Scripps Student Symposium

September 25, 2019
Scripps Seaside Forum

Welcome

Wednesday, September 25th, 2019. Scripps Seaside Forum.

Dear SIO Community,

Thank you for joining us for the 6th Annual Scripps Student Symposium (S^3). The primary goal of S^3 is to provide a platform for Scripps graduate students to present and discuss their research with colleagues from across SIO. This student-inspired symposium was created to foster interdisciplinary collaboration amongst the student population and to introduce incoming students to the wide variety of research going on at SIO. As we celebrate the 6th anniversary of the symposium, S^3 has grown into an event that not only promotes the tradition of exceptional research here at SIO, but celebrates the synergistic, outreach-oriented and artistic nature of the Scripps community.

Today's schedule includes oral and poster presentations from graduate students in all research sections of SIO, as well as a presentation by Director of Ship Operations Bruce Appelgate and remarks from Margaret Leinen, the UCSD Vice Chancellor for Marine Sciences, Director of Scripps Institution of Oceanography, and Dean of the School of Marine Sciences. We welcome students from High Tech High Chula Vista, Mission Bay High, and Escondido Union High School District, who are here to learn about the exciting world of ocean and earth sciences. Representatives from local biotechnology, engineering, and consulting firms have joined us for the day to network with Scripps graduate students and learn about the cutting-edge research they are conducting. Please take a moment today to reconnect with fellow scientists, meet new friends, and to celebrate!

In addition to showcasing graduate student work, we are excited to welcome Dr. Kimberly Cobb as our keynote speaker. Dr. Kim Cobb's research uses observations of past and present climate to advance our understanding of future climate change impacts. Kim has received numerous awards for her research, most notably a NSF CAREER Award in 2007, and a Presidential Early Career Award for Scientists and Engineers in 2008. She is honored to be a Lead Author for the IPCC Sixth Assessment Report. As a mother to four, Kim is a strong advocate for women in science, and champions diversity and inclusion in all that she does. As of late, she has traded in her Platinum Frequent Flier status for a battle-worn bike, solar panels, and a penchant for planting urban trees. In alignment with these goals, Dr. Cobb will be giving her keynote remotely.

We would like to thank each of you for joining us for this day of science, art, and community; we hope that S^3 will continue to inspire students for many years to come!

All the best,

The 2019 S^3 Organizing Committee

Kelli Mullane
Stephanie Sommer
Ariel Pezner
Athina Lange
Angela Szesciorka
Duncan Wheeler
Emelia Chamberlain
Natalia Erazo

Agenda

Wednesday, September 25th, 2019. Scripps Seaside Forum.

08:00-08:50 Registration & Poster Setup

08:50-09:00 Welcome Address: S^3 Committee

09:00-09:15 Welcome by Margaret Leinen

09:15-10:30 Oral Session 1

10:30-11:30 Poster Session 1

11:30-12:45 Oral Session 2

12:45-13:45 Group Photo, Lunch

13:45-15:00 Oral Session 3

15:00-15:15 UC Ship Funds Presentation: Bruce Appelgate

15:15-16:15 Poster Session 2

16:15-17:05 Keynote Speaker: Dr. Kimberly Cobb, PhD '02

Georgia Power Chair and ADVANCE Professor at Georgia Institute of Technology

17:05-17:30 Awards Ceremony and Closing

17:30-19:30 Symposium Social Hour and Scientific Art Show: Surfside

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Oral Sessions

Wednesday, September 25th, 2019. Scripps Seaside Forum.

Oral Session 1

09:15-09:30 **Angela Szesciorka**, "Timing is Everything: Drivers of Interannual Variability in Blue Whale Migration"

09:30-09:45 **Kayla Wilson,** "Diving into the Origins of Small Molecules from a San Diego Marine Sponge"

09:45-10:00 **Margot White,** "Division of Marine Dissolved Organic Matter from the Eastern North Pacific by Thermal Reactivity"

10:00-10:15 **Alaina Smith,** "Contrasting *Prochlorococcus* Temperature Niches in the Lab and Across Ocean Basins"

10:15-10:30 **Srishti Dasarathy,** "Multi-Year Seasonal Trends between Sea Ice, Chlorophyll Concentration, and Clean Marine Aerosol Optical Depth in the Bellingshausen Sea"

Oral Session 2

11:30-11:45 **Olavo Marques,** "Tales from Topographic Tasmania: Remote Internal Tides as they Approach the Land"

11:45-12:00 **Sara Rivera,** "Bacterial Activity and Abundance in the California Current Ecosystem Region 2006-2017"

12:00-12:15 **Natasha Mazon,** "Characterizing Genes in Axonal Repair in the Medicinal Leech"

12:15-12:30 **Raphael Reher,** "A SMART Approach to Illuminate Secondary Metabolites for Drug Discovery"

12:30-12:45 **Orion McCarthy,** "Identifying the Drivers of Structural Complexity on Hawaiian Coral Reefs Using Structure from Motion"

Oral Session 3

13:45-14:00 **Ariel Pezner,** "Effects of Natural Variability in Temperature, Dissolved Oxygen, and pH on Massive Coral Growth in a Seagrass Meadow"

14:00-14:15 **Kelsey Alexander,** "Fatuamide A, a Unique Secondary Metabolite from the American Samoan Cyanobacterium *Leptolyngbya* sp."

14:15-14:30 **Eric Snyder,** "Cuvier's Beaked Whale Tracks in Southern California"

14:30-14:45 **Erica Ferrer,** "The Carbon Footprints of Mexican Small-Scale Fisheries Reveal New Insights into Marine Resource Tradeoffs"

14:45-15:00 **Chase James,** "The Structure and Diversity of Prokaryotic and Eukaryotic Plankton Communities Within the Southern California Bight (2014-2018)"

Poster Sessions

Wednesday, September 25th, 2019. Scripps Seaside Forum.

Poster Session 1: 10:30-11:30

P001 An Organic Source of Alkalinity in the Open Ocean?, **Michael Fong**

P003 Sea Ice Melt Methods and Impacts on the *in situ* Microbial Community, **Emelia Chamberlain**

P005 Soil Soundscapes from Seismic Arrays: Monitoring Bioturbation in Mima Mounds, **Travis Clow**

P007 Comparison of Temperature Preference and Q_{10} Between two Juvenile Shark Species, **Zachary Skelton**

P009 Neuroanatomy in *B. stephanieae* Through Immunohistochemistry, **Carl Whitesel**

P0011 Observations of Runup, Inner-Surf Zone Waves, and Beach Morphology During Energetic Storm Events Using a Stationary LiDAR, **Lauren Kim**

Poster Session 2: 15:15-16:15

P002 Biogeochemical Observations and Baseline CO_2 Conditions in the Agua Hedionda Lagoon, **Kenisha Shipley**

P004 Scripps Community Outreach for Public Education, **Wiley Wolfe**

P006 Fishes as ‘Mobile Monitors’ of Hypoxic Conditions Across Ocean Basins, **Leticia Cavole**

P008 Exploring the Survival and Growth of *Sicyonia ingentis* Under Ocean Warming and Ocean Acidification like Conditions, **Zoe Sebright**

P010 The California Current Ecosystem (CCE) Interactome, **Sara Rivera**

P012 Insights into the Adaptation of Hydrocarbon-Degrading Microbes to Life at High Pressure: the Role of Motility and Chemotaxis, **Kelli Mullane**

Abstracts

Wednesday, September 25th, 2018. Scripps Seaside Forum.

Oral Session 1

Oral Session 2

Oral Session 2

Poster Session 1

Poster Session 2

Timing is Everything: Drivers of Interannual Variability in Blue Whale Migration

Angela R. Szesciorka[1], Lisa T. Ballance[1,2,3], Ally Rice[1], John Hildebrand[1], Ana Širović[4], Mark D. Ohman[1], and Peter J.S. Franks[1]

The growth and survival of large-bodied marine predators depend on temporal synchrony with resource availability. Baleen whales migrating long distances must therefore accommodate interannual variability to avoid predator-prey mismatches. Highly migratory and acoustically active, blue whales are a model species for investigating the drivers and timing of migration. Using passive acoustic recordings collected from moorings during 2007-2017, we examined the relationship among migration timing (inferred from blue whale calls), environmental indices, and euphausiid (prey) biomass. The leading driver, sea surface temperature (SST) at the Costa Rica Dome breeding grounds, predicted arrival time at the Southern California feeding grounds one month later. Interannual variations revealed that colder SSTs correlated with earlier arrival and greater krill biomass in Southern California. In years with greater krill biomass, whales switched earlier from social, foraging-related to reproductive-related calls at the feeding grounds. Our results show a phenotypically plastic response to interannual environmental variability and allowed us to examine potential consequences of climate change on plasticity. However, as temperatures increase due to climate change, blue whales are extending their residence time at the feeding grounds by up to two months, which may increase anthropogenic impacts, such as ship strikes and entanglements in fishing gear.

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Diving into the Origins of Small Molecules from a San Diego Marine Sponge

Kayla A. Wilson[1]

Marine sponges are prolific producers of a wide array of chemical compounds with impressive bioactivity, including anti-cancer, antiviral, and antibacterial activities. Many of these sponge-derived compounds are actually produced by the sponge's microbiome, a community of bacteria, archaea, and other microbes that live on and in the sponge itself. By sequencing the DNA of the sponge and its microbiome, we can identify and characterize the genes responsible for the production these bioactive compounds. My research focuses on a unique class of compounds known as nitrogenous terpenes, which are only found in marine sponges, and whose biosynthetic machinery has remained a mystery for decades. In this presentation, I will discuss how I have used metagenomic sequencing and genetic engineering to make progress towards discovering the biosynthetic origin of nitrogenous terpenes in a local San Diego sponge.

