Ocean Carbon and Biogeochemistry Program
Ocean Acidification Principal Investigators' Meeting
March 22-24, 2011

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Number of Registrants: 116

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Last updated February 2010

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Research Interests:

My research involves development, testing and deployment of novel chemical sensors. Much of my prior work has entailed method development and field testing of the spectrophotometric elemental analysis system (SEAS) instrument. SEAS, a single-channel in situ instrument rated to 1,000 meters depth, can be configured to produce high-resolution measurements of carbon system parameters such as pH as well as analytes such as nitrite, nitrate, and phosphate. My interests include analyses of chemical distributions as they relate to phytoplankton community structure and biogeochemical cycling in the coastal and open oceans.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects, "Collaborative Research: Development of an in situ sensor for high-resolution measurements of total dissolved inorganic carbon," (NSF OCE-1030019; co-PIs E.A. Kaltenbacher and R.H. Byrne) aims to add the total dissolved inorganic carbon (C_T) measurement capability to the SEAS analysis suite. We completed the optical cell design and fabrication, made modifications to the software and firmware, and commenced laboratory testing. We expect to start field tests using a combination of SEAS pH and C_T instruments in the next few months.

Another research project, "Carbonate Ion Sensor Development," (NOAA NA09OAR4310067; PI R.H. Byrne; Co-PI E.A. Kaltenbacher) entails design, fabrication and testing of an instrument to directly measure carbonate ion concentrations in seawater. Our current work involves ascertaining an optimal optical cell design and completing the control electronics. We anticipate construction of the instrument by early autumn with field tests to commence soon thereafter.

I currently serve on the NOAA Cooperative Institute for Ocean Exploration, Research and Technology (CIOERT) Science Advisory Council. CIOERT organized an Ocean Acidification and Instrument Needs Workshop (http://cioert.org/oa-workshop) in March of 2010 that was held at the SRI St. Petersburg facility.

Related information:

Villareal, T. A., L. Adornato, C. Wilson, and C. A. Schoenbaechler , 2011. Summer blooms of diatom-diazotroph assemblages and surface chlorophyll in the North Pacific gyre: A disconnect, J. Geophys. Res., 116, C03001, doi:10.1029/2010JC006268.
Adornato, L.R., E.A. Kaltenbacher, D.R. Greenhow, and R.H. Byrne, 2007. High-resolution in situ analysis of nitrate and phosphate in the oligotrophic ocean. Environmental Science and Technology 41:4045-4052.
Adornato, L.R., E.A. Kaltenbacher, T.A. Villareal, and R.H. Byrne, 2005. Continuous in situ determinations of nitrite at nanomolar concentrations. Deep Sea Research I 52:543-551.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
_3_ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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Research Interests:
My research focuses on the role of coastal oceans and freshwater ecosystems in the global carbon cycle, including ocean acidification (OA) in coastal ecosystems, interactions between OA and other natural or anthropogenic stressors (e.g., hypoxia, climate change), and air-sea CO_2 exchange in coastal oceans.

Synopsis of current ocean acidification-relevant research or work:
Currently, my ocean acidification-relevant research focuses on the North American West Coast, including estuarine systems such as Puget Sound. We are currently funded by NOAA's Global Carbon Cycle Program to develop predictive relationships for hindcasting and forecasting ocean acidification conditions along the West Coast (specifically *p*H and carbonate saturation states) using proxy variables such as oxygen and temperature (co-PIs Burke Hales, Richard Feely, Chris Sabine, Greg Johnson). The method has proven to be very robust in applications along the Pacific Northwest coastline, as well as in the Southern California Bight. The focus of the present project is to refine the performance of the predictive algorithms under low oxygen conditions. The observational component of this project includes regional and large-scale hydrographic cruise sampling, high-resolution towed sensor surveys, and moored and underway carbon observations.

In addition, I am leading the effort to upgrade the underway CO_2 systems on NOAA's West Coast and Pacific research vessels to perform high-quality measurements of a second carbon parameter and oxygen concentrations. I am also involved with data synthesis efforts on coastal carbon that have direct relevance to understanding patterns of ocean acidification and interactions between OA and other environmental stressors.

Related information:
Feely, R.A., S.R. Alin, J. Newton, C.L. Sabine, M. Warner, A. Devol, C. Krembs, and C. Maloy (2010): The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. *Estuar. Coast. Shelf Sci.*, 88, doi: 10.1016/j.ecss.2010.05.004, 442–449.

Hauri, C., N. Gruber, G.-K. Plattner, S. Alin, R.A. Feely, B. Hales, and P.A. Wheeler (2009): Ocean acidification in the California Current System. *Oceanography*, 22(4), 60–71.

Juranek, L.W., R.A. Feely, W.T. Peterson, S.R. Alin, B. Hales, K. Lee, C.L. Sabine, and J. Peterson (2009): A novel method for determination of aragonite saturation state on the continental shelf of central Oregon using multi-parameter relationships with hydrographic data. *Geophys. Res. Lett.*, 36, L24601, doi: 10.1029/2009GL040778.

For more information visit our website at: http://www.pmel.noaa.gov/co2/

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
_3_ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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Research Interests:

Broadly speaking, my research interests focus on global environmental change owing to both natural and anthropogenic processes on modern time scales. In particular, my research has focused on the effects of rising CO_2 and ocean acidification on biogeochemical processes, marine organisms, and ecosystems in coastal ocean environments. I am especially interested in the effects on coral reef ecosystems and processes such as calcification and $CaCO_3$ dissolution. As part of this I am very intrigued by the controls on the formation and dissolution of Mg-calcite minerals.

Synopsis of current ocean acidification-relevant research or work:

Most of my efforts are currently focused on "Bermuda ocean acidification and coral reef investigation, BEACON" (NSF OCE 092965; co-PIs N. Bates, and S. de Putron), which aims to characterize calcification and $CaCO_3$ production at different scales including individual coral colonies, local reef communities, and regional coral reef ecosystems exposed to different seawater carbonate saturation state (W) and pH over time and space on the Bermuda platform. The Bermuda coral reef is a marginal reef system and may be among the first coral reefs to respond to OA. This makes it an important system to study in the context of OA. Preliminary results suggest that the Bermuda coral reef may already be close to a condition where it is subject to a net loss of $CaCO_3$ in the wintertime, i.e., calcification is balanced by dissolution and net ecosystem calcification is close to zero. BEACON is an expanding research program with several ongoing subprojects investigating the effect of ocean acidification on molecular, cellular, and physiological processes, bioerosion, and $CaCO_3$ dissolution.
http://www.bios.edu/research/beacon/index.html

One project falling under the wide umbrella of BEACON is titled "Mg-calcite mineral dynamics in natural seawater systems: relevance to oceanic uptake of anthropogenic CO_2 and ocean acidification" (NOAA GCC NA10OAR4310094; co-PI N. Bates). The objective of this project is to improve the current understanding of the behavior and dynamics of biogenic Mg-calcite minerals in the natural environment. Currently, there is a large discrepancy between experimentally determined solubilities of biogenic Mg-calcite mineral phases and it is poorly understood how these solubilities relate to the behavior of Mg-calcite phases in the natural environment. This project attempts to address this problem.

Related information:

Andersson, A. J., Mackenzie, F. T., and Gattuso, J. -P., *in press*. Effects of ocean acidification on benthic processes, organisms, and ecosystems, *in Ocean Acidification*, Gattuso, J. –P. and Hansson, L., eds., Oxford University Press.

Andersson, A. J., Kuffner, I. B., Mackenzie F. T., Tan, A., Jokiel, P. L., and Rodgers, K. S., 2009. Net loss of $CaCO_3$ from a subtropical calcifying community due to seawater acidification: mesocosm-scale experimental evidence. *Biogeosciences*, 6, 1811-1823.

