Non-Native Predator Impacts on North Coast Olympic Mudminnow (Novumbra hubbsi)
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Olympic mudminnow (Novumbra hubbsi), Washington’s only endemic fish species, was listed as “Sensitive” at the state level in 1999. However, limited knowledge and understanding has stalled conservation efforts. This study investigates the impact of invasive fishes on Olympic mudminnow, focusing on Lake Ozette in Olympic National Park. Using stable isotopes from the species present in Lake Ozette, the trophic ecology of mudminnow was determined. Stable isotopes are naturally occurring and can be used to trace the pathways of aquatic- and terrestrial-derived energy and carbon transfer in aquatic ecosystems. This analysis method investigates carbon (13C, 12C) and nitrogen (15N, 14N) found within samples. The presence of these isotopes depends on what a species eats. Moving up the food chain, the ratios of 13C/12C and 15N/14N increase, identifying a species’ feeding position within a community. The higher the trophic position, the more 13C and more 15N will be present in the sample. Through analysis of the entire community, including fish, invertebrates, and plants, a generalized food web was constructed for Lake Ozette. Using linear models and a permutation method, the fish species were compared to the model to test for statistically significant differences between the measured ratio of carbon to nitrogen. If the position of the fish species was significantly different from the model prediction, then there is no niche overlap and competition is unlikely. The combined results of the stable isotope and spatial overlap analyses indicated which species impact Olympic mudminnow as well as the invasive species present in Lake Ozette. Since there is little known concerning this species, there are many opportunities to extend the knowledge base continuing both with the predator prey interactions and with other knowledge gaps.

Olympia Oysters, Population Connectivity, and LASERS
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The Olympia oyster (Ostrea lurida), Washington’s only native oyster, was brought to near extinction during the last century due to overharvesting and habitat destruction. Populations have failed to recover naturally leading to a need for active restoration. O. lurida provide ecosystem services including filtering water, providing habitat and food, and increasing the overall diversity of the ecosystem. In order to restore the Olympia oyster to healthy population numbers in Puget Sound, WA, spatial patterns and population connectivity of O. lurida veliger larvae need to be studied to provide efficient and targeted restoration for the species. It can be difficult to determine larval transport patterns due to high larval mortality, small size, difficult identification, and long potential dispersal distances. By following methods of Carson et al. 2010, using trace elemental fingerprinting, it is possible to trace veliger larvae back to predicted natal populations. This is achieved by comparing the chemical signatures of settlers, veligers and brooded larvae using analysis by Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS). During the 10-12 day brooding period, trace metals from larval bay of origin are embedded into the natal shell during early life, leaving a record of past locations in the shell. Analyzing samples collected at natural and restored sites of O. lurida in Puget Sound, WA allow us
to compare site and spatial variability. These results will shed light on the dispersal and larval behavior of *O. lurida* which could inform restoration of native shellfish to create a network of self-sustaining sub-populations.

**Interpretation of the Relationship between Benthic Fauna, Geologic Distributions, and Methane Seeps at Southern Hydrate Ridge, Oregon Continental Margin**

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Deposits of methane sequestered along continental margins and their associated seeps are found worldwide. These seeps are of increasing interest and importance because of their potential as an energy source, their contribution to greenhouse gases, and the unique community of chemosynthetic microorganisms and fauna that they host. One of the best-studied methane seep sites is Southern Hydrate Ridge, which is at a water depth of ~800 m. It is located ~90 km west of Newport, Oregon. Despite extensive geophysical and biological research completed here, no studies have quantified the relationship of seep sites and seafloor geology to the spatial distribution and abundances of microbial and macrofaunal communities. High resolution, georeferenced photomosaics of the individual seeps and the associated biological communities at this site were collected in 2011, using the remotely operated vehicle ROPOS. Detailed visual and spatial analyses of these images has allowed for the quantification and characterization of the diversity and structure of the faunal community. Results show that both the distribution and abundances of seep organisms are highly variable. Further examination of these photomosaics may improve understanding of the relationships between faunal distributions and seep locations, with implications for the impacts that chemical gradients have on these ecosystems.

