RESEARCH PROJECT PROFILES

December 2011

PROJECT TITLE: NOAA OCEAN ACIDIFICATION MOORING NETWORK

CONTACT INFORMATION: Research Institution: NOAA Pacific Marine Environmental Laboratory (PMEL)

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PROJECT DESCRIPTION:

The focus of PMEL's ocean carbon observation program is to document the evolving state of ocean carbon chemistry using measurements on ships and autonomous platforms, study the processes controlling the role of the ocean in the global carbon cycle, and investigate how rising atmospheric CO_2 and climate change affect the chemistry of the oceans and its marine ecosystems. Since ocean acidification emerged as an important scientific issue, the PMEL Carbon Group has been augmenting and expanding our observational capacity by adding pH and other biogeochemical sensors (O_2, chlorophyll, turbidity) to a variety of observing platforms. In particular, high frequency observations on moorings provide valuable information for better understanding natural variability in ocean acidification over daily to seasonal cycles. In addition, we have responded to the critical need for intensive time series measurements in highly productive coastal systems by focusing much of our initial efforts on upgrading coastal CO_2 moorings around the U.S. to include ocean acidification measurements. Our ocean acidification mooring network now includes 10 moorings in open ocean waters, coastal systems, and coral reefs. The major goals of this research are to contribute to a better understanding of the temporal and spatial variability of carbon chemistry in the surface ocean and to expand the observational basis for developing predictions of future changes in ocean acidification and its consequences for marine ecosystems.

KEYWORDS:

ocean acidification, ocean carbon, observations, autonomous platforms, buoys

FUNDING AGENCY: NOAA

PROJECT TITLE: SANTA CRUZ OCEAN OBSERVATORY PLATFORM (SCOOP)

CONTACT INFORMATION:

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***PROJECT DESCRIPTION*:**

The SCOOP was designed with several goals in mind. The primary goal behind the development and installation of the station is to detect and investigate harmful algal blooms (HABs) and red tides. The station will aid researchers in monitoring the presence, distribution, abundance and population dynamics of HAB and red tide forming species. Monitoring such features of bloom-forming phytoplankton species as well as the oceanographic conditions related to bloom formation is an essential step towards prediction of HABs and red tides, which ultimately impact human health, wildlife, and fisheries. Additionally, the pier-based station provides researchers with a platform where emerging technologies and instrumentation can be tested. New tools are routinely developed that can allow for enhanced ecosystem research and resource management, and the station serves as a trial for new instruments. This station is considered a prototype – its success could lead to the development of a cost-effective model for possible adaptation and deployment by organizations in other regions.

KEYWORDS

Ocean observing; harmful algal bloom; phytoplankton;

***FUNDING AGENCY* :**

California Ocean Protection Council
California Sea Grant
Central and Northern California Ocean Observing System (through NOAA funding)
NOAA Harmful Algal Bloom program

PROJECT TITLE: WILL A WARMER, MORE ACIDIC OCEAN LEAD TO INCREASED PSEUDO-NITZCHIA BLOOM TOXICITY IN THE SOUTHERN CALIFORNIA BIGHT?

CONTACT INFORMATION:

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PROJECT DESCRIPTION:

Ocean acidification may have additional negative impacts on shellfish culturing and harvesting other than the well recognized direct deleterious effects on calcification and larval development. For instance, the shellfish industry along the West Coast of the U.S. has also been heavily impacted by harmful blooms of the toxic diatom Pseudo-nitzschia spp., during which marine food web accumulation of the neurotoxin domoic acid has led to economic damage through harvesting closures. Our recent work suggests that elevated seawater CO_2 can strongly stimulate the production of domoic acid by Pseudo-nitzschia cells, leading to potentially much more toxic blooms. Thus, anthropogenic enrichment of the ocean with CO_2 (e.g., ocean acidification) could greatly exacerbate the already substantial damage that these harmful algal blooms do to commercially important species ranging from shellfish to finfish. However, almost nothing is currently known about how the toxicity of Pseudo-nitzs
chia species will be affected by increasing CO_2 in combination with other concurrent climate change variables, such as sea surface warming and changes in nutrient supplies and light fields. Our Sea Grant-funded pilot project is examining domoic acid production by cultured and natural populations of local Pseudo-nitzschia species under simulated future ocean conditions of temperature, CO_2 (pH), irradiance, and nutrient availability. This information will allow marine resource managers and the aquaculture and fishing industries to better predict and help prepare for the potentially much more toxic harmful algal blooms that may occur in the future.