Andersson, A. J., Mackenzie, F. T., and Bates, N. R., 2008. Life on the margin: Implications of ocean acidification on Mg-calcite, high latitude and cold water marine calcifiers. *Marine Ecology Progress Series*, 373, 265-273.

Andersson, A. J., Bates, N., and Mackenzie, F. T., 2007. Dissolution of carbonate sediments under rising pCO_2 and ocean acidification: observations from Devil's Hole, Bermuda. *Aquatic Geochemistry*, 13(3):237-264.

Andersson, A. J., Mackenzie, F. T., and Lerman, A., 2005. Coastal ocean and carbonate systems in the high CO_2 world of the Anthropocene. *American Journal of Science,* 305:875-918.

Andersson, A. J., Mackenzie, F. T., and Ver, L. M., 2003. Solution of shallow water carbonates: An insignificant buffer against rising atmospheric CO_2. *Geology*, 31(6):513-516.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
1__ Observations & Monitoring
1__ Physiological Responses
1__ Ecology & System Responses
1__ Biogeochemistry & Modeling

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Research Interests:
I am a biochemist and computational biologist by training, who has studied protein sequence, structure and function relationships in order to model and predict the effects of genetic variation on biomolecular functions. I have previously focused on protein-DNA interactions, and in particular the intrinsically flexible sequence recognition of homing endonucleases found in many microorganisms, including *Chlamydomonas reinhardtii*. Now as a postdoctoral researcher with principal investigators Mónica V. Orellana and Nitin S. Baliga at the Institute for Systems Biology (ISB), I am taking advantage of new molecular and analytical approaches to investigate the organization and function of gene regulatory networks, which fundamentally depend in part on transcription factor-DNA interactions. By studying how many individual components of the cell interact and work together or simultaneously, I aim to construct putative regulatory models that explain biological responses. This will help us to better understand the emergent properties of complex biological systems, and the highly flexible ways that they are able to adapt and evolve to changing conditions.

Synopsis of current ocean acidification-relevant research or work:
I am currently characterizing the molecular responses (e.g. gene expression patterns) of the model diatom *Thalassiosira pseudonana* to changing environmental conditions, including increases in carbon dioxide and temperature, nutrient limitation, and pH changes. In collaborative project with the Armbrust Group, we are building upon previously successful transcriptomic analyses to increase the resolution and depth of gene expression patterns in response to laboratory-simulated environmental perturbations. I have been using custom DNA microarrays to characterize system-wide patterns of RNA expression in *T. pseudonana* that correlate with continuous changes in multiple environmental factors. Currently, I am looking for differences in gene expression that correlate with changes in carbon dioxide levels and temperature, as well as carbon assimilation, nutrient uptake, and secretion. Using machine-learning algorithms developed by the Baliga Group at the ISB, we will transform these and future data into finely clustered condition- and time-dependent correlations between genes that are likely to be co-regulated. This will help us to make detailed biological predictions about the responses of marine diatoms to ocean acidification and climate change scenarios.

Related information:

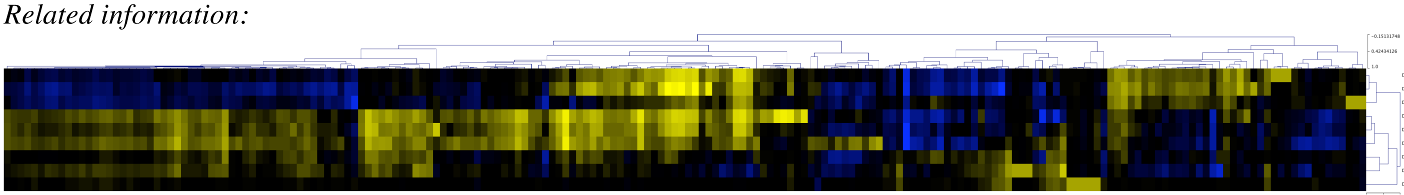

Figure 1. We observe strong patterns of differential expression over multiple environmental gradients in continuous culture.

Notable previous publications:

Ashworth J, Havranek JJ, Duarte CM, Sussman D, Monnat RJ, Stoddard BL, Baker D (2006). Computational redesign of endonuclease DNA binding and cleavage specificity. *Nature* 441(7093), 656–9. PMC2999987

Ashworth J and Baker D. (2009) Assessment of the optimization of affinity and specificity at protein-DNA interfaces. *Nucleic Acids Research* 37(10), e73. PMC2691843

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1_ Physiological Responses
_2_ Ecology & System Responses
_3_ Biogeochemistry & Modeling

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Research Interests:
I am a Partner PI in the Alliance for Coastal Technology (ACT), a NOAA funded program to promote the development and application of moored sensor technology for the coastal environments. ACT has 6 partner institutions nation-wide, representing different coastal environments. We have three main activities: maintaining a searchable data-base on sensor technology, providing workshops to encourage collaboration between industry, academic and management personnel, and testing and evaluating established and prototype sensors on coastal moorings. To date, ACT has developed a data-base of 4000 instruments from 300 companies, conducted 38 technology workshops involving 1500 participants, and released reports on about 226 performance evaluations of 40 instruments. In 2005 we conducted a workshop on Measurement of Dissolved Inorganic Carbon Speciation in Natural Waters in Honolulu Hawaii. A recommendation of this workshop was to conduct a "demonstration project" to demonstrate the application of new pCO_2 instruments on coastal moorings.
My own research for 30 years has been on carbon budgets of coral reefs, including effects of ocean acidification on coral reef metabolism and coral growth.

Synopsis of current ocean acidification-relevant research or work:

ACT recently finished the first phase of testing pCO_2 sensors in Hood Canal Washington and Kaneohe Bay Hawaii. pCO_2 instruments were from vendor participants, including: ProOceanus, Sunburst, Contros, and PMEL mapp (now Battelle), representing 3 very different technological approaches to measuring pCO_2. (see report on-line). Currently we are testing these systems in Alaska coastal waters in cooperation with J. Mathias, Univ Alaska (an ACT Partner with P Winsor) and PMEL.

ACT is planning a demonstration project on in-situ pH sensors in this next 2-year cycle of testing and evaluation.

Related information:

See www.act-us.info for reports

Atkinson MJ 2005 In-situ Measurement of Dissolved Inorganic Carbon Speciation in Natural Waters: pH, pCO_2, TA and TCO_2. ACT Workshop Report February 14-16, 2005 UMCES CBL 05-076.

Tamburri MN, Johengen TH, Atkinson MJ, Schar DH, Robertson CY, Purcell H, Smith GJ, Pinchuk A, Buckley EN 2010 Alliance for Coastal Technologies: Advancing moored pCO_2 instruments in coastal water. Marine Technology Society Journal 45(1):43-51

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
1 Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

Since May 2007, I have served as the executive officer of the Ocean Carbon & Biogeochemistry (OCB) Project Office, which is based at the Woods Hole Oceanographic Institution in Woods Hole, MA. In this position, my primary responsibilities include strategic planning, community building, and the development and implementation of OCB scientific activities, products, and outreach materials to meet the needs of the OCB research community, educators, and policy makers. My academic research has recently focused on the development of tropical (Benway et al., 2006) and North Atlantic (Benway et al., 2010) paleoceanographic records to study large-scale changes of the last deglaciation and associated feedbacks between the tropics and the high latitudes. I have conducted stable isotope ($\delta^{18}O$, $\delta^{13}C$) and Mg/Ca (ICPMS, SIMS) analyses of foraminiferal tests preserved in marine sediments. I have recently become interested in biomineralization and paleo-ocean acidification proxies (corals and foraminifera), and am seeking new collaborations.

