North Carolina, during July-August 2001 and swimming activity was recorded for 3 to 5 d under constant conditions with a time-lapse video system. Crabs with egg masses containing late-stage embryos ($<$ 6 days from hatching) displayed a circatidal activity rhythm with two activity peaks per lunar day. In most cases, maximum swimming activity occurred near the time of expected slack-water before ebb in the field. Following larval release, the activity of most crabs became arrhythmic. Similarly, this rhythm was not expressed by gravid females possessing egg masses containing early-stage embryos ($>$ 7 days from hatching). These results are consistent with field observations of the migratory behavior of crabs obtained using ultrasonic telemetry and support the hypothesis that a tidal rhythm in swimming is the behavioral basis of ebb-tide transport in ovigerous *C. sapidus*.

### OS41M-05 0940h

### Field Observations of Ebb-Tide Transport of the Blue Crab *Callinectes sapidus* Near a Barrier Island Inlet Using Ultrasonic Telemetry

Sarah D. Carr[1] (sdcarr@email.unc.edu)

Richard A. Tankersley[2] (rtankers@fit.edu)

James L. Hench[1] (hench@marine.unc.edu)

Richard B. Forward[3] (rforward@duke.edu)

Richard A. Luettich[1] (rick_luettich@unc.edu)

[1]Institute of Marine Sciences University of North Carolina at Chapel Hill, 3431 Arendell Street, Morehead City, NC 28557, United States

[2]Department of Biological Sciences Florida Institute of Technology, 150 West University Boulevard, Melbourne, FL 32901, United States

[3]Duke University Marine Laboratory, 135 Duke Lab Road, Beaufort, NC 28516, United States

Female blue crabs *Callinectes sapidus* migrate from low salinity estuarine regions to high salinity regions near the ocean to release their larvae. In order to characterize movement patterns during these spawning migrations, we used ultrasonic telemetry to track ovigerous crabs near Beaufort Inlet, North Carolina, during July-August, 2001. Crabs with mature egg masses were caught in the estuary during nocturnal ebb tides, tagged with ultrasonic transmitters, and quickly released in the vicinity of Beaufort Inlet. Crabs were then tracked by boat using an ultrasonic receiver and hydrophone. Current measurements were obtained while tracking using a boom-mounted shipboard ADCP.

Ten crabs were tagged during the spawning season. Tracking duration ranged from $<$ 1 h to $>$ 37 h. Three crabs were tracked through the initial night ebb and