KEYWORDS:

Ocean acidification, Pseudo-nitzschia, domoic acid, toxins, harmful algal blooms

FUNDING AGENCY : California Sea Grant

PROJECT TITLE: CALIFORNIA DEPARTMENT OF FISH AND GAME SHELLFISH HEALTH LABORATORY

CONTACT INFORMATION:

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PROJECT DESCRIPTION :

My laboratory, which is located within the UC Davis Bodega Marine Laboratory, conducts research on infectious diseases of economically and ecologically important California shellfish. A large focus has been on a bacterial disease of abalone, withering syndrome, and the role of temperature in expression of the disease. I am generally interested in the effects of ocean acidification on shellfish disease processes, particularly as they apply to fisheries management, restoration of depleted species and aquaculture. My laboratory monitors wild and cultured California shellfish populations for the occurrence of pathogens and diseases, currently on an intermittent basis.

KEYWORDS :

disease, pathogen, infection, oyster, abalone

FUNDING AGENCY (if available):

PROJECT TITLE: CHARACTERIZING CARBONATE CHEMISTRY AND BIOLOGICAL RESPONSE IN THE SAN JUAN ARCHIPELAGO; UNIVERSITY OF WASHINGTON AND FRIDAY HARBOR LABORATORIES

CONTACT INFORMATION:

Research Institution:	NANOOS, University of Washington
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PROJECT DESCRIPTION :

We have initiated a seawater sampling program in the San Juan Archipelago intended to generate a time series of carbonate chemistry measurements in local waters. The project builds on an existing sampling program directed by Jan Newton combined with new work by students and faculty at FHL, including O'Donnell, Carrington, and Klinger. Focused biological research is conducted by student investigators and in several courses offered at FHL. Student training in ocean acidification research is a chief objective of the integrated program.

KEYWORDS:

Salish Sea, San Juan Archipelago, Puget Sound, training

FUNDING AGENCY (if available):

PROJECT TITLE: DOCUMENTED pH DECLINE IN COASTAL WASHINGTON AND ECOSYSTEM IMPLICATIONS

CONTACT INFORMATION:

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PROJECT DESCRIPTION:

My work in marine ecology has focused on the processes that determine the success of species in the nearshore environment. I am taxonomically general, but have special affection for seaweeds, invertebrates and fishes. Through my long-term studies on the outer coast of Washington state, I have developed an appreciation for the combined roles of ocean-driven events to the idiosyncratic effects of particular species interactions.

My concern and expertise in ocean acidification have come about due to the patterns that I have documented at Tatoosh Island in Washington state (collaborative with Tim Wootton) showing: 1. a decline in seawater pH over the past 10 years that is 7 times greater than expected[1], and 2. a similar decline in the carbon isotope value of the shell material of California mussels over the past decade[2], 3. the unprecedented stable carbon isotope values recorded by shells now compared with those from previous decades and millennia[2], 4. the decline in mussel shell thickness from pre-Columbian time to the present[3].

Current research in my lab related to OA emphasizes both continued seawater monitoring and data collection to link changes in ocean chemistry with *in situ* responses of ecosystems in nature, using community dynamics data as well as target studies with particular species. The seawater monitoring that we do is summarized in the table below. The biological monitoring includes Wootton's continued point censuses and population count of all organisms in replicated plots in the mussel bed (initiated in 1993, Pfister's estimates of kelp demography for *Alaria nana* (since 1997) and *Pleurophycus gardneri* (since 1991), and tidepool fish recruitment (since 1989).

Seawater parameters collected at Washington sites	Shore-based Locales: Tatoosh Isl‡	Shore-based Locales: 3 sites eastward toward Port Angeles, WA§	Ship-based Offshore: All 4 sites 2 km offshore
water nutrients	*monthly*	*monthly*	*monthly*
temperature	*10-30 min*	*10 min*	*monthly*
pH, DO,chl *a*, sal	*30 min*	*opportunistically*	*monthly*
spectrophotometric pH	*~10 d/month*		
pCO_2, TA (Scripps)	*~6 d/month*		*monthly*

‡(48.32,-124.74),§Second Beach(48.37,-124.40),Slip Point(48.26,-124.25),Observatory Pt(48.26,-124.25)

We are further targeting several species where we can analyze historical versus modern indicators of the environment. For example, my graduate student, Sophie McCoy, is repeating the identical experimental analysis of crustose coralline algal growth and species interactions on Tatoosh that R. T. Paine did in the early 1980s, while supplementing these with pCO_2 manipulations at the Shedd Aquarium in Chicago. Nanxi Bian, a geophysical sciences student, is further developing high resolution stable isotope sampling, and using Laser Ablation ICP-MS to look for elemental changes in mussel shells over decades and millenia, and their relationships to contemporary pH change.