**Effects of a Turbid Plume on Phytoplankton Abundance at the Mouth of the Elwha River**

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The Elwha River was dammed between 1911 and 2014 trapping millions of cubic meters of fine and coarse-grained sediment in the two reservoirs created by these dams. Upon dam removal, much of this sediment was re-suspended and transported into the Strait of Juan de Fuca, reducing light availability to photosynthetic organisms. Phytoplankton abundance has not previously been studied near the Elwha Delta, so it is unknown how the dam removal has affected these organisms. Phytoplankton net tows and chlorophyll samples were collected at several stations surrounding the mouth of the Elwha River to determine overall abundance and diversity in and out of the plume. Chlorophyll concentration and phytoplankton abundances were compared to turbidity levels and salinity to determine their location within the plume. Phytoplankton abundance and chlorophyll concentration was reduced in high turbidity, low salinity water, i.e., inside of the plume. The chlorophyll concentrations measured within the plume were less than half the Strait of Juan de Fuca fall and winter average chlorophyll concentrations as documented in Mason and Peña (2009). The purpose of this study is to provide a foundation for the Elwha dam removals and future dam removals effect on the base of the marine food web.

**Influence of El Niño on Nutrients and Anaerobic Processes in the Eastern Tropical North Pacific**

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El Niño and La Niña are large-scale ocean-atmosphere phenomena that originate in the equatorial Pacific Ocean and last on scales of months to years. In addition to driving the global climate, the El Niño-Southern Oscillation (ENSO) also influences local-scale activities such as oceanic nutrient concentrations and microbial processes. The location where ENSO temperature oscillations originates is upstream of the world’s largest, naturally occurring oxygen deficient zone (ODZ), implying that ENSO temporal variations could impact ODZ dynamics. With very little to no oxygen in these waters, microbes use nitrogen species for anaerobic processes, denitrification and anaerobic ammonium oxidation (anammox), in lieu of oxygen. These microbial processes identify by their chemical markers: nitrate, nitrite, and ammonium. This project was to examine ENSO-driven changes in both the vertical extent of oxygen deficient waters and nutrient concentrations in the Eastern Tropical North Pacific (ETNP) off the coast of Manzanillo, Colima, Mexico. In addition to data from 1965, 1969, 1972, 1994, 2007 and 2012 to the ETNP, I collected seawater samples from December 2016 to January 2017 aboard the R/V Sikuliaq to compare oxygen and nutrient profiles over the past 50 years. I hypothesized that ENSO influences fluctuations in oxygen, nutrient, and microbial process regimes. Nutrient data was compared to the global ENSO and oceanographic state during the preceding and following years of each cruise to examine possible relationships between the variables. Rates of denitrification and anammox were also calculated to see if anaerobic processes also correspond with the ENSO cycle. This project provides insight on the microbial and oceanographic response to ENSO dynamics in an economically and ecologically critical part of the ocean. El Niño and La Niña are modules of the global climate, which are becoming stronger and more
frequent in response to anthropogenic climate forcing.