Synopsis of current ocean acidification-relevant research or work:

OCB has been providing national leadership on ocean acidification education, outreach, and research initiatives since its inception in 2006. An OCB scoping workshop in October 2007 focused on ocean acidification, and the report emerging from that workshop played an instrumental role in the recent NSF ocean acidification research program solicitation. I have been actively involved in numerous ocean acidification education, outreach, and community building activities, including a teacher workshop, outreach publications, an ocean acidification website, and an OCB community response to the EPA request for data and information on ocean acidification. In November 2009, I collaborated with Sarah Cooley to develop and run a hands-on ocean acidification short course in Woods Hole, MA for participants with expertise in various sub-disciplines of biological and chemical oceanography. Building on materials from the instructors' course lectures, OCB is now coordinating an ASLO web lecture series on ocean acidification. We are also working on a short film describing ocean acidification's potential impacts on ecosystem services in the northeastern U.S. for the NOAA Ocean Today Kiosk Network, which will debut at the Smithsonian's Sant Ocean Hall.

Related information:

Benway, H. M. et al. (2010). Hydrographic changes in the eastern subpolar North Atlantic during the last deglaciation. *Quaternary Science Reviews* 29, 3336-3345.

Benway, H. M., S. R. Cooley, S. C. Doney (2010). A Catalyst for Ocean Acidification Research and Collaboration: Ocean Carbon and Biogeochemistry Short Course on Ocean Acidification; Woods Hole, Massachusetts, 2–13 November 2009. *Eos* 91 (12).

Benway, H. M. et al. (2006). Eastern Pacific Warm Pool paleosalinity and global climate variability: 0-30 kyr. *Paleoceanography* 21, PA3008, doi: 10.1029/2005PA001208.

Cooley, S. R., H. M. Benway (2010). Linking introductory chemistry and the geosciences through ocean acidification. *The Earth Scientist* (quarterly publication of the National Earth Science Teachers Association) 26(1), 39-42.

OCB Subcommittee on Ocean Acidification (2009). OCB response to the EPA Notice of Data Availability on ocean acidification. Available at http://www.us-ocb.org/publications/EPA_OCB_FINAL.pdf

OCB website: http://www.us-ocb.org
OCB Ocean Acidification informational website: http://www.whoi.edu/OCB-OA/
OCB Ocean Acidification short course website: http://www.whoi.edu/courses/OCB-OA

Meeting scientific themes relevant to this research:

__1_ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My main research goal is to better understand the biogeochemistry of chemocline sediments because reduction-oxidation reaction (redox) processes are so important to nutrient regeneration, carbon cycling, and the sedimentary geologic record. My secondary focus involves an ecologically and paleoceanographically important protistan group, the foraminifera, by investigating the controls on geochemical proxies recorded in calcareous foraminiferal tests (shells), as well as other aspects of foraminiferal biology. My recent research has concentrated on modern environments and organisms, but my career began interpreting the fossil record, and I continue to do paleoecologically and paleoceanographically relevant research.

Synopsis of current ocean acidification-relevant research or work:

(1) With Dan McCorkle and postdoctoral investigator Anna McIntyre-Wressnig, we are currently studying the effects of predicted increases in oceanic [CO_2] on bathyal and neritic temperate and tropical benthic foraminiferal survival and test (shell) microfabric. Analyses are ongoing, but results suggest that the calcareous benthic foraminifera used in this study lived after exposure to elevated CO_2 for 6 weeks and, in the case of the reef species *Amphistegina gibbosa*, reproduced. Elevated pCO_2 affected test microstructure, as expected. The calcite produced during these experiments and at different pH values is currently being analyzed by B. Hönisch (Lamont) for B/Ca and, potentially, $\delta^{11}B$, which will be the first calibration of these pH proxies done on cultured foraminiferal carbonate. It is unclear how longer incubations and those over multiple generations will affect foraminiferal population dynamics. Future work must determine the ecological consequences of altered test microstructure on the survival and reproductive capacity of calcareous benthic foraminifera; we hope to study this in the field.

(2) Sequestration of CO_2 in the deep ocean is being considered as a feasible mechanism to mitigate the alarming rate in its atmospheric rise. Little is known, however, about how the resulting hypercapnia (an excess of intracellular CO_2) and the concomitant pH decrease affects marine fauna. In an effort to better understand aspects of the protistan reaction to such environmental perturbations, MBARI colleagues and I studied the survivorship of benthic foraminifera in response to deep-sea CO_2 release, in two experiments performed at ~3km water depth. Foraminifera are an ideal group to study in this regard because they have both calcareous and non-calcareous representatives. Results indicate that survivorship rates of agglutinated and thecate foraminifera were not significantly impacted by direct exposure to the CO_2 hydrate but the survivorship of calcareous foraminifera was significantly lower in direct exposure treatments compared to controls (Bernhard et al. 2009 *Global Change Biology*). Observations suggest that, if large scale CO_2 sequestration is enacted on the deep-sea floor, survival of two major groups of this widespread and numerically-significant protistan taxon may not be severely impacted, while the populations of calcareous foraminifera will are likely to decrease in areas directly exposed to CO_2 hydrate. Laboratory experiments at atmospheric pressure on thecate foraminifera were consistent with these field results (Bernhard et al. 2009 *Global and Planetary Change*).

Related information:

Bernhard, J.M., J.P. Barry, K.R. Buck, V.R. Starczak (2009) Impact of carbon dioxide hydrate sublimation on deep-sea benthic foraminiferal survival. *Global Change Biology*. doi: 10.1111/j.1365-2486.2008.01822.x

Bernhard, J.M., E. Mollo-Christensen, N. Eisenkolb, V.R. Starczak (2009) Tolerance of allogromiid foraminifera to severely elevated carbon dioxide concentrations: Implications to future ecosystem functioning and paleoceanographic interpretations. *Global and Planetary Change*. doi:10.1016/j.gloplacha.2008.10.013.

Meeting scientific themes relevant to this research:

_2__ Paleo & Proxies/Modeling
___ Observations & Monitoring
_3__ Physiological Responses
_1__ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests (8 lines)

Our research focus is on understanding, and thus gaining predictive capability of, how biological processes operate to transform and transport carbon in the sea. The carbon flows in the ocean are substantial (50 Pg C/y fixation and 10 Pg C/y export) and rapid (photosynthetic biomass turns over on the time scale of 1 week) and there are open questions regarding the stability of these flows due to human induced warming and acidification of the ocean. Our ocean profiling Carbon Explorer (CE) and Carbon FLUX Explorer (CFE) floats are designed to observe in real time the diurnal variability of particulate organic carbon (POC) and particulate inorganic carbon (PIC) concentrations and fluxes to kilometer depths on a 24/7/365 basis to address these questions. Our group also studies internal ocean cycling of biogenic major, minor and trace chemical species and their transport mechanisms from continent to ocean interior.

Synopsis of current ocean acidification-relevant research or work: (15 lines)

Two projects are relevant to the ocean acidification problem. The first (OCE 0936143, Oct 2009), together with Engineers at LBNL and the Scripps Instrument Development Group is to develop the Carbon FLUX Explorer (CFE), an imaging optical sedimentation recorder (OSR) integrated with a Lagrangian ocean profiling float. The OSR is designed to quantify POC and PIC fluxes on hourly time scales for seasons to years. We have nearly completed a redesign of all CFE systems – complete with CAD-CAM documentation, conducted laboratory (thermal cycling and component pressure testing), and field deployment of an interim CFE in October 2010 for multiple half day long missions. In 2011, the fully redesigned CFE will be deployed for mission durations from week to month time scales to debug longer-term issues, such as biofouling and component longevity. We expect to deploy up to three CFE's in the subarctic N Pacific for multi month missions in 2012. The second project (OCE 09654888, July 2010 start), joint with WETLabs Inc. will transform an advanced prototype sensor for particulate inorganic carbon (PIC) to a commercial quality sensor capable of deployment across a broad spectrum of platforms from ship CTD's to Lagrangian profiling floats. The initial redesign of the PIC sensor has been achieved and it will be CTD profiled and calibrated with filtered particulate matter samples during three expeditions in 2011 and deployed in the subarctic N. Pacific Ocean on a pair of Carbon Explorers in 2012. Our CE and CFE's and sensors will establish the oceanic baseline for surface and subsurface PIC and POC concentrations and fluxes where none exists. Data are critically needed for C prediction.