My work through the years has been made possible by funding from the NSF, the Mellon Foundation, and the SeaDoc Foundation. The Makah Tribal Nation has generously allowed access.

[1]Wootton, J. T., C. A. Pfister, J. D. Forester. 2008.Dynamical patterns and ecological impacts of changing ocean pH in a high-resolution multi-year dataset. *Proceedings of the National Academy of Sciences* 105:18848-18853. [2]Pfister, C. A., S.J. McCoy, J. T. Wootton, P. A. Martin, A. S. Colman, D. Archer. 2011. Rapid environmental change over the past decade revealed by isotopic analysis of the California mussel in the northeast Pacific. *PLoS ONE* 6(10):e25766. doi:10.1371/journal.pone.0025766. [3]Pfister, C. A., K. Roy, , J. T. Wootton, S.J. McCoy, R. T. Paine, , T. H. Suchanek, E. Sanford. submitted ms. Long-term decline in shell calcification of a foundational species in the northeast Pacific Ocean.

KEY WORDS: pH decline, mussels, Mytilus californianus, carbon isotopes, elemental analysis, long-term research, Tatoosh Island, kelp, decreased calcification, Laser Ablation ICP-MS, crustose coralline algae (CCA)

PROJECT TITLE: OCEAN ACIDIFICATION AND EMERGING DISEASES IN THE PACIFIC NORTHWEST

CONTACT INFORMATION:

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PROJECT DESCRIPTION:

Shellfish are important species for our growing marine shellfish aquaculture industry and play critical roles in our marine ecosystems, an environment that is increasingly threatened by environmental change. In the Pacific Northwest the environment has changed in a manner that has contributed to increase mortality of bivalve larvae in hatcheries and also appears to have decreased natural recruitment. Several local shellfish hatcheries, upon which nearly the entire bivalve culture industry relies, have experienced severe losses over the past few years. Several factors have been attributed to this problem including temperature, ocean acidification, and re-emerging pathogens. Given the large-scale environmental change observed in our marine ecosystems and the relationship of host stress response and pathogen virulence with environmental conditions, it is critical to examine the problems facing bivalve larvae from a regional perspective by systematically assessing how the environment influences the spread of disease and the ability of oysters to effectively respond to stress. The goal of this proposal is to characterize the factors that threaten the aquaculture industry and wild shellfish. The primary approaches include a series of laboratory experiments and environmental sampling. This research effort has been developed to test the following hypothesis: Environmental stressors (elevated temperature and reduced pH) will enhance disease expression and reduce larval bivalve survival. More specifically we will test the impact of single and multiple biotic and abiotic stressors on larval bivalves with a focus on the most economically important regional species, the Pacific oyster. In order to assess the impact of biotic and abiotic environmental factors on bivalve health, we will also assess the abundance of oysters and other larvae in the wild in relation to water quality parameters. The specific research objectives are to: 1) Characterize the interrelationship of altered environmental conditions, pathogen, and oyster response under controlled conditions and 2) Identify factors in Pacific Northwest hatcheries and in the wild that are associated with poor oyster larvae survival. Upon completion of this research we will have a better understanding of how environmental change will impact our marine ecosystem. This information will allow us to better predict mortality events, improve hatchery practices, manage wild populations, and develop improved broodstock. Furthermore, marine bivalves are an excellent sentinel species for environmental perturbation and the novel bio-monitoring procedures developed in this project could easily be transferred to other species and systems.

KEYWORDS:
oyster, Vibrio tubiashii, transcriptomics, disease, temperature, pathogen, aquaculture, larvae

FUNDING AGENCY (if available): NOAA Saltonstall-Kennedy Grant Program

PROJECT TITLE: OCEAN ACIDIFICATION RESEARCH ON CRABS AND COCCOLITHOPHORES

CONTACT INFORMATION:

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PROJECT DESCRIPTION:

The Stillman laboratory is presently engaged in three research projects involving ocean acidification, two on crabs and one on coccolithophores. The first crab project, on intertidal zone porcelain crabs, is supported by NSF and involves 2 aims: (1) an analysis of how OA impacts the physiology of early life history stages (embryos, larvae, recruits) and (2) synergistic effects of acidification and thermal stress in adults. The first aim involves acclimation of crab early life history stages in water with differing pCO_2 and measurement of response variables including growth rate, respiration rate, heart rate, morphology, lipid and protein content (C/N), lipid consumption rate, and molecular phenotypes at the transcriptome and proteome level. The second aim involves acclimation to differing thermal and pCO_2 variability followed by measurement of metabolic rate, cardiac rate, cardiac CT_{max}, and molecular phenotypes, as above. The second crab project, a contract with the NOAA aquaculture facility in Kodiak Alaska involves examination of genomic variation in red king crab early life history stages following acclimation to differently acidified waters. The coccolithophore project, a collaboration with Co-PIs Ed Carpenter and Tomoko Komada and postdoctoral fellows Stephane Lefebvre and Ina Benner, involves an examination of multi-factor long term acclimation responses of *Emiliania huxleyi* grown in continuous culture for many hundreds of generations. In this NSF funded project we have investigated the impacts of combined effects of varying pCO_2 and nitrogen source (NO_3 vs. NH_4), and the combined effects of varying pCO_2 and temperature on the physiology of the coccolithophorids. Response variables include growth rate, cell size, cell morphology, PIC and POC, N assimilation rates, and molecular phenotypes at the transcriptomic, proteomic and metabolomic levels. Our first paper, showing that N source plays a larger role in regulation of calcification rate than does pH, has just been published in *Global Change Biology* (Lefebvre et al., 2011).

KEYWORDS:

intertidal zone, crabs, coccolithophores, nitrogen, temperature, synergistic effects, genomics

FUNDING AGENCY: NSF, NOAA

PROJECT TITLE: PHYSIOLOGICAL ASSESSMENT OF THE VULNERABILITY OF ESTUARINE AND MARINE ORGANISMS TO OCEAN ACIDIFICATION

CONTACT INFORMATION:

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PROJECT DESCRIPTION:

As an environmental physiologist, my research program aims to understand how organisms respond to changes in their natural environment (e.g. increases in CO_2, increases in temperature, decreases in oxygen levels) and the physiological mechanisms that allow them to tolerate these changes. Currently, we are interested in understanding the impacts of ocean acidification (OA) as well as other environmental drivers of climate change (e.g. ocean warming) on marine ecosystem by taking a species-level approach. We are assessing the vulnerability of estuarine and marine organisms to ocean acidification through investigations of the physiological "weak links" that underlie an organism's inability to tolerate increases in CO_2. Our research combines field and laboratory studies and takes an integrative approach where we assess the performance of animals to environmental change from molecular (e.g. transcriptomic analysis), biochemical (e.g. metabolic enzyme activity) and whole-organism (i.e. growth, development & survival) levels. Responses to multiple stressors are complex. Organisms may be able to adjust their physiology to cope with elevated levels of CO_2 but this compensatory response could result in less energy available for mounting a stress response to further environmental change. Understanding how multiple stressors interact to shape an organism's physiology is essential if we are to provide insight into the "winners" and "losers" of global climate change. Recent research on the impacts of ocean acidification has involved projects looking at larval development of sea urchins and oysters to conditions of elevated CO_2 as well as elevated temperature based on predictions provided by the Intergovernmental Panel on Climate Change. In collaboration with Gretchen Hofmann at UC Santa Barbara, we examined the growth and development of purple sea urchin, *Strongylocentrotus purpuratus*, and the painted urchin, *Lytechinus pictus*, under conditions of elevated CO_2 and investigated the molecular mechanisms underlying their response to these conditions (i.e. changes in the expression of genes involved in biomineralization, stress tolerance and metabolism). In collaboration with the Bodega Ocean Acidification Research group at UC Davis's Bodega Marine Lab (PIs Gaylord, Hill, Russell & Sanford), we are investigating the energetic costs associated with growing and developing under future ocean conditions in the native Olympia oyster, *Ostrea lurida*.

The ultimate goal of our research is to more broadly understand the processes and mechanisms that set limits on an animal's capacity to tolerate changes in their natural environment. This information will allow us to better predict shifts in animal distribution and abundance in response to climate change.