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Division of Marine Dissolved Organic Matter from the Eastern North Pacific by Thermal Reactivity

Margot E. White[1], Tran B. Nguyen[1], Irina Koester[1], J. Michael Beman[2], Ken Smith[3], Ann McNichol[4], Steven Beaupré[5], and Lihini I. Aluwihare[1]

Marine dissolved organic matter (DOM) is a complex mixture of molecules with diverse chemistries, sources, and ages. Consequently, few techniques allow unbiased analysis of the entire extracted sample. We used ramped pyrolysis/oxidation to divide solid phase extracted Pacific Ocean DOM based on thermal reactivity. The resulting thermograms, together with radiocarbon and stable carbon isotope measurements, yield information about how DOM differs across biogeochemical gradients. Some samples were subjected to acid hydrolysis to remove the more 'modern' fraction, dominated by amino acids and carbohydrates. Hydrolysis resulted in significant changes to the thermogram, with these differences being most pronounced in the shallower samples. Radiocarbon data suggest homogeneity within samples, though from surface to deep we see the expected age gradient and good correspondence with measurements of bulk DOC from similar depths.

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Contrasting *Prochlorococcus* Temperature Niches in the Lab and Across Ocean Basins

Alaina N. Smith[1], Gwenn M.M. Hennon[2], Erik R. Zinser[3], Benjamin C. Calfee[3], and Andrew D. Barton[1]

Prochlorococcus, a diverse group of marine cyanobacteria, are the most abundant photosynthetic organisms in the world, accounting for up to 48% of global primary production. Previous studies have shown that different strains of *Prochlorococcus* prefer different optimum temperatures for maximum growth and thus can coexist along temperature gradients through niche partitioning. However, the temperature distributions for individual strains measured in the field (i.e. realized temperature niches) are not always the same as the temperature distributions predicted from laboratory growth rate experiments (i.e. fundamental temperature niches). While recent studies have shown evidence of these niche differences, the expected and measured temperature distributions for strains of *Prochlorococcus* have not been quantified and compared across ocean basins. We aggregated both lab-derived growth rates and field-derived abundance distributions across temperatures for four genetically distinct groups of *Prochlorococcus* (eMED4, eMIT9312, eMIT9313, and eNATL2A). Using statistical modeling methods, we quantified the fundamental and realized temperature niches for each of these four groups. We found that the fundamental temperature niches and the realized temperature niches are different. In addition, we found that the realized niches for each of the four distinct groups of *Prochlorococcus* differ across ocean basins suggesting some level of either phenotypic plasticity, local adaptation, or variation in community dynamics.

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Multi-Year Seasonal Trends Between Sea Ice, Chlorophyll Concentration, and Clean Marine Aerosol Optical Depth in the Bellingshausen Sea

Srishti Dasarathy[1], Jayanta Kar[2], Jason Tackett[2], Sharon D. Rodier[2], Xiaomei Lu[2], Mark Vaughan[2], Travis Toth[2], Charles Trepte[2], & Jeff Bowman[1]

Biogenic aerosols, formed through either atmospheric oxidation of precursors such as dimethylsulfide (DMS), organohalogens, and other organic compounds, or through direct injection into the atmosphere, have the potential to shape the regional and global climate. Although the formation of secondary organic aerosols (SOA) from volatile organic compounds (VOCs) released by terrestrial biota has been well-explored, despite considerable effort major questions remain in our understanding of aerosol formation from marine biogenic emissions, particularly in polar regions. To determine how sea ice and chlorophyll-a (CHL) concentration are associated with marine aerosol formation we undertook a multi-year satellite remote-sensing analysis in the Bellingshausen Sea for the period (2006-2018). We developed seasonal climatologies and time-series of sea ice, CHL, and layer-integrated clean marine optical depth (CMOD) using satellite-derived data products from passive microwave remote sensing instruments, Moderate Resolution Imaging Spectroradiometer (MODIS) Aqua, and the Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observations (CALIPSO), respectively. We identified strong seasonality, with CMOD and particulate color ratio (PCR) increasing in late spring until early fall, synchronous with a decrease in sea ice concentration and increase in CHL. Inter-annual variation in the strength of the CMOD and PCR increase appear tied to the extent and duration of the decrease in sea ice concentration and increase in CHL concentration. This is consistent with the hypothesis that the production of biogenically derived marine aerosol is seasonal, with the peak in biogenic aerosols concurrent with the phytoplankton growth season from late spring to early fall.

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Tales from Topographic Tasmania: Remote Internal Tides as They Approach the Land

Olavo B. Marques[1], Matthew H. Alford[1], Jennifer A. MacKinnon[1], Jonathan D. Nash[2], Harper L. Simmons[3], Jody M. Klymak[4], and Rob Pinkel[1]

As a rock falls into a pond, the surface of the water is perturbed and part of the energy is converted into ripples that radiate away. In a much similar way, the surface tide can perturb the density structure of the ocean and generate internal tides, which are waves that propagate within the density field. When these waves break, they lead to vertical mixing, which is critical in establishing the circulation and the distribution of heat in the abyssal ocean. I will present results from an experiment designed to study the interaction of the remote internal tide impinging on the continental slope of Tasmania. Models and observations show processes in a wide range of scales, which are in turn related to different aspects of the internal tide dynamics and give rise to a complex internal wave field. While large-scale features of the slope determine the bulk of the energy flux, the processes associated with internal wave breaking are highly dependent on the shape of small (1 km) bathymetric features. These results indicate the representation of vertical mixing in large-scale climate models needs to incorporate the physical processes that are appropriate for small-scale topography in the ocean.

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Bacterial Activity and Abundance in the California Current Ecosystem Region 2006-2017

Sara R. Rivera[1], Farooq Azam[1], and Lihini I. Aluwihare[1]

Heterotrophic bacteria, as dominant recyclers of organic matter, play a critical role in determining the net metabolic state of the ocean. In this current study, which spans 2006-2017, we provide a baseline study of heterotrophic bacterial properties within the California Current Ecosystem (CCE). We find that the variability across biogeographic boundaries in heterotrophic bacterial parameters is much larger than the interannual variability encountered within a region — including during an El Niño event. Our data are also consistent with the hypothesis that the CCE oligotrophic offshore environments can be net heterotrophic. Additionally, this study provides the necessary framework for future work trying to disentangle natural variability from new climate-related changes.

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Characterizing Genes in Axonal Repair in the Medicinal Leech

Natasha Mazon[1,2], Eduardo Macagno[2], Jenna Lycan[2], Lina Abdulnoor[2], and Terry Gaasterland[1,3,4]

Spinal cord injuries affect over 500,000 people in North America and over 102 million worldwide. Human central nervous system (CNS) regeneration after traumatic damage is incomplete. The medicinal leech, *Hirudo medicinalis*, has capacity to repair and restore CNS circuits lost in traumatic damage. We have assembled a genome and transcriptome to provide tools to examine the molecular basis of axonal regrowth after injury. To identify molecular signals that may facilitate regrowth of interrupted axons and restore function, gene expression changes were measured at 24 hours and 48 hours post-injury in leech ganglia flanking an axon cut site, with bodywall cuts as controls. RNA was extracted for sequencing and mapped to the transcriptome. Transcripts were ranked on degree and direction of change. Transcripts were aligned with known NCBI proteins and annotated with functional domains. Genes most strongly up-regulated at both time points included homologs of mouse and human genes involved in neuronal repair or expressed in neurodevelopment, including neuroglian, profilin, lachesin, stathmin, and six1. One up-regulated gene was a homolog of Regeneration Up-regulated Protein 5 (RUP5) from *E. japonensis*. Transcription factors KLF11, TWIST, CREB1, and LIN28 were observed as up-regulated. Quantitative PCR assays to validate results are underway. Pathway analysis of differential genes will be conducted to identify regulatory connections. Upstream promoters will be extracted from the recently assembled genome and inspected for transcription factor binding sites. The resulting expression patterns and regulatory connections between genes will provide molecular insights into CNS repair after traumatic injury.

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A SMART Approach to Illuminate Secondary Metabolites for Drug Discovery

Raphael Reher[1], Chen Zhang[1,2], Hyunwoo Kim[1], Henry Mao[2], Louis-Felix Nothias[3], Garrison W. Cottrell[2], Pieter C. Dorrestein[3], and William H. Gerwick[1,3]

Secondary metabolites, often designated as natural products (NPs), are the single most important source of drug leads and new therapeutics. To rapidly identify known as well as putatively new bioactive NPs, mass spectrometry-based Molecular Networking has remarkably accelerated NP and metabolomic research over the past 5 years (https://gnps.ucsd.edu/ProteoSAFe/static/gnps-splash.jsp, Dorrestein lab, UCSD). However, despite several recent advancements in annotation methods, only 2-5% of the detected metabolites could be identified by spectral matches to reference libraries. Resultantly, there is still an urgent and continuing need in this field for fast and accurate structure determination of novel NPs, and this represents a bottleneck in the drug discovery workflow. To rapidly illuminate the structures of unknown metabolites, we developed a novel artificial intelligence-assisted NMR analysis tool called SMART 2.0 (Small Molecule Accurate Recognition Technology). We trained a Deep Convolutional Neural Network (DCNN) for visual pattern recognition on 30,000 NMR (^{1}H-^{13}C HSQC) spectra of NPs. This tool is now available to the community in a beta version to address questions ranging from dereplication of known compounds, identification of new compounds, and generally an acceleration of the processes of drug discovery and chemical ecology. We anticipate that future integration with mass spectrometry and genomics will pave the way to rapidly describe entire metabolomes of diverse organisms as well as their pleiotropic interactions.