Related information:

Bishop, J. K. B., and T. J. Wood (2009), Year-round observations of carbon biomass and flux variability in the Southern Ocean, *Global Biogeochemical. Cycles*, doi:10.1029/2008GB003206. *Carbon Explorers observe Southern Ocean N&S of polar front >1 year. High-biomass low-export.*

Bishop, J.K.B (2009) Autonomous Observations of the Ocean Biological Carbon Pump. *Oceanography, 22 (2). 182 – 193. Carbon Cycle, sensors and experience with NOPP development mechanism.*

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_X_ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_X_ Biogeochemistry & Modeling

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Research Interests:

My research focuses on interdisciplinary and integrated ecosystem observations, biodiversity assessments, and long-term monitoring of the coral reefs of the U.S. Pacific Islands to provide the scientific basis to support effective implementation of ecosystem approaches to management and conservation in a changing climate. During biennial Pacific Reef Assessment and Monitoring Program research cruises to each of the ~50 US islands/atolls spanning the Pacific from Hawaii to American Samoa to the Marianas, and including the Pacific Remote Islands in the central equatorial Pacific, our research monitors the distribution, abundance, diversity, and condition of fish, corals, other invertebrates, algae, and microbes in the context of their diverse benthic habitats, varying oceanographic environments, and anthropogenic threats. Using these integrated ecosystem observations, this research uses comparative approaches to examine ecosystem organization and the role of biodiversity in maintaining resilience across gradients of biodiversity, physical and biogeochemical ocean conditions, and human impacts.

Synopsis of current ocean acidification-relevant research or work:

Most efforts to examine the response of marine calcifying organisms and ecosystems to changes in carbonate chemistry have focused primarily on laboratory or mesocosm-based response experiments and/or simple food web-based ecosystem models, respectively, with only limited research and monitoring examining the impacts on coral reefs in nature. To inform, validate, and improve laboratory and modeling studies, NOAA's Pacific Reef Assessment and Monitoring Program has initiated efforts to concurrently monitor spatial patterns and long-term temporal trends of seawater carbonate chemistry, benthic community structure and biodiversity, and calcification rates of corals and calcareous algae around ~40 islands spanning gradients of biogeography, oceanographic conditions, and anthropogenic stressors across the central and western Pacific. Around each of the islands surveyed, surface and near-bottom water samples provide carbonate chemistry characterization, rapid ecological assessments and towed-diver surveys provide composition and abundance of key benthic functional groups, standardized Autonomous Reef Monitoring Structures provide indices of cryptic invertebrate biodiversity, and sets of Calcification Acidification Units provide calcification rates of sessile reef builders (e.g. calcareous algae). Coral cores and samples collected at a subset of islands provide recent growth and calcification rates of key reef-building corals. Collectively, these observations of the ecological responses to ocean acidification in the real ocean are essential to support resource managers and policy makers in their efforts to implement effective strategies to enhance resilience of coral reefs.

Related information:

Hoeke, RK, PL Jokiel, RW Buddemeier, RE Brainard (in press). Projected changes to growth and mortality of Hawaiian corals over the next 100 years. *PLoS One*.

Brainard, R, S Bainbridge, R Brinkman, CM Eakin, et al. (2010). "An International Network of Coral Reef Ecosystem Observing Systems (I-CREOS)" in *Proceedings of OceanObs'09: Sustained Ocean Observations and Information for Society (Vol. 2),* Venice, Italy, 21-25 Sept 2009, Hall, J., Harrison DE & Stammer, D, Eds. ESA Pub WPP-306.

Brainard RE, D Butterfield, M Eakin, RA Feely, et al. (2010). NOAA Pacific Islands Region Ocean Acidification Research Plan. In: *NOAA Ocean and Great Lakes Acidification Research Plan*. NOAA Spcl Rpt, 59-76 pp.

Knowlton, N, RE Brainard, MJ Caley, R Fisher, M Moews, L Plaisance (2010). Coral Reef Biodiversity. In: *Life in the world's oceans: diversity, distribution, and abundance*, Edited AD McIntyre. Blackwell Publishing Ltd, pp. 65-78.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
_2_ Ecology & System Responses
_3_ Biogeochemistry & Modeling

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Research Interests: My background is in community and behavioral ecology. A major focus of my research has been on the effects of low dissolved oxygen and nutrient enrichment on food webs and fisheries. I am especially interested in how alterations to the physical environment that affect individual organisms scale up to effects seen at higher levels of ecological organization. I've also been interested in the effects of multiple stressors and the possibility that multiple stressor interactions increase the likelihood of threshold responses in ecological systems.

Synopsis of current ocean acidification-relevant research or work: Co-PIs Tim Targett, Kenny Rose, Howard Townsend, Bruce Michaels and I have a 5-year grant to examine whether shallow water diel-cycling hypoxia and the accompanying diel-swings in pH, can shift the relationship between nutrient loading and upper trophic level production from positive to negative ('CHRP: Shallow water hypoxia –tipping the balance for individuals, populations and ecosystems'; NOAA-CSCOR award #NA10NOS4780138). Understanding and predicting the effects of hypoxia on upper trophic level species at large spatial scales has been difficult because a number of mechanisms potentially mask or compensate for negative effects on fish and shellfish abundances and fisheries landings. In particular, increased prey production in shallow waters may compensate for lost production in deeper hypoxic habitat. Loss or reduced suitability of this productive shallow water refuge may therefore negatively affect fish and shellfish both within shallow habitat itself, and system-wide as the relative production of deep and shallow water habitats converge. The accompanying diel-cycling pH – diel variation on the order of a full pH unit - may exacerbate impacts of hypoxia, and the combination of these factors may lead to more severe effects than predicted by experiments that examine effects of low oxygen in isolation.

The objectives of the project are to: (1) determine the quantitative relationship between diel-cycling hypoxia and diel-cycling pH in shallow water habitats in Chesapeake Bay; (2) determine the behavioral responses of fish to diel-cycling hypoxia and co-occurring low pH in the field; (3) conduct lab experiments to test the individual and interactive effects of diel-cycling hypoxia and diel-cycling pH on juvenile growth, mortality and reproduction of finfish and oysters, and on the acquisition and progression of *P. marinus* infections in oysters; (4) Refine and use exposure-effects models to predict effects of diel-cycling hypoxia and pH fluctuations on fish and oysters under conditions experienced in Chesapeake Bay; and (5) Use spatially explicit food web models to predict how shallow water diel-cycling oxygen and pH affect (a) system compensation for lost production resulting from seasonal bottom water hypoxia, and (b) sustainable yields of exploited species in Chesapeake Bay.

Related information:
Breitburg, D.L., Hondorp, L.W. Davias, and R.J. Diaz. 2009. Hypoxia, nitrogen and fisheries: Integrating effects across local and global landscapes. Annual Reviews in Marine Science 1: 329-350.
Tyler RM, Brady DC and TE Targett (2009) Temporal and spatial dynamics of diel-cycling hypoxia in estuarine tributaries. Estuaries & Coasts 32:123-145.

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
__3_ Observations & Monitoring
_2__ Physiological Responses
_1__ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:
I study the interaction of marine invertebrate disease, host response, and the environment using molecular tools. This includes shifts in host/pathogen/environment dynamics due to anthropogenic changes including global climate change and ocean acidification. Shifts in this relationship may cause an increased disease incidence due to stress on the host and/or a more suitable environment for the pathogen. I am interested in understanding whether in the long-term, hosts will evolve to survive in the changed environment. The host immune response will likely play a role in resistance to disease and/or environmental tolerance, and a clearer understanding of the complex yet "simple" invertebrate immune system is needed to characterize this response.