KEYWORDS:

oysters, sea urchins, environmental genomics, physiological performance, temperature, salinity, multiple stressors

FUNDING AGENCY: CSU Council on Ocean Affairs, Science and Technology

PROJECT TITLE: A MECHANISTIC UNDERSTANDING OF THE IMPACTS OF OCEAN ACIDIFICATION ON THE EARLY LIFE STAGES OF MARINE BIVALVES

CONTACT INFORMATION:

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PROJECT DESCRIPTION :

The shift in the carbonate chemistry of marine waters, as a result of direct anthropogenic CO_2 addition and climate-driven changes in circulation, poses a threat to many organisms. A rapidly expanding body of literature has shown that increasing levels of carbonic acid and decreasing carbonate ion levels will have deleterious effects on many marine organisms; however little is known about the mode of action of these changes in water chemistry on marine bivalves. Many marine organisms, particularly bivalves, depend critically on the production of calcium carbonate mineral, and this material becomes thermodynamically unstable under more acidic conditions. The actual mineral precipitation, however, takes place within interstitial volumes intermittently separated from ambient seawater by biological membranes. Therefore, abiotic relationships between solid phase minerals and seawater thermodynamics are oversimplified representations of the complex interplay among seawater chemistry, bivalve physiology, and shell growth processes.

In this integrative, multi-disciplinary project we will develop and apply novel experimental approaches to elucidate fundamental physiological responses to changes in seawater chemistry associated with ocean acidification. The four primary objectives of this project are to: 1) develop a novel experimental approach and system capable of unique combinations of pCO_2, pH, and mineral saturation state (Ω), 2) conduct short-term exploratory experiments to determine bivalve responses to different carbonate system variables, 3) conduct longer-term directed studies of the integrated effects of different carbonate system variables over early life history of bivalves, and 4) compare these biological responses among a group of bivalve species that differ in shell mineralogy and nativity to the periodically acidified upwelling region of the Pacific Northwest coast of North America. By isolating the effects of different components of the carbonate system on the early life stages of marine bivalves, e.g. does an oyster larvae respond more strongly to pCO_2 or mineral saturation state?, we can begin to identify the mechanisms behind bivalve responses as well as understand how these organisms survive in transiently corrosive conditions.

Laboratory based experiments on three primary taxa (oyster, mussel, clam) having native and non-native species pairs to Oregon's coastal waters: oysters Ostrea lurida and Crassostrea gigas; mussels Mytilus califonianus and Mytilus galloprovincialis; and clams Macoma nasuta and Ruditapes philippinarum, will allow for species comparisons among different shell mineralogy, microstructure, life-history, and adaptability. High-precision pCO_2 and dissolved inorganic carbon (DIC) instruments will be used in experiments to control and properly constrain the carbonate chemistry. A compliment of response variables will be measured across the early life stages of these species that include tissue acid-base balance, shell mineralogy and chemistry, respiration rate, and behavior. Additionally, our emphasis will be placed on observation of development, growth, and shell structure by directly linking observational data with other measured response data. An adaptive strategy using short-term experiments to determine the most salient variables in the carbonate system to manipulate in longer-term studies is being employed. This approach allows us to evaluate acute effects, mimicking diurnal changes to carbonate variables often found in coastal areas, and integrated chronic effects mimicking a more gradual acidification due to the rise in atmospheric CO_2.

KEYWORDS (to facilitate searching): Bivalves, calcification, early life history, larvae, mechanisms, physiology

FUNDING AGENCY:
National Science Foundation, CRI-OA

PROJECT TITLE: EFFECTS OF UPWELLING AND OCEAN ACIDIFICATION ON WEST COAST BIVALVE SPECIES

CONTACT INFORMATION:

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Project website link:	

PROJECT DESCRIPTION:

In conjunction with George Waldbusser, Burke Hales and Brian Haley (Oregon State University), my laboratory is working on a study to better understand the physiological responses of West Coast bivalve larvae to variation in components of seawater carbonate chemistry (e.g. pH, pCO_2, alkalinity, mineral saturation state) associated with ocean acidification events. We will measure carbonate chemistry effects on a broad range of larval physiological responses, including shell formation and composition, metabolism, feeding rates and control of intracellular pH. Experiments will be conducted under both acute (24 - 48 h) and longer-term (days) conditions in which the responses of native and introduced mussel, oyster and clam species are compared.

In 2006, blooms of *V. tubiashii* were associated with strong upwelling on the Oregon coast and coincidently high mortalities of oyster larvae were reported in a major commercial West Coast hatchery. In conjunction with Claudia Hase (Oregon State University), we are studying the effects of the shellfish pathogen *Vibrio tubiashii* and mutants (with deleted genes for toxic extracelluar proteases) on mussel and oyster larvae under various culture conditions in order to develop strategies for hatcheries to avoid future impacts of this pathogen.