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Identifying the Drivers of Structural Complexity on Hawaiian Coral Reefs Using Structure from Motion

Orion S. McCarthy[1], Jennifer E. Smith[1], Stuart A. Sandin[1], and Vid Petrovic[2]

Structural complexity on coral reefs is commonly associated with high abundance of reef fish and high coral cover. As such, methods to efficiently and accurately assess structural complexity are relevant for coral reef monitoring and conservation. Using Structure from Motion (SfM), it is now possible to quantify the structural complexity of coral reefs using interactive 3D models. This study quantifies one metric of structural complexity, linear rugosity, across spatial scales at reefs in the Main and Northwestern Hawaiian Islands (MHI and NWHI) using SfM. Cross-scale patterns of rugosity differed among reef types: coral-dominated reefs exhibited more complexity at small scales (millimeters to centimeters) than reefs dominated by algae, with a rapid decrease in complexity at larger scales (decimeters to meters). Conversely, the underlying topography of the reef contributed more to complexity at larger scales. Furthermore, cross-scale patterns of rugosity were found to be a good predictor of coral cover, in many cases better than a single-scale assessment of rugosity. Using these methods, cross-scale differences in rugosity between the MHI and NWHI were attributed to higher coral cover in the MHI, rather than geologic differences (i.e., underlying reef topography or island age) between regions. Overall, the scale of measurement and the rate at which rugosity changes across scales are important considerations when assessing linear rugosity. The ability to rapidly measure rugosity across scales using SfM can improve our ability to identify which aspects of the reef (biotic vs geologic) are driving structural complexity and contextualize changes in complexity over time.

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Effects of Natural Variability in Temperature, Dissolved Oxygen, and pH on Massive Coral Growth in a Seagrass Meadow

Ariel K. Pezner[1], Wen-Chen Chou[2], Hui-Chuan Chu[2], Travis A. Courtney[1], Samuel A.H. Kekuewa[1], Rong-Wei Syu[2], Yi Wei[3], Keryea Soong[3], and Andreas J. Andersson[1]

Coral reefs are increasingly facing threats from many different stressors, including warming, ocean acidification, and eutrophication. However, relatively few studies have investigated the impacts of hypoxia on coral reefs, despite the likely co-occurrence of low oxygen and low pH conditions in the field. Recent research has shown that corals may be differentially tolerant to hypoxia, depending on exposure level, duration, and interactions with other environmental parameters. In this study, we investigated coral calcification rates across a natural gradient in seawater temperature, pH, and oxygen variability in a seagrass bed on the Dongsha Atoll, Taiwan. Spatial surveys of water chemistry across a 0.7 km^2 section of seagrass with small patches of massive *Porites* sp. and *in situ* sensor measurements showed dramatic changes in temperature, dissolved oxygen (DO), and pH over space and time. Temperature ranged from 29.1°C to 32.2°C from early morning to midday. Corresponding DO levels were as low as 16 µmol kg^{-1} in the early morning, and as high as 332 µmol kg^{-1} in the late afternoon. Similarly, pH ranged from 7.7 in the early morning to 8.6 in the late afternoon. Cores were collected from colonies of massive *Porites* sp. along a gradient of zero to high seagrass density and analyzed for annual calcification rates to determine whether seagrass environments affected coral growth. Understanding how coral growth and calcification is affected by temperature, DO, and pH variability will help us better assess how coral reefs may fare under increased ocean deoxygenation and hypoxic events.

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Fatuamide A, a Unique Secondary Metabolite from the American Samoan Cyanobacterium *Leptolyngbya* sp.

Kelsey L. Alexander[1], Brendan Duggan[2], C. Benjamin Naman[3,4], Arihiro Iwasaki[5], Tiago Leao[3], Eduardo Caro-Diaz[3], Evgenia Glukhov[3], Lena Gerwick[3], and William H. Gerwick[2,3]

Marine cyanobacteria are known for their ability to produce structurally diverse and biologically active secondary metabolites. One such interesting organism, the marine cyanobacterium *Leptolyngbya* sp. ASX-22JUL14-2, was laboratory cultured after it was collected in American Samoa. This culture provided an organic extract that was cytotoxic to NCI-H460 human lung cancer cells *in vitro*. LC/MS-MS molecular networking allowed for the targeted isolation of a new secondary metabolite, given the name fatuamide A, from the cytotoxic fraction. Multiple spectroscopic techniques suggested that it is a hybrid PKS/NRPS cyclic peptide. To elucidate the unique structure of fatuamide A, a variety of analytical techniques were used. 2D NMR, while of critical importance for marine natural products structure elucidation research, can be very time consuming. However, shortened acquisition times can be achieved through newer NMR techniques such as ASAP (Acceleration by Sharing Adjacent Polarization) and NUS (Non Uniform Sampling). This allows for faster data collection and thus expedited dereplication/elucidation of structures. From these methods, a provisional structure for fatuamide A has been proposed. Additionally, a plausible biosynthetic pathway for fatuamide A was determined using genomic sequence information from the producing organism.

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Cuvier's Beaked Whale Tracks in Southern California

Eric Snyder[1], Sean Wiggins[1], Ryan Parkes[1], Simone Baumann- Pickering[1], and John Hildebrand[1]

Cuvier's beaked whales (*Ziphius cavirostris*) are difficult to study due to infrequent sightings and their deep-diving behavior. Consequently, their abundance and distribution remain unclear. One approach to studying their behavior is to use arrays of hydrophones to localize and track individual beaked whales. We collected over one year of small aperture (~1 m) broadband acoustic array recordings at different sites offshore of the coast of Southern California, a region with a considerable presence of Cuvier's beaked whales. We use the time difference of arrival between hydrophone pairs in our arrays to determine the direction of an echolocating beaked whale. When the source directions are cross-fixed from multiple arrays, the location of an animal can be determined and sequential locations can be used to form tracks. Tracks can be used to determine a number of signal characteristics, such as source sound pressure level, beam directionality, and click temporal patterns as well as a number of animal behaviors including swim speed, group size, descent angle, and foraging depth. These features can be combined to assess density and abundance of the species.

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The Carbon Footprints of Mexican Small-Scale Fisheries Reveal New Insights into Marine Resource Tradeoffs

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Notable studies have explored the carbon footprint of global fisheries, often using data that is coarse relative to the heterogeneity observed across operations. We contend that previous studies which examine the carbon footprint of global fisheries in aggregate have, in the absence of robust data, very likely underestimated the footprint of small-scale fisheries. We provide evidence of this using fine-scale fisheries data, generated by voluntary monitoring efforts in Northwest Mexico, combined with landings data reported to the Mexican government. Additionally, we calculated the "emissions intensities" of various seafoods produced by small-scale fisheries throughout the region, comparing the footprint of these to other sources of animal protein, such as industrial wild catch and terrestrial livestock. Some of these small-scale fisheries (like clam and crab fisheries) may offer low-carbon to moderate-carbon sources of animal protein, while others (like shrimp fisheries) do not. Connecting these results to prior knowledge of climate change and fishing impacts, and incorporating new ideas about socially-just policy and management in the Anthropocene, we end with a discussion about how to weigh the benefits of certain small-scale fisheries against the social-ecological costs of carbon pollution.

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The Structure and Diversity of Prokaryotic and Eukaryotic Plankton Communities Within the Southern California Bight (2014-2018)

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To investigate the structure and diversity of planktonic communities within the Southern California Bight, CalCOFI teamed up with the J. Craig Venter Institute in 2014 to collect and generate a database of samples for high throughput amplicon sequencing of both prokaryotic (16s) and eukaryotic (18sv9) communities. Combining this amplicon sequencing database with CalCOFI's existing physical-chemical sampling regime, this project aims to explore how the prokaryotic and eukaryotic communities are structured by their environment. In order to extract digestible features from this data-rich source, I utilize a machine learning approach known as self-organizing maps to identify distinct communities directly from the highly dimensional amplicon datasets (greater than 20,000 unique amplicon sequence variants). Both the prokaryotic and eukaryotic datasets cluster into nearshore-offshore communities — mapping closely to patterns in sea-surface temperature variability across the Southern California Bight. For eukaryotes, gradients in diversity, evenness, and species richness orient along the nearshore to offshore, with the highest levels of all three ecological variables occurring offshore. Prokaryotic communities, however, show no significant horizonal distribution for the same three ecological parameters — rather communities in the deep chlorophyll maximum appear to be more diverse, even, and species rich than communities at the surface.

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An Organic Source of Alkalinity in the Ocean?

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From an analysis of the consistency of CO_2 measurements on four GO-SHIP cruises, a systematic discrepancy was found between directly measured total alkalinity and the value of this parameter as calculated from concurrent measurements of pH and dissolved inorganic carbon. These observations suggest the widespread presence of an unaccounted contribution to the measured total alkalinity of seawater. This observed apparent excess alkalinity was observed to have a distribution related to apparent oxygen utilization. We hypothesize an organic source for this apparent excess alkalinity.