Synopsis of current ocean acidification-relevant research or work:
I am currently working on the research project "Collaborative Research: Influence of Temperature and Acidification on the Dynamics of Coral Co-infection and Resistance" (NSF: OCE 0849776, co-PIs D. Harvell and L. Mydlarz). We are focusing on transmission dynamics of diseases of the sea fan, *Gorgonia ventalina*, using field and laboratory based transmission experiments to better under the influence of environment (temperature, acidification) on sea fans exposed to single and/or co-infections. Objectives of this research include 1) what are the health outcomes of the host (*G. ventalina*) to exposure to pathogens in the presence and absence of stressors; 2) do single or dual-pathogens alter these outcomes; and 3) what are the physiological or immune responses that act to protect the host. We hope to better understand whether changing environmental conditions, including temperature and acidification will compromise sea fan immunity and increase virulence of specific pathogens; results may be predictive of other coral or marine invertebrate disease interactions. We are currently analyzing data on exposures of *G. ventalina* to single and serial pathogen exposures; we plan to run additional experiments in the Spring and Summer of 2011 with single and dual pathogen exposures including temperature and acidification.

Another current and related project is, "Collaborative Research: Impact of the 2010 Caribbean Coral Bleaching Event: Assessing Changes in Coral Immune Function" (NSF: OCE 1105201, D. Harvell, with sub-awardees L. Mydlarz, & E. Weil) is focused on physiological, host responses, and microbial responses of *G. ventalina* and the reef building coral *Montastraea flaveolata* to coral bleaching. Objectives of this research include 1) what are the physiological and molecular responses of each species to coral bleaching compared to pre-bleaching levels; 2) are there shifts in normal host surface microbial community during a temperature/bleaching event; and 3) what is the recovery of specific tagged individuals. This project specifically is interested in host physiology, molecular responses, and microbial changes which likely aid our investigation into health, physiological, and immune responses of *G. ventalina* to pathogens, temperature, and acidification.

Related information:
Kim, K and **CD Harvell**. (2004) The rise and fall of a six-year coral-fungal epizootic. American Naturalist **164**: S53-S62

Hoegh-Guldberg, O, Mumby, PJ, Hooten, AJ, Steneck,RS, Greenfield, P, Gomez, E, **Harvell, CD**, Sale, PF, Edwards, AJ, Caldeira, K, Knowlton, N, Eakin, CM, Iglesias-Prieto, R, Muthiga, N, Bradbury, RH, Dubi, A and E Hatziolos (2007). Coral Reefs Under Rapid Climate Change and Ocean Acidification. Science **318:** 1737- 1742

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
_3__ Observations & Monitoring
_1__ Physiological Responses
_2__ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My lab has broad interests in the evolutionary genetics, functional genomics and physiology of marine organisms. We have used a range of genetic approaches to address the following issues:

1) Application of modern genomic tools to understanding organismal responses to thermal, osmotic and pH changes in the environment. Recent advances (such as whole transcriptome sequencing) permit genome-wide analyses of gene regulation even on non-model systems.
2) Functional consequences of genetic variation. Genetic polymorphism results in both protein variation and variation in gene expression. We are interested in the way both these types of variation contribute to physiological adaptations to the environment. New RNA interference approaches permit experimental manipulations of expression of single target genes.
3) The role of nuclear and mitochondrial genome interactions in the fitness of hybrids. When isolated populations diverge through time, they ultimately evolve genetic incompatibility and become reproductively isolated. We have found that some incompatibilities can be traced to rapid evolution of mitochondrial DNA.
4) The genetic structure of natural populations. Determining the spatial structure of marine populations and patterns of connectivity are key to understanding local adaptation and modes of speciation.

Synopsis of current ocean acidification-relevant research or work:

My lab has yet to engage in ocean acidification research. We have worked on thermal and osmotic responses in the intertidal copepod *Tigriopus californicus*. This species has broad physiological tolerances and encounters a broad range of pH in its tidepool habitat; understanding the mechanisms it employs to cope with environmental extremes may give insights into what sets physiological limits on less tolerant species and provide a predictive framework for species that are less amenable to experimentation. Recent work suggests that regulation of heat shock genes differs among populations and may be responsible for observed differences in survivorship of thermal stress.

Related information:

Lab website: http://web.mac.com/ronburton1/iWeb/Site/Home.html

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1_ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

Shallin Busch
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NOAA Northwest Fisheries Science Center
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206-860-6782

Research Interests:

My research focuses on how human changes to the environment affect populations and communities through physiological mechanisms. My work on ocean acidification (OA) addresses this question for North Pacific ecosystems in response to climate change. With colleagues at NOAA and the University of Washington (UW), I 1) conduct experiments on the effects of climate change (OA and changes in dissolved oxygen and temperature) on ecologically and economically important species in coastal marine ecosystems, 2) model the implications of these effects on population dynamics, and 3) project how climate change may affect marine food webs. Integrating results from the organismal to the ecosystem level allows us to generate data relevant to management of species and communities in a changing environment.

Synopsis of current ocean acidification-relevant research or work:

I lead or participate in experiments on how ocean acidification, deoxygenation, and temperature change affect the early life stages of a variety of species. We have conducted preliminary experiments on geoduck, pinto abalone, Pacific oyster, and krill (*Euphausia sp*.), and plan for future studies on black rockfish, copepods (*Calanus sp.)*, Dungeness crab, Olympia oyster, and littleneck clam. My research focuses on the demographic and morphologic responses to treatments, and I collaborate with colleagues (C. Friedman, S. Roberts, J. Keister, A. Dittman) to study behavioral, genomic, and immune responses. I also lead the carbon chemistry work that supports our OA experiments. Our lab has developed stand-alone, Java software to facilitate spectrophotometric measurement of pH and titration-based measurement of total alkalinity.

I am currently working on two modeling projects on the response of food webs to ocean acidification. Working with C. Harvey and P. McElhany, I have developed scenarios of how ocean acidification will impact Puget Sound species, and imposed them on an EcoPath with EcoSim model of Puget Sound's central basin. I focus the results of these simulations on changes to food web structure and ecosystem services (e.g., harvest). For this project, I also developed a database of all species in Puget Sound and their mineralogy. I am also involved in a collaborative project to simulate the impacts of climate change on five north Pacific food webs (collaborators: C. Ainsworth, J. Samhouri, W. Chueng, J. Dunne, T. Okey). Our scenarios attempt to model ocean acidification, deoxygenation, range shifts of vertebrates, shifts in zooplankton community structure, and changes in primary production. We have published one summary paper (Ainsworth et al., in press), and are writing two more (how uncertainty in our ability to model climate change and its impacts on ecological communities influences our study's results, lead by me; how trophic interactions influence the impacts of climate change, lead by Samhouri).

Related information:

1) Ainsworth, C., J. Samhouri, D. S. Busch, W. Cheung, J. Dunne, T. Okey. In press. Potential impacts of climate change on Northeast Pacific marine fisheries and food webs. ICES Journal of Marine Science.
2) See West Coast chapter of NOAA OA research plan for summary of issues and research (http://www.pmel.noaa.gov/co2/story/NOAA+OA+Plan)

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1_ Physiological Responses
_3_ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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(727) 553-1508

Research Interests:

My research has involved the development and application of novel methods and instrumentation for studies of the physical chemistry of seawater and freshwater. A portion of this work has included development of spectrophotometric procedures for measurements of pH, dissolved inorganic carbon, total alkalinity, CO_2 fugacity, and carbonate ion concentrations. Other work has included the development of long-pathlength (liquid core waveguide) procedures for measurements of macronutrients and trace metals at nanomolar and sub-nanomolar levels. A major thrust of my research has involved development of in situ spectrophotometry and mass spectrometry for analysis of CO_2 system parameters and dissolved gases.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects, "Purification and Calibration of Indicators for Measurement of Seawater pH" (NSF OCE-0727082; co-PIs W. Yao and X. Liu), has resulted in (a) procedures for purification of meta cresol purple, and (b) characterization of mCP equilibrium and spectral characteristics requisite to pH analysis over a wide range of salinities, temperatures, and pressures. Ongoing research involves the purification and characterization of other indicators including cresol red, bromothymol blue, and bromocresol green.