Lastly, my laboratory houses the Molluscan Broodstock Program that selects for high yielding stains of Pacific oysters - economically the most important cultured bivalve species on the West Coast. We are interested in studying the responses of different genetic strains of the Pacific oyster to ocean acidification conditions to better understand the scope for adaption to predicted global changes in seawater conditions.

KEYWORDS:

Bivalve, mollusk, larvae, physiology, genetics, adaptation, oyster, *Vibrio*

FUNDING AGENCIES: NSF, Oregon Sea Grant, USDA/NIFA, NOAA

PROJECT TITLE: BUILDING STAKEHOLDER CAPACITY TO MONITOR OCEAN ACIDIFICATION IN THE US AND INTERNATIONALLY

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PROJECT DESCRIPTION:

1. Funding ocean chemistry monitoring programs on the West Coast

SFP obtained $79,000 from the Educational Foundation of America to support continuation and expansion of shellfish growers' efforts to monitor pCO_2, pH, DO, and other parameters and to conduct parallel bioassays to identify and adapt to effects on oyster larvae. Funds are provided to the PCSGA to support this collaborative effort by the Whiskey Creek Shellfish Hatchery, Taylor Shellfish Farms, Oregon State University, NOAA, and others

2. Organization of the workshop: Ocean Acidification Workshop for Virginia Shellfish Producers: An introduction to OA, its impacts, and monitoring tools to protect hatchery production

This workshop was prompted by inquiries from hatchery operators who suspect recent larval mortality may be related to changing estuarine chemistry. Held on October 25th in Yorktown, VA and co-sponsored by SFP and VIMS, representatives from the VA shellfish industry, academia, the House of Representatives, NOAA, Whiskey Creek Shellfish Hatchery, and Virginia Tech attended. Speakers included Alan Barton, Whitman Miller, Christopher Gobler, and Richard Zimmerman. Growers learned about OA and its impacts on shellfish production in the West Coast, adaptation, instrumentation and geochemical dynamics of estuarine environments that may hinder larval success by limiting availability of carbonate. This was the second workshop of its kind held by SFP; an earlier workshop in January 2011 helped shellfish hatcheries in Maine OA begin monitoring to address suspected effects of changing seawater chemistry.

3. Development of proposals USDA's Agriculture and Food Research Initiative (AFRI) Competitive Grants Program.

A proposal is in preparation for the AFRI Program "Integrated Approaches to Climate Adaptation and Mitigation in Agroecosystems". The Director is Mark Green of St. Josephs College, with Warren and Capson as collaborators. The proposal posits to use large-scale buffering of coastal mud flats in Maine to increase populations of *Mya arenaria* and to educate stakeholders about acidification and methods for mitigation and adaptation. Potential funding is $750,000 over two years.

A second proposal is also in preparation for the AFRI program, "Regional Approaches for Adaptation to and Mitigation of Climate Variability and Change". The Director is George Waldbusser of OSU, and team leaders include Joe Salisbury, Chris Gobler, Burke Hales and Todd Capson. Objectives include: (1) Development of a monitoring network in commercial shellfish hatcheries to support adaptation and mitigation; and (2) using this network and a coordinated research, education, and outreach effort to develop, implement, test, and improvement practices to protect shellfish production from climate-related stressors. The program encompasses the Pacific and Atlantic Coasts over a 5 year period with potential to secure up to $10,000,000 in funding.

4. Development of the pre-proposal to build capacity to monitor OA in the Tropical Eastern Pacific, the Humboldt Current System, and Southeastern Africa

SFP has built an international team that proposes to monitor OA in Costa Rica, Panama, Ecuador (the Galapagos Marine Reserve), Chile and Kenya. The monitoring program would: (1) raise awareness of the need to address OA on national and international levels, (2) provide essential data for fisheries, aquaculture, and marine resource managers, (3) enhance our understanding of the global carbon cycle, (4) contribute to informed responses to marine consequences of carbon dioxide emissions, and (5) provide a model for international cooperation to address OA, including the creation on an international OA monitoring network. Proposed instrumentation includes the SeapHOX instrument package in addition to a Battelle pCO_2 monitor and mooring in the Strait of Magellan. Participants are from government, academia, and NGOs.

PROJECT TITLE: OCEAN ACIDIFICATION IMPACTS ON SHELLFISH AQUACULTURE

CONTACT INFORMATION:

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PROJECT DESCRIPTION:

We, while partnering with federal and state agencies, universities, non-profits and shellfish growers are trying to understand present day and future impact of acidified waters. Research has been localized in Pacific coast estuaries and in the Puget Sound focusing on native and pacific oysters and mussels. Areas of interest are bivalve larval and seed development, shell pitting and growth along with phytoplankton production. Outreach and education are also components of our efforts as we all further explore the problem and its consequences.