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Sea Ice Melt Method and Impacts on the *in situ* Microbial Community

Emelia J. Chamberlain[1] and Jeff S. Bowman[1,2]

Sea ice serves as a critical habitat for biology with many polar marine organisms dependent on sea-ice and the microbial communities living within its crystal matrix for survival. Most studies examining these microscopic communities depend on melting the ice to extract cells for analysis. However, the ice habitat is heavily stratified and constrained by steep gradients in temperature and salinity. The literature details several techniques to control the thermohaline properties of the ice during the melting process in an effort to minimize osmotic stress; but with no consensus on accuracy. Here we tested three of the most cited melting techniques – direct melt, high salinity isohaline melt, and a sterile 35 PPT seawater dilution – to determine if different melting methods impact the accuracy of measurements of microbial community structure and physiology. 18 identical ice cores were collected from coastal sea ice in Utqiagvik, Alaska and melted at 5ºC with 6 cores in each salinity condition. We found significant differences between melt conditions in fluorescence measurements and cell counts for both heterotrophic and autotrophic communities. Cell counts and bulk chlorophyll were highest in the sterile seawater dilution, indicating that this condition caused the least amount of osmotic stress and cell loss for organisms suited to a coastal ice environment. From this experiment, it is clear that melting method can significantly affect certain physiological processes and microbial community structure. This highlights the importance of taking *in situ* thermohaline conditions into account before developing a sampling plan in this extreme, but ecologically relevant environment.

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Soil Soundscapes from Seismic Arrays: Monitoring Bioturbation in Mima Mounds

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Seismic arrays are ubiquitous around the globe, with large volumes of data gathered continuously to monitor processes (typically earthquakes and explosions) that generate elastic waves and ground motion. However, these distinct events occur only during a small fraction of the time and the data at other times, comprising the bulk of the dataset, are considered ‘noise’ and are ignored. However, recent work has demonstrated that low-energy elastic waves can be generated by processes in the critical zone, potentially opening up a new avenue in shallow geophysical research: utilizing this previously discarded ‘noise’ to characterize near-surface processes like bioturbation in order to provide insight into connections between mechanistic drivers of change and source processes that act as catalysts for geomorphic evolution. To test the feasibility of this potentially ground-breaking frontier that bridges geomorphology, geophysics, and biology, we utilize a variety of techniques in order to provide real-time monitoring of bioturbation and other processes that likely exert a first-order influence on geomorphic features known as mima mounds in San Diego, California. We have installed a dense array of high-frequency, passive-source geophones at this site in an attempt to monitor and characterize this biotic disturbance, primarily driven by pocket gophers, to the subsurface for the first time. This technique is strengthened by the use of ground penetrating radar (GPR) and repeat active source surveying using a 40 kg propelled energy generator (PEG) to image the subsurface and model the shallow velocity field in order to better understand morphological change over time.

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Comparison of Temperature Preference and Q_{10} Between two Juvenile Shark Species

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Many ectotherms, including sharks, behaviorally thermoregulate to optimize physiological processes. Juvenile sharks often utilize estuaries as nursery grounds, that, among other benefits, provide warm water temperatures that increase metabolism and facilitate growth. Discerning how temperature influences the behavior and physiology at the juvenile life stage is important in understanding how environmental changes (e.g. human encroachment and climate change) may affect the distribution and movement of local species. Here we compare two abundant coastal species that possess contrasting activity levels: the benthic horn shark (*Heterodontus francisci*) and the demersal leopard shark (*Triakis semifasciata).* The aim of this study was to isolate temperature as a single variable to investigate the relationship of behavioral thermoregulation and metabolism. The objectives were threefold: 1) identify the temperatures juveniles prefer and avoid, 2) assess how temperature affects metabolism (Q_{10}) via measurements of oxygen consumption, and 3) compare between sexes and species. Both species exhibited increasing metabolic rates with increasing temperatures. Leopard sharks exhibited higher metabolic rates than horn sharks across all temperatures. However, horn sharks exhibited a higher overall Q_{10} suggesting they may experience greater metabolic stress traveling across thermal regimes. Our results suggest horn sharks are more likely to target environments closer to their preferred temperature than leopard sharks. Ultimately, this baseline assessment should be paired with future *in situ* tracking to elucidate the role of these parameters on habitat selection in juvenile sharks.

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Neuroanatomy in *B. Stephanieae* Through Immunohistochemistry

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The use of nudibranchs as model systems for adult neuroethology has been pivotal to elucidating the basis of animal behaviors, such as the role of neurotransmitters and circadian rhythms in controlling locomotive behaviors. These shell-less heterobranch molluscs are particularly suited to such investigations, given their distinguishable swimming and crawling behaviors and accessible sensory organs. However, very little is known about early life stages: how the neural system of nudibranchs controls their behavior during embryonic, larval and juvenile stages remains unclear, mostly due to the intractability of embryos in species currently used as model systems. Understanding the link between neuronal development and animal behavior at these early life stages is essential to comparing the dichotomous juvenile and adult behaviors. Therefore, we have established the aeolid nudibranch, *Berghia stephanieae*, as a model system; this species is easily manipulated during development, enabling us to study all stages of its brain's developmentWe found that the post-metamorphic juvenile brain is organized similarly to the adult brain of nudibranch neuroethological models. The cerebropleural ganglia are positioned dorsally to the pedal and buccal ganglia. Acetylated Tubulin-Like Immune Reactivity localizes in neurons connecting the oral tentacles, buccal ganglia, and rhinophores to the anterior end of the cerebropleural ganglion, and in neurons extending posteriorly to the ciliated foot. These neurons are visible under differential interference contrast microscopy. These results provide a starting point for building a clearer picture of the neuroanatomy of post-metamorphic *B. stephanieae*, and allow for future neuroethological studies.

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Observations of Runup, Inner-Surf Zone Waves, and Beach Morphology During Energetic Storm Events using a Stationary LiDAR

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Water level and beach elevation were observed with a stationary LiDAR sampling at 7 Hz during Hurricane Jose (9/18/17-9/21/17) and a Nor'Easter (2/7/2016-2/11/2016) at the U.S. Army Corps of Engineers Field Research Facility in Duck, NC. This extensive data set allows us to investigate the morphological response of the foreshore beach and the hydrodynamic components of runup and inner-surf zone (ISZ, located at the base of the swash zone) waves during energetic storm events. In both events, offshore incident wave heights reached ~4 meters at a pressure sensor array in 8-m water depth. During Hurricane Jose, hourly observations of the sub-aerial beach showed periods of upper beach accretion and lower beach erosion, which may be related to an existing scarp at the hurricane onset. LiDAR-observed significant ISZ wave heights reached a maximum of 0.8 meters with infragravity (IG) and seaswell (SS) components of similar magnitude. However, the runup during this storm event was IG dominated, with the IG component nearly twice that of the SS component. During the Nor'Easter, the entire sub-aerial beach profile eroded during the first half of the storm, with upper beach accretion and lower beach erosion occurring during the latter half. This switch from erosive to accretive regimes possibly corresponds to a change from IG dominated to SS dominated runup. ISZ significant wave heights in the SS band tended to be higher than in the IG band and reached a maximum of 1.25 meters. Empirical estimates of runup (based on foreshore beach slope and H_0L_0) were significantly correlated with observations. The IG runup component was generally well parameterized, but the SS and setup components were often underpredicted by up to ~50% and ~70%, respectively. Ongoing work, that combines observations and morphodynamic models, explores the relationship between ISZ wave heights, runup, and morphological change, and the drivers of error between observed and estimated runup.

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Biogeochemical observations and baseline CO_2 conditions in the Agua Hedionda Lagoon

Kenisha Shipley[1] and Todd Martz[1]

Next Generation Sequencing technologies have enabled many advances across biology with microbial ecology benefiting primarily through expanded sample sizes. Although the cost of running sequencing instruments has decreased substantially over time, the price of library preparation methods has largely remained unchanged. In this study, we developed a low cost, Estuarine environments are uniquely diverse coastal subsystems located at the land-river-ocean interface. Across different systems, carbon dioxide (CO_2) parameters and anthropogenic inputs can vary greatly given the heterogeneity between individual estuarine systems, which makes it difficult to characterize coastal ocean systems as a whole. The Agua Hedionda Lagoon (AHL) is a local estuary located in Carlsbad, CA comprising three interconnected basins, which make up a total of about 400 acres off the Pacific coast. This lagoon is highly impacted by the surrounding urbanization, land use, and densely populated community, making it susceptible to anthropogenic impacts. One of the primary features operating at the lagoon is the Carlsbad Aquafarm (CAF), which raises over one million pounds of Mediterranean Blue Mussels (*Mytilus edulis*) and Pacific oysters (*Crassostrea gigas*) every year. Understanding the baseline chemical distribution and variability will provide critical information needed by the stakeholders to manage the CAF and lagoon ecosystem. To assess the variable conditions in the AHL, an autonomous shore station system was employed at the CAF to collect continuous measurements for total dissolved CO_2 (TCO_2) every hour, and the partial pressure of CO_2 (pCO_2), pH, temperature, and salinity taken every 15 seconds. Additional sensors deployed in the adjacent lagoon basins and outside of the lagoon collected *in situ* data for salinity, temperature, dissolved oxygen, pH, and pressure, every 30 minutes. Data collected during November and December 2018 has been analyzed specifically to capture the changing estuarine CO_2 conditions during several rain events that occurred in this time frame.

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Scripps Community Outreach for Public Education

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Scripps Community Outreach for Public Education (SCOPE) is an example of a thriving, student-led, volunteer-driven, outreach program at a primarily research-focused institution. SCOPE started as a grassroots movement dedicated to engendering change through public education. Our unique educational approach of connecting graduate students and researchers directly with the public renews enthusiasm and respect for the environment and the scientific process. Additionally, this model provides an avenue for scientists to share their work, engage broader audiences, and improve their informal science communication skills. SCOPE has earned praise from participants and successfully expanded outreach and educational services to local and global communities through Scripps Institution of Oceanography (SIO) in the 17 years of program operation. Moving forward, SCOPE aims to further develop STEM outreach opportunities, especially for underserved students, and to incorporate content in creative ways which allow communities to experience research at SIO. SCOPE thus serves as a tractable model for a successful outreach organization that may be replicated at other STEM research institutions to the benefit of both the researchers and their broader communities.