Another project, "Development of Methods for Direct Determination of Carbonate Ion Concentrations in Seawater" (NSF OCE-0927108), entails characterization of the equilibrium behavior and ultraviolet spectral characteristics of Pb^{II} in seawater over a wide range of salinity, temperature, and pressure. In analogy with sulfonephthalein measurements of seawater pH (as described above), the strong complexation of Pb^{II} by carbonate ions and chloride ions forms a basis for direct determinations of carbonate ion concentrations in seawater. A notable advantage of this procedure relevant to in situ analysis is the extremely rapid equilibration of Pb^{2+} with chloride and carbonate ions in seawater.

A third project, "Development of a Novel Sensor for In Situ Measurements of Carbonate Ion Concentrations in Seawater (NOAA NA09OAR4310067; co-PIs L. Adornato and E. Kaltenbacher), involves design, fabrication, and testing of an instrument for in situ measurements of carbonate ion concentrations. This project builds on the equilibrium and spectral characterizations of Pb^{II} in seawater described above.

A fourth project, "Collaborative Research: Development of an in situ Sensor for High-resolution Measurements of Total Dissolved Inorganic Carbon" (NSF OCE-1029778; PI L. Adornato, co-PIs R. H. Byrne and E. Kaltenbacher), seeks to combine in situ measurements of total dissolved inorganic carbon and pH, and thereby provide comprehensive in situ characterizations of the marine CO_2 system.

Related information:

Byrne, R.H., S. Mecking, R.A. Feely, and X. Liu. 2010. Direct observations of basin-wide acidification of the North Pacific Ocean. *Geophysical Research Letters* 37, L02601, doi:10.1029/2009GL040999.

Wang, Z.A., X. Liu, R.H. Byrne, R. Wanninkhof, R. Bernstein, E.A. Kaltenbacher, and J. Patten. 2007. Simultaneous spectrophotometric flow-through measurements of pH, carbon dioxide fugacity and total inorganic carbon in seawater. *Analytica Chimica Acta* 596:23–36.

Bell, R.J. R.T. Short, F.H.W. van Amerom, and R.H. Byrne. 2007. Calibration of an in situ membrane inlet mass spectrometer for measurements of dissolved gases and volatile organics in seawater. *Environmental Science and Technology* 41:8123–8128.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
__1_ Observations & Monitoring
___ Physiological Responses
__3_ Ecology & System Responses
__2_ Biogeochemistry & Modeling

Wei-Jun Cai
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Research Interests:

1. Coastal ocean CO_2 dynamics and control mechanisms. Our analysis of historical data and our recent data in the U.S. southeastern shelf suggest that surface water pCO_2 (and thus pH and carbonate saturation) in the US east coast does not follow closely that of the atmosphere (thus less OA). Rather, mixing of surface water with the offshore subsurface controls the pCO_2, pH and carbonate saturation.
2. pH decrease and reduction of carbonate saturation in coastal hypoxia water (see my poster)
3. CO_2 dynamics and ocean acidification in the high latitude oceans (Western Arctic Ocean and margins)
4. Development of microelectrodes (pH, CO_3^{2-}, Ca^{2+}, Cl^-, etc.) to measure internal pH and carbonate saturation of calcifying organisms.

Synopsis of current ocean acidification-relevant research or work:

1. NOAA National OA Monitoring Program, Grays Reef NMS site (offshore GA) (with Scott Noakes and Xinping Hu). This is a program coordinated by NOAA involving university PIs. At our site, we have high resolution pCO_2 mooring data since July 2006 (MAP-CO_2, C. Sabine). Recently we added a pH sensor (SAMI pH) to the buoy. In addition, we have a SAM CO_2 sensor on the sea floor.
2. Collaborative Research - Ocean Acidification Category 1: Interactive Effects of Temperature, Nutrients, and Ocean Acidification on Coral Physiology and Calcification (NSF EF-1041070 with PI Andrea Grottoli and co-PI Mark Warner). The Cai group will quantify seawater carbonate parameters during the course of lab incubation as well as applying microelectrodes (pH and CO_3^{2-}) to study the mechanism how corals maintain their internal pH and saturation state and how they change with external seawater pCO_2, temperature and nutrient level.
3. Collaborative Research: Satellite Assessment of CO_2 Distribution, Variability and Flux and Understanding of Control Mechanisms in a River Dominated Ocean Margin (NSF OCE-0752110 with Steve Lohrenz and Kjell Gundersen).
    a. (surface water) Biological production is the main control on plume water pCO_2, pH (as high as 8.6) and carbonate saturation whereas multiple end-member mixing plays an important role in TA and DIC distributions.
    b. (subsurface water) Large decrease in pH (~0.45) and reduction in carbonate saturation were found in coastal hypoxia waters. Synergisms between OA and hypoxia were indentified (see my poster).
4. Controls on Sea Surface pCO_2 Variability and CO_2 Uptake in the Western Arctic Ocean Margins (NSF ARC-0909330). In the marginal seas, surface waters have high pH due to biological uptake; in the southern Canada Basin, surface waters have OA due to the uptake of atmospheric CO_2; in the northern basin, there is no OA in surface water due to ice-cover but pH in the subsurface waters is low due to respiration-derived CO_2.

Related information: http://www.marsci.uga.edu/directory/wjcai.htm
http://ocean.otr.usm.edu/~w301130/research/gulfcarbon_new.htm

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
__2_ Observations & Monitoring
_3__ Physiological Responses
___ Ecology & System Responses
_1__ Biogeochemistry & Modeling

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Research Interests:

My research has focused on the development and application of biochemical methods to estimate rate processes in marine organisms. I have primarily utilized a nucleic-acid based index (RNA/DNA) as an indicator of nutritional condition in larval fish and as an indirect measure of instantaneous growth rates. With this index I have investigated linkages between environmental variability and larval cod and haddock growth rates as part of the US GLOBEC Northwest Atlantic/Georges Bank program. Recently I have been investigating two potential non-lethal indicators of growth rate and nutritional condition in post-smolt salmon: bioelectrical impedance analysis (BIA) and insulin-like growth factor I (IGF-I).

Synopsis of current ocean acidification-relevant research or work:

Growth rates are integrative, and among the most sensitive indicators of fitness. My contribution to ocean acidification research will be to measure growth rates in *Calanus sp*. copepods from both laboratory studies and field collections. I will be collaborating with Jeffrey Runge from the Gulf of Maine Research Institute on his proposed study to investigate possible ocean acidification and temperature effects on the reproductive success and growth rates of *C. finmarchicus, C. glacialis,* and *C. hperboreus*. Growth rates will be estimated using either RNA:DNA ratios or aminoacyl-tRNA synthetase (AARS) activity.

Related information:

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1__ Physiological Responses
__2_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Tiburon CA 94920

Research Interests:

Research is done together with CO-PIs Jonathan Stillman and Tomoko Komada and it concerns the ability of the coccolithophore Emiliania huxleyi to adapt to pH and pCO2 conditions expected at the end of the century. We are growing E. huxleyi in long-term chemostats (several hundred generations) in which we compare gene expression and other physiological parameters under present day and future conditions. The research involves "experimental evolution" and is funded by the NSF (OCE-0723980) "EN-GEN: A functional genomic analysis of how a major calcifying phytoplankton species responds to ocean acidification predicted for the end of the century."