KEYWORDS:

OA, shellfish, oyster, Puget Sound, aquaculture, Pacific Ocean, plankton, mussel

FUNDING AGENCY (if available):

PROJECT TITLE: BODEGA OCEAN ACIDIFICATION RESEARCH (BOAR)

CONTACT INFORMATION:

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PROJECT DESCRIPTION:

The Bodega Ocean Acidification Research (BOAR) group (Professors Hill, Gaylord, Sanford & Russell) at the University of California Davis Bodega Marine Laboratory is a major research collaboration addressing the impacts of acidification on coastal upwelling and estuarine ecosystems. Using an interdisciplinary approach that draws on the expertise of oceanographers, marine chemists, and ecologists, we combine moored, shipboard and coastal measurements of seawater chemistry with controlled laboratory and field studies of ecological responses in key species. BML is situated on Bodega Head, a rocky headland within a major upwelling center where the effects of acidification may be exacerbated.

To address changes in regional oceanography and seawater properties, we are using highly instrumented oceanographic moorings combined with broad scale coastal and intertidal measurements along the West Coast of the U.S. Our "coast wide" sampling transect includes 47 sites along the West Coast that are sampled 2x per year for a full suite of water chemistry parameters. At several individual sites along this transect, we are collecting higher resolution pH and water quality data. For example, an oceanographic mooring located offshore of BML has been continuously monitoring pH and pCO_2 since November 2010. This mooring is coupled with intertidal pH and water chemistry measurements at the shore on Bodega Head.

Nearby Tomales Bay is a 20 km long estuary that supports productive oyster aquaculture. Like many estuaries in California, Tomales Bay receives fresh water inflow seasonally, with dramatic effects on pH. A second mooring to be deployed in Tomales Bay in 2011 will be combined with ongoing monthly oceanographic surveys (since 2009) to extend an existing historical record of water chemistry and understand the relative roles of climate and hydrology in influencing estuarine pH.

Utilizing these key oceanographic data collected along the California coast, we are addressing ongoing and future ecological impacts of ocean acidification on calcifying marine invertebrates that play critical roles in local ecosystems. Efforts to date have targeted the California mussel (*Mytilus californianus*), the Olympia oyster (*Ostrea conchaphila*), and the Purple urchin (*Strongylocentrotus purpuratus*). We are using a novel culturing facility at BML that allows us to raise larvae under elevated-CO_2 conditions through the full pelagic period and into juvenile life. We are especially interested in "carry-over" effects that originate from exposure during the larval stage, but influence subsequent growth and survival of benthic juveniles, themselves critical as population bottlenecks for adult demographics.

The BOAR group is dedicated to the training and education of future scientists in ocean acidification research. Through support of the National Science Foundation and the UC Multicampus Research Programs & Initiatives, BOAR is involved in the training of 7 graduate students and 2 postdoctoral fellows.

KEYWORDS: Tomales Bay, Bodega, California Current, oyster, mussel, urchin, upwelling, calcification

FUNDING AGENCY: National Science Foundation, UC Multicampus Research Programs & Initiatives

PROJECT TITLE: MECHANISMS CONTROLLING BIVALVE REPRODUCTION IN WILLAPA, WA

CONTACT INFORMATION:

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PROJECT DESCRIPTION:

Objectives:

1) Evaluate long-term records of environmental conditions (daily water temperature, meteorological observations, water chemistry) for evidence of spatio-temporal patterns, and their predictive power for the magnitude and timing of oyster recruitment.

2) Compare present-day spatial and temporal patterns of larval abundance and recruitment among 3 estuarine bivalves, specifically addressing a) connectedness among spatially discrete populations (whether spatial patterns of recruitment are related to spawning), and b) species-specific constraints to recruitment across life history stages and environmental conditions.

3) Extend long-term records of environmental conditions (temp, salinity, pH, chlorophyll, nutrients) and recent measurements of pCO_2 throughout the estuary.