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Fishes as "Mobile Monitors" of Hypoxic Conditions Across Ocean Basins

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Oxygen minimum zones (OMZs) contain the largest reservoirs of hypoxic waters in the world, comprising around 7% of total ocean volume. Climate change is expanding OMZs worldwide through a process known as deoxygenation, which is expected to have cascading effects throughout the open ocean and in to the deep sea. For example, deoxygenation can alter the distribution and decrease the biodiversity of fishes, ultimately affecting fisheries yields. The OMZ expansion and shoaling have already compressed the habitat for midwater fish in the southern California Current ecosystem, but the extent to which increasingly-low levels of oxygen affect fish growth and microchemistry remains poorly understood. We hypothesize that the hypoxic conditions found in different OMZs (both the Southern California Bight and the Benguela current ecosystem) will lead to unique elemental signatures in fish otoliths, which are similar to earbones and grow to reflect the surrounding environmental conditions much like the rings of a tree. Through the analysis of different fish species, we were able to detect common elemental patterns in the otoliths of those species living inside OMZs, across different ocean basins. This unique elemental signature was significantly different from that of a shallow marine fish species living outside the OMZs. By using fish as "mobile monitors" of hypoxic conditions, we seek to elucidate how the past, current, and future deoxygenation processes are likely to affect fish growth.

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Exploring the Survival and Growth of *Sicyonia ingentis* Under Ocean Warming and Ocean Acidification like Conditions

Zoe C. Sebright[1] and Jennifer R.A. Taylor[1]

Crustaceans are relatively understudied in regard to their vulnerability to the changing ocean conditions of ocean acidification and ocean warming. Although they are generally considered less vulnerable to reduced pH and increased temperature than other calcifying groups, studies have found potential effects on their growth, behavior, and physiology. In this study, we examined the vulnerability of the ridgeback prawn, *Sicyonia ingentis*. Prawns were exposed to reduced pH (7.50 ± 0.05) and increased temperature (16 ± 1°C) conditions in a full factorial design for twelve weeks. Prawns were monitored for survival, growth, and molting throughout the experiment. Growth was evaluated in terms of carapace length (CL), mass (M), and buoyant mass (BM). Growth in the second molt in terms of CL and M was significantly reduced for the reduced pH and increased temperature treatment in comparison to the control. An examination of pH and temperature interactions associated with this show that percent growth decreases as temperature increases for all measures of growth. CL and M also show differences in percent growth for pH, with both having larger percent growth for ambient pH in comparison to reduced pH. Both groups experiencing ambient temperature had a survival rate of 66%, regardless of pH treatment. The combined effects treatment had an 8% survival rate, while the increased temperature, ambient pH treatment saw a 25% survival rate. These results indicate that the combined effects of reduced pH and increased temperature have a greater effect on growth than reduced pH alone.

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The California Current Ecosystem (CCE) Interactome

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Mesoscale features are prominent in the California Current Ecosystem (CCE). One such feature, westward propagating coastal filaments, can mediate the lateral transport of nutrients and organic matter from eutrophic nearshore to oligotrophic offshore regions. Heterotrophic bacteria, as dominant recyclers of organic matter, play a key role in modulating this transport by transforming dissolved and particulate organic carbon (DOC and POC). Here we present results from study of a coastal filament that developed near Morro Bay, CA in June of 2017. Interactions between microbial community members, examined using 16S and 18S rRNA transcripts, were identified and visualized via microbial correlation networks. These relationships were further evaluated in the context of regional chemotypes as detected by environmental metabolomics. These networks allow us to examine how relationships between primary and secondary producers shifted across gradients in nutrient status and carbon production as the filament was propagated offshore.

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Insights into the Adaptation of Hydrocarbon-Degrading Microbes to Life at High Pressure: the Role of Motility and Chemotaxis

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The *Deepwater Horizon* (DWH) oil spill is unique from previous anthropogenic oil spills in that it originated at depth. The unexpectedly extensive microbial response to the deep-sea oil plume that developed at ~1,100 meters below sea level (mbsl) following DWH raised questions regarding the impact of hydrostatic pressure on microbial access to and degradation of hydrocarbons. While studies have demonstrated that hydrostatic pressure inhibits the motility of mesophilic bacteria and hydrocarbon degradation, the impact of pressure on hydrocarbon chemotaxis has yet to be investigated. Here we address this question using hydrocarbon-degrading bacteria — belonging to the genera *Halomonas, Shewanella,* and *Alcanivorax* — isolated from the Gulf of Mexico following DWH as model organisms. We hypothesized that our model strains — since they are not piezophiles — would show inhibited growth, activity, motility and chemotaxis at pressures relevant to DWH. While growth decreased at high pressure for all study strains, pressure had little effect on activity of the strains. Motility — assessed using a high-pressure microscope chamber — was found to be relatively resilient to pressure, showing little change in fraction of motile cells and swimming speed between 0.1 and 60 MPa (equivalent to ~6,000 mbsl). In fact, decreased temperature had a greater influence on motility than pressure. Ongoing studies include assessment of pressure effects on hydrocarbon chemotaxis, as well as isolation and characterization of motility and chemotaxis mutants using transposon mutagenesis to identify genes important for hydrocarbon chemotaxis, both at atmospheric and high pressure. Cumulatively, these analyses will enable a better understanding of the impacts of pressure on microbial motility and hydrocarbon chemotaxis in the deep sea.

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Soil Soundscapes from Seismic Arrays: Monitoring Bioturbation in Mima Mounds

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Seismic ~~Noise~~?

- Seismic arrays are ubiquitous around the globe, with obvious applications (EQs)
- The vast majority (99%) of data recorded are considered noise and are filtered out
- Recent work[1] demonstrates that processes in the critical zone generate waves

In this exploratory work, we ask...

Can we utilize this 'noise' to characterize near-surface processes like bioturbation?

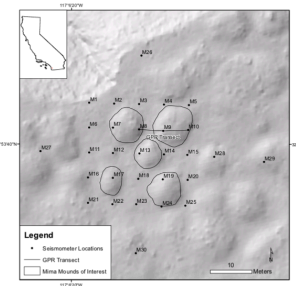

Fig. 1) DEM of the field site in San Diego, CA (see inset) showing the locations of Mima mounds of interest, the installed seismic array, and the GPR transect seen in Fig. 5

To test the feasibility of this potentially ground-breaking frontier that bridges geomorphology, geophysics, and biology, we have installed an array of 30 high frequency, passive source geophones centered over five prominent Mima mounds in the Elliot Chaparral Reserve maintained by UCSD (Fig. 1) in an attempt to monitor and characterize bioturbation to the very-shallow (<1m) subsurface for the first time.

Additionally, we utilize repeat-survey ground penetrating radar (GPR) over these same mounds to detect physical changes in the subsurface [tunnels]

What is a Mima Mound?

Fig. 2) **Top** photo oriented NE at field site, mound in foreground is ~1m tall and ~8m in diameters; **Middle** photo oriented S at field site; note vernal pool ponding in foreground; **Bottom** photo oriented NNE of array in late April -- lots of vegetation!

Mima mounds (Fig. 2) are also ubiquitous across the globe
They are found on every continent except Antarctica[2]

"They are a mystery that has been discussed for over 150 years… and have generated a greater variety of hypotheses than any other geologic feature" – Higgins, *Geology* 1990

These geomorphic features are low relief (<2 m), relatively circular and domelike mounds composed of loose, unstratified, often gravelly silt or loamy soil material

How do they form?

Great question. There are over **40** hypotheses...
Burrowing? Coppicing? Seismicity? Shrink/swell?

In San Diego, they are *at least* maintained by bioturbation and associated soil translocation from pocket gophers[3]

Their genesis is still not totally solved, but is most likely polygenetic and involves many soil-geomorphic processes during formation

Preliminary Data and Discussion

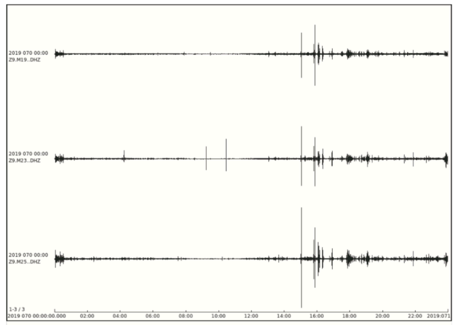

Fig. 4) Unfiltered and unprocessed seismic waveforms from three geophone stations (top: M19, middle: M23, bottom: M25 [see Fig. 1]) for the same 24-hour period on March 11, 2019.

25 seismometers at 6 m intervals over a 575 m^2 area along wih 5 additional seismometers at varying distances in all cardinal directions have been continuously recording ground motion since December 19, 2018 at 500 samples per second

They can record frequencies up to ~200 Hz and down to as low as 1 Hz

These seismometers record a lot of high frequency events -- mainly from aircraft and vehicles...

...we will employ waveform differencing between stations (e.g. Fig. 4) to filter these out

Ideally, we are then left with sets of unique, low frequency events from the mounds that we can characterize over time

GPR potentially allows for us to detect changes in the subsurface of these mounds (Fig. 5) via redistribution of stoney layers (inset) and foraging tunnels over time. We scan the same transects/grids every 3 months in an attempt to characterize this.

