500 square Nmi per day. Longitude errors were approximately 0.5 degrees and latitude errors about 1.0 degrees. We applied several measures of sinuosity to analyze the estimated tracks. The distribution of sinuosity estimates indicate different behavioral modes. These results indicate that despite large uncertainties in geolocation estimates, new insights into in situ tuna behavior can be detected by detailed analysis of tracking data.

OS41J-14 1205h

Diving behavior of Pacific bluefin tuna (Thunnus thynnus orientalis) recorded by archival tags

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Immature Pacific bluefin tuna marked with archival tags were released off Tsushima Island in the East China Sea. Using time-series data on swimming depth, ambient temperature and peritoneal cavity temperature recorded by the tags retrieved, we examined the effect of ambient temperature on their dives in relation to the occurrence of feeding events. The development of their diving performance with growth was also discussed. In the East China Sea, the bluefin swam within the s urface mixed layer in winter, while as the thermocline developed in summer the bluefin spent most of the time at the surface and made in daytime repeated dives to depths through the thermocline. Further, feeding events were mostly recognized in accordance with the diving performance, suggesting that their diving is for feeding.

In summer, some bluefin migrated to the Pacific, where they made few dives in the daytime despite a deeper surface mixed layer, and they mainly made dives at dusk and dawn. This suggests that their diving patterns may possibly be affected by vertical prey distribution. The dives at dusk and dawn were supposed to be a behavioral response to temporal change in illumination since few feeding events were recognized in accordance with these dives. Additionally, diving depth and vertical swimming speed increased with growth. In conclusion, seasonal and spatial changes in the vertical thermal structure and vertical food distribution may have a great influence on the diving behavior. It is also evident that their diving performance develops with growth.

OS41K HC: 323 B Thursday 0830h

Biophysical Factors Affecting the Growth and Survival of Aquatic Organisms III

Presiding: **C Stevens,** New Zealand National Institute for Water Atmospheric Reasearch

OS41K-01 0830h INVITED

Temperature, stratification and barnacle larval settlement in two Californian sites

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The hypothesis that internal waves and bores transport planktonic larvae predicts more settlement in sites with more energetic internal motions. Barnacle settlement was monitored in five sites 20 - 100 km apart along the coast of Alta and Baja California. In five periods of observations completed between 1991 and 1996, *Chthamalus* spp., *Pollicipes polymerus*, and *Balanus glandula* settlement was consistently higher in the northern site, La Jolla, than in the southern site, La Salina. For *Chthamalus*, the most abundant settler, settlement was higher in La Jolla in 58 out of 60 paired dates, by a mean factor of 141. In 1996, time series of temperature in about 15 m of water showed that the stratification was 72% higher, on average, and that the thermocline was shallower in La Jolla than in La Salina. Consequently, internal motions of tidal and higher frequencies were more energetic and closer to the surface in La Jolla compared to La Salina, supporting the prediction of the internal bore hypothesis. The hypothesis was also supported by the result in La Jolla in that changes in settlement were positively correlated with changes in stratification. Adult barnacle density was much higher in La Jolla than in La Salina, suggesting the hypothesis that differences in stratification and settlement rate result in differences in adult density

OS41K-02 0915h

Transport of Postlarval Bivalves: Effects of Predator Activity, Sediment Grain Size, and Clam Species

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In soft bottom habitats, postlarval transport of benthic invertebrates has the potential to greatly influence patterns of recruitment. In laboratory flume experiments, the effects of a variety of factors on rates of transport of juvenile bivalves have been examined. In one experiment, the effects of sediment grain size on transport rates of juveniles of two species (*Mya arenaria* vs. *Mercenaria mercenaria*) were assessed. Rates of transport of *M. mercenaria* were greater than those of *M. arenaria*, which burrowed deeper into the sediment. Transport rates also varied with sediment grain size, being lower in coarse sediments than finer sediments for both species of clams. The potential for foraging by predators to cause disturbance, and thus to enhance transport of clams has also been examined. Transport of juvenile *M. arenaria* was increased by the presence of the seven spine bay shrimp, *Crangon septemspinosa*, but not by juveniles of the green crab, *Carcinus maenas*. Foraging *C. septemspinosa* excavate pits, disturbing the sediment surface and increasing bottom roughness. In a high flow speed treatment, ripples formed only in the presence of the shrimp. Juvenile *C. maenas* were efficient predators of *M. arenaria*, but caused less disturbance of the sediment surface and did not affect transport rates. These laboratory experiments indicate that a variety of factors will affect rates of postlarval transport of bivalves in the field. Knowledge of distances of transport also is necessary if we are to understand and predict patterns of postlarval transport. A laboratory experiment measuring transport distances of juvenile *M. arenaria* is in progress.