Synopsis of current ocean acidification-relevant research or work:

Coccolithophores are unicellular phytoplankton producing calcium carbonate coccoliths as an exoskeleton. Emiliania huxleyi is the most abundant coccolithophore in the world's ocean, and plays a major role in the global carbon cycle by regulating the exchange of CO2 across the ocean-atmosphere interface through photosynthesis and calcium carbonate precipitation. In the future climate, ammonium concentration in seawater is expected to rise. This is due to increasing anthropogenic nitrogen deposition, increasing rates of cyanobacterial N2 fixation due to warmer and more stratified oceans, and decreased rates of nitrification due to ocean acidification. To examine the synergistic effect of elevated pCO2 and increased ammonium/nitrate ratio on Emiliania huxleyi, we maintained continuous cultures for at least 200 generations under different conditions of pCO2 and nitrogen source. Here we show that assimilation of nitrogen as ammonium depresses calcification at both ambient and elevated pCO2, alters coccolith size and shape, and increases primary production. We observed that both nitrogen source and pCO2 synergistically drive growth rates, cell size and the ratio of inorganic to organic carbon. Our results emphasize the need to assess various environmental parameters in combination in order to develop accurate predictions of phytoplankton responses to ocean acidification. At present, anthropogenically-driven increases in ammonium concentrations occur primarily in coastal and low nutrient waters. However, with increased acidification and nitrogen oxide emissions, increased ammonium availability may extend to more open waters and could reduce bio-mineralization by calcifying organisms, while increasing primary production in these species, thus exerting feedback on climate.

Related information:

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1__ Physiological Responses
__2_ Ecology & System Responses
__3_ Biogeochemistry & Modeling

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Research Interests:

My research interests are focused on how the physiology and ecology of coral reef organisms are driven by physical factors including light, water flow, and seawater chemistry. Of particular interest are the relative roles of different physical factors in modulating rates of coral reef primary production and calcification, and how these effects are manifest across reefs that vary in community structure. One important question is: Is the function (metabolism) of coral reef communities determined more by physical drivers or by community structure? The relative importance of these two factors will likely determine how coral reefs respond to continued environmental change and shape their future structure and .

Synopsis of current ocean acidification-relevant research or work:

We are taking a hypothesis-driven approach to compare the effects of OA on reef taxa and coral reefs in Moorea. The project is being conducted in close collaboration with the Moorea Coral Reef LTER program that provides a larger spatial scale and longer temporal scale context for our project. We will utilize microcosms to address the impacts and mechanisms of OA on biological processes, as well as the ecological processes shaping community structure. Experiments will be conducted to quantify rates of calcification and photosynthesis/respiration over 6 pCO_2 levels to detect nonlinearities in responses. These experiments will include 8 species of corals with explicit contrasts between skeletal structure and morphology, and 8 species of calcified algae representing constrasts in morphology, site of calcification, and carbonate polymorph. Additional experiments will be conducted on the effects of OA on coral recruitment to CCA and bioerosion of corals. Additional comparative experiments on similar taxa will be conducted in Hawaii in collaboration with M. Atkinson, to address regional variation in the response of calcifiers to OA. Additionally, studies of reef-wide metabolism will be used to evaluate the impacts of OA on intact reef ecosystems, to provide a context within which the experimental investigations can be scaled to the real world, and critically, to provide a much needed reference against which future changes can be gauged.

Related information:

This is a collaborative project with Peter Edmunds at CSUN.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1__ Physiological Responses
__2_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Friday Harbor Laboratories
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Friday Harbor WA 98250
206-221-4676

Research Interests:

My research program, in its broadest sense, investigates the physiological ecology of marine organisms. I generally focus on organisms common to wave-swept rocky shores, where they are alternately exposed to marine and terrestrial conditions with the rise and fall of the tides. How do environmental fluctuations affect the growth, survival, and reproduction of organisms with such different body plans and life histories? My research involves both plants and animals and spans many levels of biological organization, from the mechanics of biological materials, to the persistence of populations, to the characterization of the physical environment and how it influences biological processes. I often take an engineering approach to the study of living systems, applying the basic mechanical principles to evaluate organismal form and function. My laboratory at UW-FHL comprises a broad range of biomechanical research tools, including several recirculating flumes and materials testing devices. In recent years, there have been three major themes to my research, all of which involve collaboration with my students and other researchers: 1) ecomechanics of wave-swept organisms (especially mussels), 2) thermal effects on ecological processes, and 3) functional morphology of seaweeds. These themes all explore how organisms perform within the physical constraints of their environment.

Synopsis of current ocean acidification-relevant research or work:
The survival of many coastal organisms is constrained by the integrity of their structural components. Is their shell strong enough to deter predators? Is their attachment to rock secure in the face of strong waves and currents? What will happen to coastal marine communities as changing environmental conditions, such as ocean acidification or warming, alter the way key biomaterials are manufactured and maintained? These are the questions guiding our team of marine biomaterials experts at Friday Harbor Labs, led by Emily Carrington in collaboration with Adam Summers (co-PI), Moose O'Donnell and Patrick Martone (EF1041213) . The impetus for the research comes from our recent insights into the seasonal dynamics of wave-swept mussel populations; their ability to manufacture strong tethers can be compromised dramatically by various environmental and physiological demands, to the point where mussels can be washed away readily by even modest storms. Clearly, the structural integrity of a mussel is constrained by environmental conditions; the new project applies this **ecomaterials** perspective to the emerging problem of ocean acidification. The research will target a suite of organisms (including mussels, snails, crabs, and calcified red algae), each with one or more well-known biomaterials that serve a critical ecological function.

Related information:
Carrington, E., G.M. Moeser, J. Dimond, J.J. Mello and M.L. Boller, 2009. Seasonal disturbance to mussel beds: field test of a mechanistic model predicting wave dislodgment. Limnol. Ocean. 54:978-986.
Website: http://faculty.washington.edu/ecarring/index.html

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1 Physiological Responses
_2_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My research focuses on 1) drivers of hypoxic zones in upwelling systems, 2) the impacts of hypoxia on changes in carbon chemistry and nutrient cycles, 3) the effects of spatial and temporal variations in ocean chemistry on ecological processes.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects, titled "EAGER: Initiation of a pH/pCO2-sensing mooring platform on the Oregon coast." (NSF OCE; co-PIs B. Menge), is focused on evaluating the operational deployment of SAMI pCO2 and pH sensors for characterizing the scales of variability in ocean acidification stress and their potential for coupling with and decoupling from hypoxia. Our efforts to date have highlighted the feasibility and challenges of in-situ sensor time-series measurements in productive upwelling shelf waters. We are working to improve the reliability of our mooring based sensor deployments through time and results gained to date point to strong cross-shelf changes in the variability of OA stress. Over the mid-shelf, elevated pCO2 levels are a seasonally persistent feature whereas pCO2 dynamics in the inner-shelf are marked by high-amplitude, high-frequency tidally-forced variations. In a second research project (Microbial diversity and activity in the seasonal hypoxic waters off Central Oregon and Chile: A comparative study. PIs: R. Letelier, O. Ulloa, J. Barth, F. Chan, E. DeLong, L. Farias, S. Giovannoni, C. Lange, A. Mix, S, Pantoja, O. Pizzaro, N. P. Revsbech, S. Schuster, Gordon and Betty Moore Foundation), my research has focused in part, on the covariation of low-oxygen and OA stress, the factors that drive their variability, and the potential consequence of changes in carbon chemistry on N-cycling. In a third research project (Collaborative Research: Acclimation and adaptation to ocean acidification of key ecosystem components in the California Current System. PIs: B. A. Menge, J. A. Barth, C. Blanchet, F. Chan, F. Chavez, B. Gaylord, T. Hill, G. Hofmann, M. McManus, S. Palumbi, A. Russell, E. Sanford, L. Washburn. NSF Ocean Acidification NSF), we are examining 1) how nearshore (surf-zone to inner-shelf) OA stress varies along the California Current from Oregon to Southern California, 2) the cross-shelf drivers of that variability, 3) the implications of chemistry variability on key invertebrate populations and 4) the scope for acclimation and/or adaptation to OA stress along the California Current. In a new project that will start in Spring 2011 (Collaborative Research: The role of calcifying algae as a determinant of rocky intertidal macrophyte community structure at a meta-ecosystem scale. PIs: B. A. Menge, F. Chan, S. Hacker, K. Nielsen, NSF BIO-OCE), my collaborators and I are further examining the potential ecological pathways by which OA can impact ecological community structure. This research will focus on the interactions between calcifying and non-calcifying macrophytes which are united in a complex interaction web via competition and facilitation.