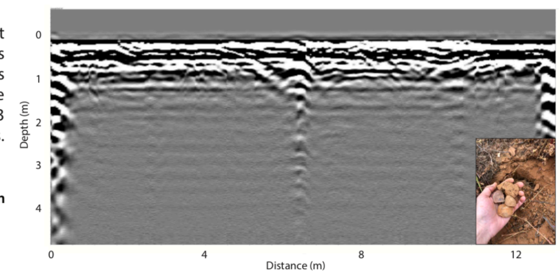

Fig.5) Unprocessed GPR transect (250 MHz antenna; 0.8 nm/s velocity) over the northeastern Mima mound (see Fig. 1); (inset photo) various stones (primarily granitic) found in the upper 3-8 cm of this Mima mound

Table 1. Mima mound statistics derived from LiDAR-ArcGIS analysis

Location	Circumference (m)	Surface Area (m^2)	Volume (m^3)	Height (m)	Max Diameter (m)	Elongation
NW Mound	26.28	64.49	85.42	0.88	8.65	1.07
NE Mound	30.67	80.79	123.18	0.83	10.52	1.21
Central Mound	21.32	40.86	49.86	0.72	7.18	1.11
SW Mound	19.64	32.02	23.21	0.52	6.97	1.36
SE Mound	26.37	60.31	77.74	0.87	9.09	1.15

Meet the Bioturbators: Pocket Gophers

Bioturbation is the common denominator of the complex origin of Mima mounds. Valley pocket gophers (right) do (most of?) the work here in CA

Mass and energy balance calculations indicate that one species of pocket gopher in central CA moved ~4.4 trillion metric tons of soil in building mounds that cover roughly 10% of the state[4]

The Dalquest-Scheffer-Cox genesis model[2]

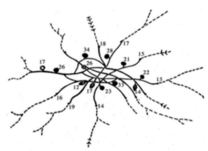

Fig. 3) Plan view of pocket gopher reproductive-food-storage-living center (~3 m in diameter) -- numbers indicate nests[2].

Any outward burrowing by soil animals from their nesting centers (Fig. 3) includes a centripetal component, where some soil is back-transferred to the center

Gophers live 2-3 years at most, and only occupy one mound at a time. Surprisingly, mounds can form in decades[5]

Worms and Creep - Future Directions

In addition to the techniques described, we will also carry out a repeat active-source survey using a 40kg propelled energy generator (Fig. 6) to obtain a model of the shallow velocity field for these mounds.

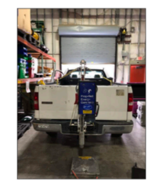

Fig. 6) The PEG mounted to the back of a pickup truck. This thing is so cool.

<u>*Coming this summer, we are also taking this show on the road*</u>

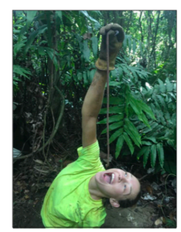

Fig. 7) Emma Harrison about to eat a worm in the Luquillo Mountains, Puerto Rico.

Seismometers, coupled with subsurface acoustic recorders, will be deployed in Puerto Rico to characterize active bioturbation by ridiculously long endogenic worms (Fig. 7).

Seismometers will be deployed along a hillslope in the Golden Gate National Recreation Area (lower right) in an attempt to monitor soil creep. We will then compare our data to recent granular hillslope models[6].

Acknowledgements & References

We would like to thank Greg Chavez, Akram Mostafanejad, and Pnina Miller at IRIS/PASSCAL at New Mexico Tech for all the assistance with setting up the arrays (and loaning us the equipment!). We would also like to thank Elsa Cleland at UCSD.

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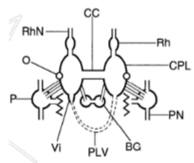
Neuroanatomy in juvenile *B. Stephanieae* through Immunohistochemistry

CA. Whitesel, V. Barone, DC. Lyons

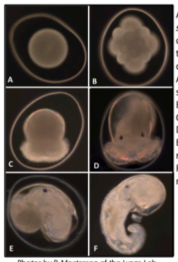
Introduction

- *B. stephanieae* is a new experimental system with potential to become an important addition to the understanding of aeolid nudibranch development.
- The juvenile brain is organized similarly to the adult brain, allowing for comparative neuroanatomical studies between the juvenile and adult stages.
- Neuroethological studies would benefit from neurotransmitter localization in the central nervous system in the juvenile due to differing behavioral responses from adult *B. stephanieae*.



Carrol & Kempf[1]

CC- Cerebral commissure
RhN- Rhinophore Nerve
O- Optical Ganglion
P- Pedal Ganglion
Vi- Visceral Ganglion
Rh- Rhinophore Ganglion
CPL- Cerebropleural Ganglion
PN- Pedal Nerve
BG- Buccal Ganglion
PLV- Plueral Visceral Loop

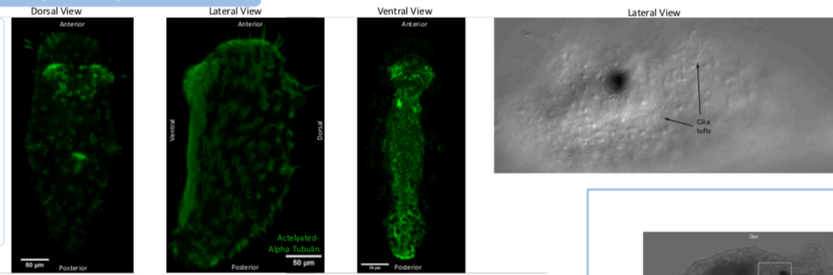


Abbreviated *B. stephanieae* development time series, detailing the A) single cell stage, B) 12 cell stage, C) early veliger, D) late veliger, E) beginning of metamorphosis, F) end of metamorphosis

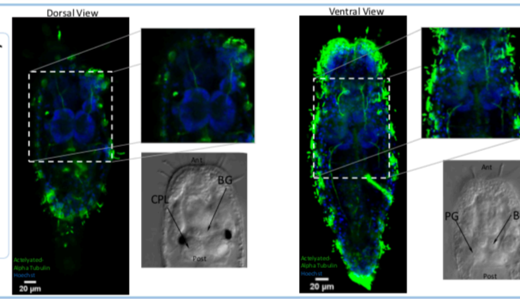
Photos by P. Masterson of the Lyons Lab

Acteylated Alpha Tubulin-LIR

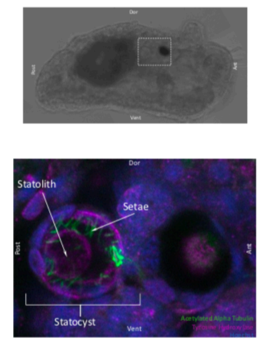
External Immunoreactivity



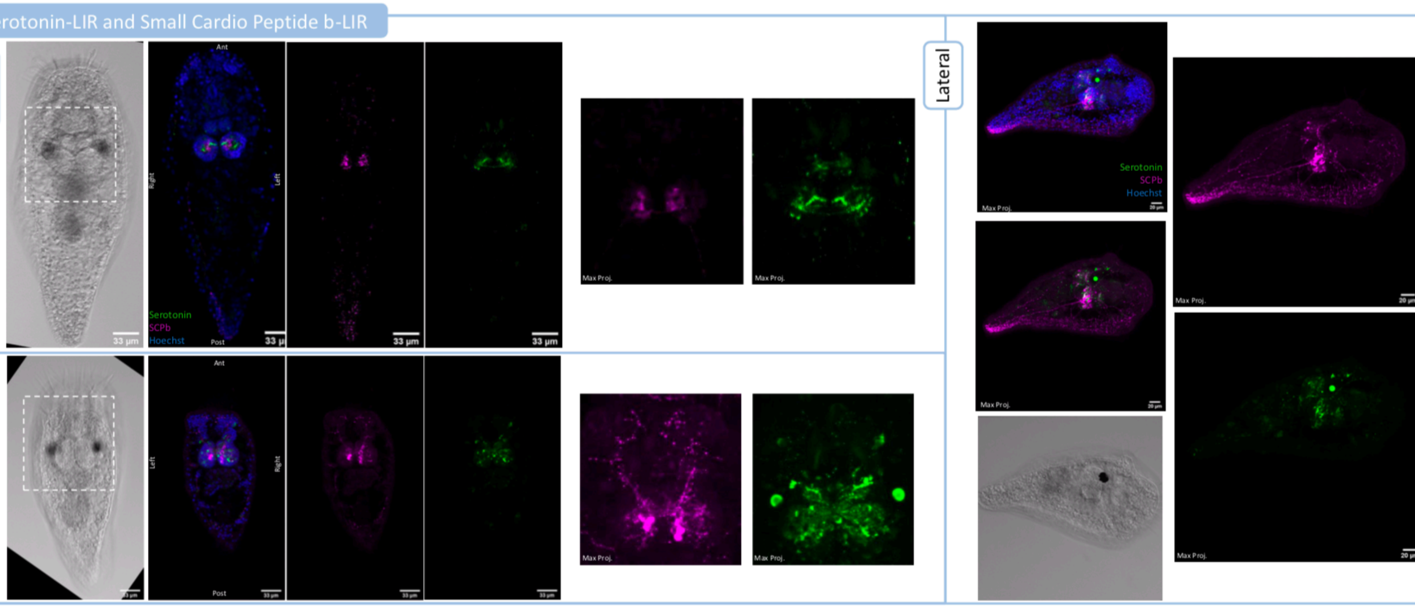
Internal Immunoreactivity



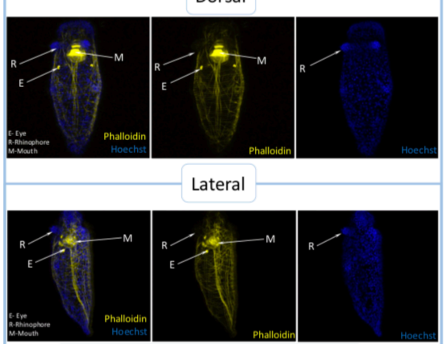
Statocyst Immunoreactivity



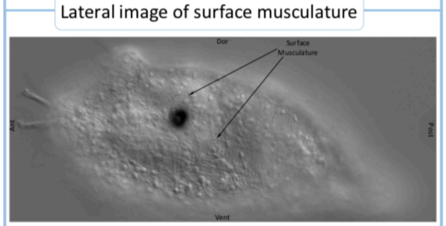
Serotonin-LIR and Small Cardio Peptide b-LIR