OS41K-03 0930h

Exchange between Embayments and the Hudson River and Implications for Zebra Mussel Populations

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The details of physical transport in rivers play a role in the spread and establishment of zebra mussel populations. Two dye studies, conducted on the Hudson River in the summers of 2000 and 2001, were designed to determine the effect of side embayments on zebra mussel transport and settlement. The dye, which was used to represent a larval cohort, was injected in the main channel near an embayment and observed over several tidal cycles. During the first study, the tides caused the dye cloud to return to the injection site over three tidal cycles. The embayment initially trapped nearly half of the dye, but runoff from a severe rainstorm flushed the dye from the embayment within a tidal cycle. These results suggest that large storms can flush larvae from embayments into the main channel, where they can settle. Measurements of larval abundance and settlement during the summer of 2000 support this conclusion.

The second study was conducted in a larger tidal bay with two, well-defined exchange locations between the bay and the main channel. Dye was injected as water started entering the bay, and a dye mass balance was evaluated by measuring dye concentrations and velocities at the two exchange sites. Visually, only a portion of the dye cloud traveled deep into the bay, while noticeable patches were trapped in dead zones near the exchange sites. These patches resulted in a large pulse out of the bay immediately after the flow direction changed. Preliminary results suggest very little of the dye re-entered the bay with the second incoming tide. These measurements allow us to estimate the fraction of a larval cohort trapped in a bay during a tidal cycle.

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OS41K-04 0945h

Isolating the Impact of Water Flow on Nutrient Uptake by Organisms Situated Within Complex Communities; An Isotope Labeling Approach

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Increased water velocity has been demonstrated to positively affect nutrient uptake kinetics at the scale of individual organisms (e.g. algae) and complex benthic communities (e.g. coral reefs and seagrass beds). However, few studies have isolated the effects of water velocity on nutrient uptake by individual organisms while they are situated within a complex community. In a series of field flume experiments conducted in a natural seagrass meadow (Thalassia testudinum), we used 15N-labeled ammonium to isolate the effects of velocity on individual components (epiphytes, seagrass, phytoplankton) of the community. The isotope label addition allowed us to determine the rate at which ammonium was removed from the water column by the entire community while measuring the rate of ammonium accumulation within the individual components.

Ammonium uptake rates for individual components and for the entire community increased significantly over a range of velocity (0.02 - 0.20 m/s) commonly observed in the field. The dependence of ammonium uptake by epiphytes and seagrass on velocity is on the order expected for mass-transfer limited uptake and suggests that water flow may control ammonium uptake by these benthic components. Furthermore, a comparison of uptake rates for seagrass leaves covered in epiphytes versus those for leaves cleaned of epiphytes indicates that epiphytes can significantly inhibit uptake of water column nutrients by seagrass leaves. Rates of ammonium uptake for phytoplankton also increased with water velocity; however, this effect appears to be indirect and a result of higher concentrations of PON in the water column with increased water flow. Results from field flume experiments conducted in other locations suggest that the effect of velocity on increased PON concentrations (and therefore uptake) is dependent on the physical and biological characteristics of the community. Results also revealed that the flow-dependent ammonium uptake by the entire community reflected the combined variable effects of velocity on uptake by individual components within the community. The application of isotope labels in field flume studies presents an effective approach for studying the effects of hydrodynamics on nutrient uptake by individual components situated within complex communities and for describing how the response of these components to water velocity relates to the overall response of the community as a whole.

OS41K-05 1020h

A Biophysical Model of Zebra Mussel Dispersal in the Illinois River

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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.

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OS41K-06 1035h

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

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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

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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

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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

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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

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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

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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