KEYWORDS:

Crassostrea gigas, Ostrea lurida, recruitment

FUNDING AGENCY: Washington Sea Grant

***PROJECT TITLE*:** Long-term observations of nearshore marine invertebrate settlement in northern, central, and southern California

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***PROJECT DESCRIPTION*:**

My colleagues and I have established a collaborative network that observes settlement of nearshore marine invertebrates at sites ranging from Mendocino to San Diego counties in California. Originally established in 1990 to observe settlement of red sea urchins (Strongylocentrotus franciscanus) as a fishery independent index of stock health, in 1994 the number of taxa observed was increased to include crabs, bivalves, and gastropods. Salient features of the project design include: long-term observations (15-21 years); high frequency of observations (weekly to bi-weekly); large geographical range (Mendocino to San Diego Counties along California coast); archival collection of all settlers. The length and geographical range of the our observations has enabled us to explore regional differences in correlations between shifting oceanographic regimes at a variety of time scales (e.g. PDO, El Nino/La Nina, within-year upwelling episodes) on settlement of a variety of taxa. The variety of taxa, the range of habitats over which their settlement patterns have been observed, and the archival collection of settlers provide a potential resource for detecting time trends in the effects of ocean acidification on important nearshore invertebrate species. Beginning this year (2011) the data set is being housed and maintained in the Santa Barbara Coastal LTER. The association with the SBC LTER will facilitate collaborative work with colleagues who are pursuing different aspects of the effects of ocean acidification on some of the same nearshore species of invertebrates observed in our program.

***KEYWORDS* :**

nearshore, invertebrate settlement, long time series, broad geographical range, high frequency observations, archival samples, crabs, urchins, gastropods, bivalves

***FUNDING AGENCY*:** California Sea Urchin Commission; South Bay Cable/Fisheries Liaison Committee

PROJECT TITLE: California Current Ecosystem LTER Site

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http://spray.ucsd.edu/pub/rel/index.php

PROJECT DESCRIPTION:

The ***California Current Ecosystem*** (CCE) Long Term Ecological Research (LTER) site is a productive coastal upwelling biome structured by remote and local physical forcing, as well as biotic interactions in the ocean water column. The CCE-LTER site, building upon >62 years of extensive ocean measurements by CalCOFI, seeks to understand the mechanisms underlying transitions between different states of the pelagic ecosystem, as well as the corollary: ecosystem resilience. This interdisciplinary research group is investigating the ecological effects of long-term forcing by a secular warming trend, the North Pacific Gyre Oscillation and Pacific Decadal Oscillation, and El Niño in altering the structure and dynamics of the pelagic ecosystem. The research program includes extensive time series measurements (shipboard, gliders, moorings, remote sensing, nearshore piers), Lagrangian-design experimental process cruises, coupled circulation-food web models, information management, and an education, outreach, and capacity-building program. A current focus of the process cruise component of the CCE-LTER site is the role of mesoscale and sub-mesoscale fronts and eddies in altering nutrient fluxes, predator-prey interactions, and biogeochemistry, and the relationship of such features to larger scale climate variability.

An aspect of the changes in the California Current System whose consequences are largely unknown is the effects of changing ocean chemistry on organisms in the water column. These processes include altered ocean acidity, hypoxia, and trace metal availability. Research pertaining to ocean acidification in the CCE-LTER site includes: (1) Two interdisciplinary moorings in collaboration with colleagues at PMEL and the Southwest Fisheries Science Center. These moorings (**CCE-1** in the offshore, low salinity core of the California Current, and **CCE-2** in the coastal upwelling region off Pt. Conception) include measurements of pCO_2, pH, dissolved O_2, meteorological variables, 7-wavelength irradiance, phytoplankton fluorescence, nitrate+nitrite, acoustic backscatter due to macrozooplankton and fish, Doppler currents, and CTD's. Partner moorings include HARP measurements of marine mammal vocalizations. (2) *Spray* ocean gliders along CalCOFI lines 80 and 90. The line 80 glider intersects the CCE-1 and CCE-2 mooring sites, and includes dissolved oxygen and temperature, from which aragonite saturation state is estimated, zooplankton acoustic backscatter, Doppler currents, phytoplankton fluorescence, and CTD. (3) Quarterly shipboard measurements of pH and carbon system variables from CalCOFI, accompanied by extensive hydrographic, plankton, fish egg, and multi-frequency acoustic measurements. (4) Studies of long-term variability in calcifying holozooplankton (esp. pteropods, heteropods, and planktonic foraminifera), and the relationship of their vertical distributions to calcium carbonate saturation state. (5) Experimental studies.

KEYWORDS: ecosystem state changes, climate change, multi-decadal variations, ENSO, ocean acidification, autonomous gliders, moorings

FUNDING AGENCY: NSF (LTER), NOAA (moorings, gliders)