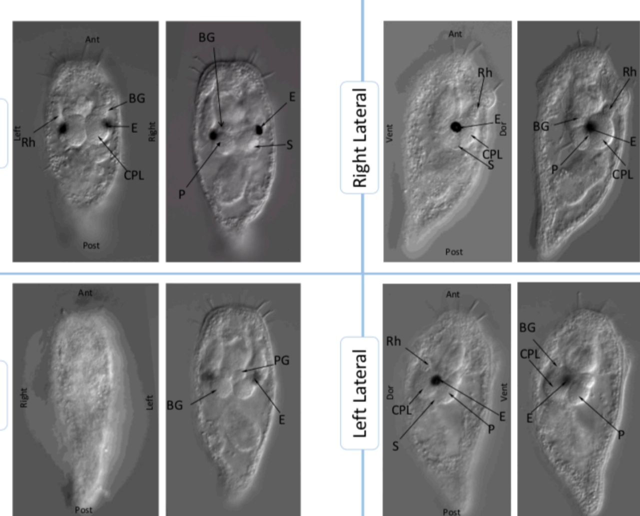
Phalloidin



Lateral image of surface musculature



Differential Interference Contrast Microscopy



BG- Buccal Ganglion
CPL- Cerebropleural Ganglion
E- Eye
O- Optical Ganglion
P- Pedal Ganglion
Rh- Rhinophore Ganglion
S- Statocyst

Methods

Fixation	30 min 6.5% $MgCl_2$; 2 hour PLP Fixative
Permeabilization	1 hour 1% Triton-X
Primary Antibody	24 to 96 hours; 1:50 to 1:2000
Secondary Antibody	24 hours; 1:500 Alexa Fluor 594/488/647
Nucleic Staining	5 minutes; 1:2000 Hoechst or 10 minutes; 1:1000 DRAQ5
Musculature	10 minutes; 1:1000 Phalloidin in Alexa Fluor 647

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SCRIPPS INSTITUTION OF OCEANOGRAPHY
UC San Diego

The California Current Ecosystem (CCE) interactome

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[1]Scripps Institution of Oceanography, University of California San Diego, La Jolla,CA
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FIGURE 2: Interactome networks of 16S and 18S communities (examined using cDNA from rRNA transcripts) with environmental metabolites (examined using LC-MS/MS and identified with GNPS)

A. Main network

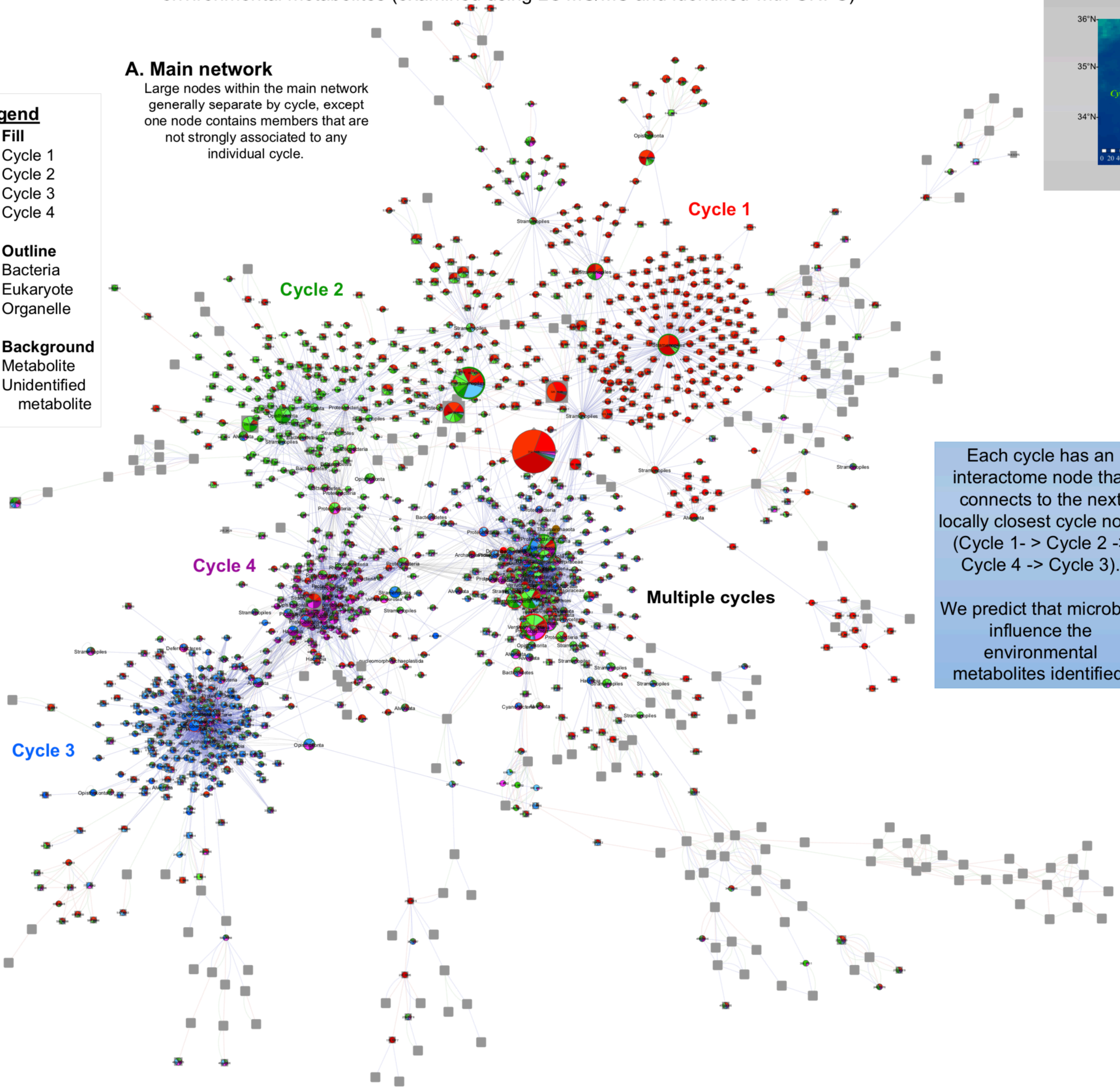
Large nodes within the main network generally separate by cycle, except one node contains members that are not strongly associated to any individual cycle.

Legend

Fill
- Cycle 1
- Cycle 2
- Cycle 3
- Cycle 4

Outline
- Bacteria
- Eukaryote
- Organelle

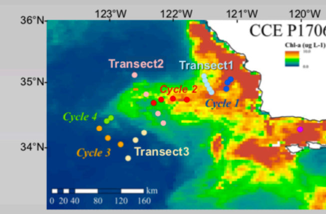
Background
- Metabolite
- Unidentified metabolite



Each cycle has an interactome node that connects to the next locally closest cycle node (Cycle 1- > Cycle 2 -> Cycle 4 -> Cycle 3).

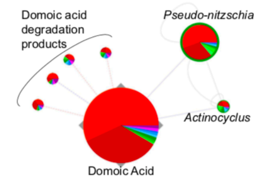
We predict that microbes influence the environmental metabolites identified.

FIGURE 1: The California Current Ecosystem (CCE)



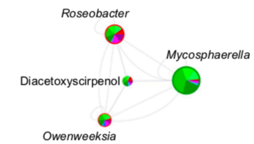
Satellite derived map of Chl *a* concentration courtesy of Brandon Stephens – High chlorophyll concentrations, indicative of productive, recently upwelled waters, were used to identify and observe the Morro Bay filament. Sampling locations are marked by dots and labelled to designate Lagrangian "cycles" from Eulerian "transects".

B. *Pseudo-nitzschia*



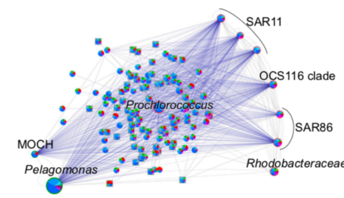
Pseudo-nitzschia is known to produce the neurotoxin domoic acid.

C. Marine Fungi



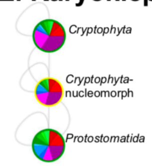
Diacetoxyscirpenol is a mycotoxin- a secondary metabolite produced by fungi. This network is likely particle associated.

D. *Prochlorococcus*



Prochlorococcus, SAR11, and *Pelagomonas* are all known to be found in oligotrophic offshore environments. Many metabolites surrounding *Prochlorococcus* are amino acid derivatives.

E. Karyoklepty



Karyoklepty is when a predatory organism steals the nucleus from another organism, here identified by the nucleomorph.