The Genomic Capacity and Physiology of Low-Oxygen Stress on Prochlorococcus
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Widespread in tropical and subtropical oceans, the marine Cyanobacteria Prochlorococcus are the smallest and most abundant photosynthetic organisms on Earth, playing an important role in global primary production. As a collective group, Prochlorococcus have a very large pangenome, consisting of a conserved core genome and variant accessory genes. Prochlorococcus forms two ecotypes, the low-light (LL) adapted lineages—which possess large amounts of accessory genes—and the more streamlined high-light (HL) adapted lineages. The gain and loss of accessory genes in Prochlorococcus reflects their genomic and physiological differences and allows ocean niche differentiation. Recently, uncultivated lineages of LL-adapted Prochlorococcus have been identified in oxygen deficient zones (ODZs) that dominate under high-nutrient, low-light, and low-oxygen conditions. In my research, I explored the possibility that LL-adapted ODZ Prochlorococcus possess accessory genes related to low-oxygen stress (e.g., redox-sensitive enzymes and redox-dependent metabolic processes such as photosynthetic electron transport and photorespiration) that are likely lost in HL-adapted Prochlorococcus. To understand the effects of low-oxygen stress on the LL-adapted Cyanobacteria Prochlorococcus, I assessed the genomic potential for low-oxygen genes through computational analysis of a metagenomics dataset capturing native ODZ Prochlorococcus as well as the annotated genomes of the LL-adapted cultured isolates MIT9303 and MIT9313. I am currently measuring the physiological response of LL-adapted culture isolate MIT9313 under low oxygen conditions through growth experiments, during which the presence and scope of metabolites showing changes in redox chemistry due to low-oxygen stress will be analyzed using liquid chromatography mass spectrometry. My results will show if LL-IV strains contain low-oxygen accessory genes, and if they combat the negative physiological effects of low O2 concentrations. As ODZs grow the global rising temperatures, knowing how LL-adapted Prochlorococcus responds to low-oxygen stress could give insight on how primary production will be affected by a changing ocean.

Recent North Atlantic Right Whale Acoustic Presence along the Western North Atlantic Coast
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The North Atlantic right whale (Eubalaena glacialis, NARW) is among the most depleted species of whale existing today, with a current estimated population of only 450. Ship strikes and entanglement issues remain the predominant cause of mortality for this critically endangered species. Thus, understanding NARW distributions, and their overlap with human activities, are a top priority for management and conservation efforts. This study analyzed passive acoustic data collected within the migratory corridor from Cape Hatteras, NC to Brunswick, GA from Oct 2015 - June 2016 as part of a comprehensive seasonal distribution look at NARWs along the Western North Atlantic coast. Four lines of 5-8 Marine Autonomous Recording Units were deployed, stretching across the shelf, in the first deployment of a three year, continuous acoustic monitoring effort. These units were processed using the Low Frequency Detection and Classification System (LFDCS), and detections were screened for daily NARW presence. The results of this study show seasonal movements to and from their calving grounds while passing through Georgia, South Carolina, and North Carolina. Off the coast of Georgia and North Carolina, NARWs are detected primarily on inshore recorders from November to March, suggesting the species take paths closer to shore while migrating. However, in late April, the groups travelling north take a path further away from the Cape Hatteras, NC shore. NARWs were picked up predominantly on inshore recorders throughout all four lines of MARUs, further supporting that critical habitats exist close to the coast in southern US waters. This information provides a better understanding as to where NARWs are spatially and temporally located, which is essential in minimizing human impacts on the species.

Jaw-Dropping Sculpins: Comparative Functional Morphology and Evolution of the Cottoid Feeding Apparatus
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Mentor: Kate Jackson, Biology, Whitman College

Dozens of sculpin species inhabit the Salish Sea, and their heads range from short and squat to long and sleek and oblong. Our study focused on jaw gearing, or the mechanical relationship between the movement of muscles and jaws, in five of these species. We measured 37 anatomic and 5 kinetic variables describing form and function in the jaws, and we phylogenetically corrected our data to track how jaws evolve. Anatomic gearing was measured in dissected speci-
imens, and kinetic gearing in live feeding fish. Both lines of data revealed that evolutionary shifts to higher gear ratios correlated with shifts to shorter muscles. This coevolution of gearing and muscle length allows diverse jaw structures to maintain similar muscle strain magnitudes and preserve high feeding performance. This intraspecific, coevolutionary relationship may help explain how dozens of sculpin species are able to maintain distinct head morphologies and coexist in the Salish Sea.