Funding provided by:

Insights into the Adaptation of Hydrocarbon-Degrading Microbes to Life at High Pressure: the Role of Motility and Chemotaxis

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1 - BACKGROUND

- In 2010 the *Deepwater Horizon* oil spill deposited 779 million liters (~209 million gallons) of Louisiana light sweet crude oil into the Gulf of Mexico[1].
- A combination of physical (pressure) and chemical (dispersant) parameters led to the development of a deep-sea oil plume after the Macondo blowout[2-4].
- Hydrocarbon-degrading microbes mainly from the class *Gammaproteobacteria* enriched near the blowout in response to the oil spill[3].
  - Suggests that microbial metabolism of oil and natural gas played a significant role in the unexpectedly rapid disappearance[5] of the crude oil.
- Motility is one of the most pressure-sensitive microbial processes yet characterized[6,7].

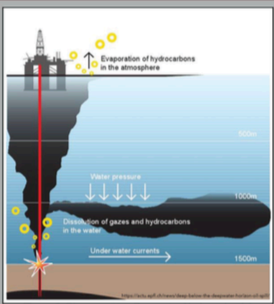


Figure 1. Diagram of the *Deepwater Horizon* oil spill's deep-sea oil plume.

2- SUMMARY OF WORK

Pressure Effects on Growth:
- Growth of study strains in standard pressure vessels was severely diminished due to oxygen limitation.
  - Addition of the biological buffer HEPEs and the alternate electron acceptor nitrate increased growth rate by at least 1 order of magnitude for all study strains.
  - All 3 study strains are moderately pressure sensitive (grow at 25 MPa, but not 50 MPa).

Pressure Effects on Activity
- BONCAT with HPG was used to assess the impact of pressure on microbial activity (protein synthesis).
  - Pressure (25 MPa, equivalent to ~2,500 mbsl) has little effect on activity of 2 out of 3 study strains. Work on 3rd strain is still ongoing.

Pressure Effects on Motility:
- Long-term pressure effects on motility were assessed using a qualitative pressurizeable serum vial method.
  - All three study strains are motile at 10 and 25 MPa (equivalent to ~1,000 and 2,500 mbsl, respectively).
- Short-term, quantifiable pressure effects on motility were assessed using a high-pressure microscopy chamber.
  - Temperature had a greater impact on both fraction of motile cells and swimming speed than pressure.
  - At pressures & temperatures relevant to *Deepwater Horizon*, all 3 study strains are still motile.

Pressure Effects on Chemotaxis:
- Development of a capillary assay to determine impacts of pressure on hydrocarbon chemotaxis is underway.
- Work to obtain motility and chemotaxis mutants at atmospheric and high hydrostatic pressure using transposon mutagenesis is currently ongoing.

3 - MOTIVATION

Physical factors such as temperature and pressure can alter the motility of microorganisms, which in turn influences rates of substrate acquisition and biogeochemical cycling. Pressures present at the depths of the Deepwater Horizon oil spill are known to inhibit the motility of mesophilic bacteria[6,8]. It is also suggested that moderate pressures can decrease rates of hydrocarbon degradation[9,10].

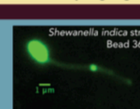
This study aims to assess how high hydrostatic pressure impacts microbial motility and hydrocarbon chemotaxis in the deep sea.

4 - STUDY STRAINS

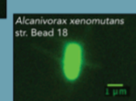
Study strains, isolated from the Gulf of Mexico after *Deepwater Horizon*, were obtained from Dr. Romy Chakraborty.

Strain Name	Bead 10BA	Bead 18	Bead 36
Closest Cultured Relative	*Halomonas titanicae*	*Alcanivorax xenomutans*	*Shewanella indica*
Isolation Depth	1509 m	1509 m	46 m
Pressure Sensitivity	0.442/0.251	0.580/0.296	0.635/0.498
Pressure-Motility Threshold	70 MPa	80 MPa	100 MPa
Swimming Speed Pressure Threshold	60 MPa	90 MPa	80 MPa

Table 1. Study strain characteristics. Closest cultured relative of study strains is based off 16S rRNA gene sequences. 'Pressure Thresholds' are the approximate pressure at which motility or swimming speed is 50% of that observed at atmospheric pressure. Pressure sensitivity is the ratio of stationary phase OD600 values for growth at 0.1 MPa/25 MPa.



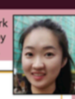
Flagellar staining with NanoOrange[11].



5 - PRESSURE EFFECTS ON ACTIVITY

Activity of cells at atmospheric and high hydrostatic pressure was assessed using BONCAT.

BONCAT work completed by Tianhan Xu.



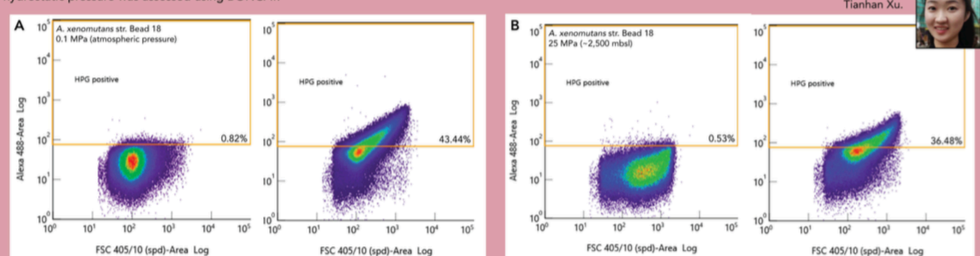


Figure 2. FACS plots of HPG-labeled cells at 0.1 MPa (A) and 25 MPa (B). In both A & B, the left plot is background fluorescence and the right plot is active cells labelled with the fluorophore.

6 - PRESSURE EFFECTS ON GROWTH

Standard pressure vessels limit oxygen available to microbes, often leading to low oxygen conditions due to microbial oxygen consumption. Growth of these strains was greatly enhanced under nitrate respiratory conditions. **Growth rates increased by at least 1 order of magnitude.**

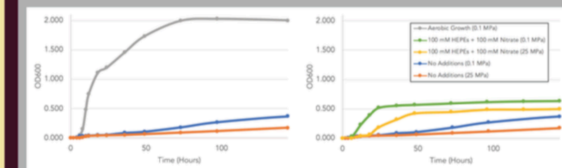


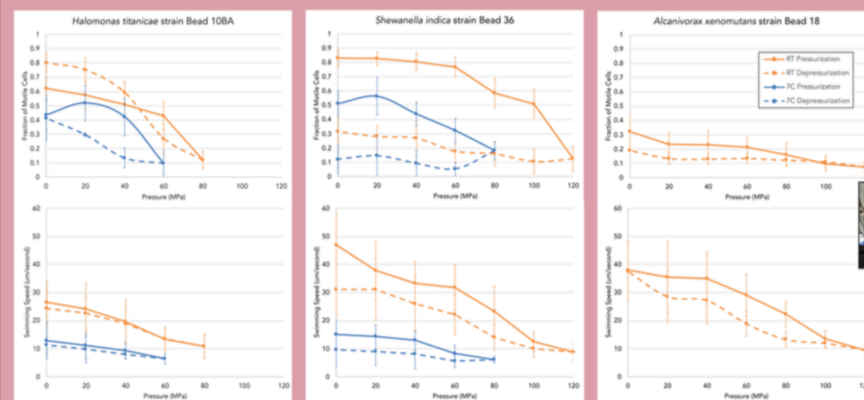
Figure 3. Growth of *S. indica* str. Bead 36 under various culture conditions. OD600 – Optical density at 600 nm wavelength.

7 - PRESSURE EFFECTS ON MOTILITY

Pressure effects on motility were assessed using 2 methods:

1. Qualitative, long-term analyses using **glass serum vials** containing motility agar.
2. Quantitative, short-term analyses using **high pressure microscope chamber.**

growth pressure = 25 MPa (equivalent to ~2,500 mbsl)



Data was collected using a high-pressure microscope chamber attached to a phase contrast microscope. System developed by Nishiyama and Sowa (2012)[13].

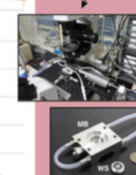
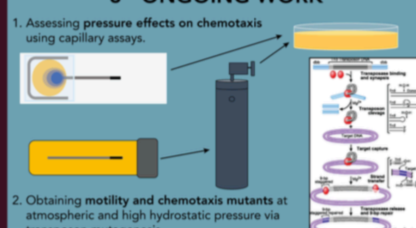


Figure 4. Pressure effects on fraction of motile cells and swimming speed. Microscopy and video analysis performed as described in Nishiyama and Arai (2017)[12].

8 - ONGOING WORK

1. Assessing **pressure effects on chemotaxis** using capillary assays.
2. Obtaining **motility and chemotaxis mutants** at atmospheric and high hydrostatic pressure via transposon mutagenesis.



9 - CONCLUSION

- **Pressure Effects on Growth:**
  - Addition of the alternate electron acceptor nitrate greatly improves growth in standard anaerobic pressure vessels.
  - Growth of all 3 study strains is moderately pressure sensitive between 10-50MPa.
- **Pressure Effects on Activity:** Pressure has little effect on cellular activity (work for *S. indica* str. Bead 36 is ongoing).
- **Pressure Effects on Motility:**
  - Pressure effects both the fraction of motile cells and the swimming speed.
  - Lack of original motility restoration after decompression indicates high pressure damage to the flagellar structure/function .
  - At moderate pressures, temperature has a greater impact on motility than pressure does.

GULF of MEXICO RESEARCH INITIATIVE

ACKNOWLEDGEMENTS

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