Related information:

Howarth, R.W., F. Chan, D. J. Conley, J. Garnier, S. C. Doney, R. Marino, and G. Billen. 2011 Coupled biogeochemical cycles: Eutrophication and hypoxia in temperature estuaries and coastal marine ecosystems. *Frontiers in Ecology and Environment*. 9: 18-26.

www.piscoweb.org

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
__x_ Observations & Monitoring
___ Physiological Responses
_x__ Ecology & System Responses
__x_ Biogeochemistry & Modeling

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508-289-2765

Research Interests:

My research interests lie in ocean informatics, the intersection of computer science, information science and oceanography.

Synopsis of current ocean acidification-relevant research or work:

My main project is the Biological and Chemical Oceanography Data Management Office (BCO-DMO) funded by the NSF Geosciences Directorate (GEO) Division of Ocean Sciences (OCE) Biological and Chemical Oceanography Sections and Office of Polar Programs (OPP) Antarctic Sciences (ANT) Organisms & Ecosystems Program. BCO-DMO manages and serves oceanographic biogeochemical, ecological, and companion physical data and information developed in the course of scientific research and contributed by the originating investigators. Data managers at BCO-DMO will work with NSF funded PIs to manage data from the Ocean Acidification research program. The BCO-DMO data system facilitates data stewardship, dissemination, and storage on short and intermediate time-frames. Our main objective is to support the scientific community through improved access to ocean science data. In addition to the data management work at BCO-DMO, I am currently working on several informatics projects including: development of an ontology for biogeochemistry data; encouraging development and use of controlled vocabularies for improving the management and efficacy of oceanographic research data; and development of a framework for the publication and citation of scientific data.

I am one of the three originating PIs for the Rolling Deck to Repository (R2R) project funded by NSF to ensure proper stewardship of data collected aboard research vessels in the US academic fleet. The R2R projects team members from LDEO, WHOI, SIO and SAMOS at FSU are working to implement a comprehensive plan for management of underway data collected aboard vessels in the US academic fleet. The R2R Web site supports a central shore-side data gateway through which underway data from each expedition since January 2010 are routinely cataloged and transmitted from UNOLS ship operators to long-term national archives. The premise is that working directly with ship operators and technicians will ensure more complete and consistent acquisition, quality, preservation, and dissemination of the original data, thereby transforming the academic fleet into an integrated global observing system.

As co-PI for the BCO-DMO, I contribute data management expertise to many large, coordinated biogeochemistry research projects including GEOTRACES, SOLAS and IMBER.

Related information:

Baker, KS and CL Chandler. 2008. Enabling long-term oceanographic research: Changing data practices, information management strategies and informatics. Deep Sea Research Part II. 55 (18-19) : 2132-2142. doi:10.1016/j.dsr2.2008.05.009

BCO-DMO Web site: http://bco-dmo.org/
R2R Web site: http://rvdata.us/

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_3_ Observations & Monitoring
___ Physiological Responses
_1_ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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South Carolina Department of Natural Resources
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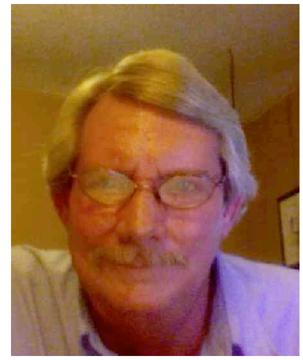

Research Interests:

My research is focused on the adaptation of populations and species to environmental changes using gene expression profiling. This has induced studies of the responses of shrimp to naturally occurring viruses, the responses of fish to arsenic exposure, gene expression as a means to gauge fertility in fish and the response of oysters to anthropogenic and naturally occurring stresses in the environment.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects has identified temperature and pH as major factors determining gene expression profiles in the oyster and these environmental conditions influence gene expression in complex and non-linear fashions. This finding was only possible using advanced machine learning algorithms, which are infinitely flexible and can deal with massively paralleled data. The findings are very clear that under high temperatures and low pH, oysters respond by limiting ATP demand and increase ATP availability. This should result in the well know Warburg shift from aerobic glycolysis to oxidative phosphorylation, which should in turn reduce the growth rate and biomineralization. As the oyster lives in habitats that are routinely subject to temperature and pH stresses well beyond those expected as a result of increasing atmospheric CO2, the environments and the organism can serve as a natural laboratory to investigate the impacts of these stressors on natural systems. We are therefore in the process of assessing the influence of temperature and pH on the genomic, metabolic and structural changes in this species.

Related information:

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_3__ Observations & Monitoring
_2__ Physiological Responses
_1__ Ecology & System Responses
___ Biogeochemistry & Modeling

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831-775-1709

Research Interests: The attendee represents the Ocean Margin Ecosystems Group for Acidification Studies (OMEGAS) team. The team is interested in how populations of ecologically important coastal invertebrates of the California Current Large Marine Ecosystem (CCLME) vary in their responses to spatial and temporal variations in sea water chemistry (pH and carbonate state). The team aims to measure the spatial and temporal variability of sea water chemistry in nearshore waters of the CCLME and to determine if the marine organisms are able to acclimatize and/or adapt to the observed varying levels of ocean acidification (OA) and those predicted to occur in the future.

Synopsis of current ocean acidification-relevant research or work: The team will investigate the impact of ocean acidification on two ecological important, calcification-dependent marine invertebrates (sea urchins and mussels) in relation to local-to-coastal variation in carbonate chemistry in the California Current Large Marine Ecosystem (CCLME). An interdisciplinary team of investigators with expertise in physical and chemical oceanography, marine ecology, biochemistry, molecular physiology, and molecular genetics will carry out an integrated, lab and field, multi-site investigation of the ecological, physiological, and evolutionary responses of sea urchins and mussels to spatial and temporal variation in OA. The research will take place in the context of a mosaic of variable oceanography, including recently documented latitudinal variation in carbonate chemistry along the upwelling-dominated US west coast. Variation in upwelling regimes from Washington to southern California generates spatial and temporal gradients in concentration of CO_2 that shoal to surface waters during upwelling events, extending shoreward into the inner shelf region. Because calcifiers in the upwelling-dominated CCLME probably have historically experienced wide fluctuation in pH, many likely are adapted to a variable carbonate chemistry environment. The new challenge to these organisms is that they may have limited ability to respond to additional increases in pCO_2. It is this challenge, the mechanistic ability of calcifying invertebrates to acclimatize or adapt to increasing CO_2 and aragonite saturation states < 1.0 that is addressed in this project.

Our proposed research includes several integrated elements. (1) Document the oceanographic context in which the study organisms operate in four regions of the CCLME with contrasting upwelling regimes, and a wide range of differences in carbonate chemistry. (2) Examine physiological, genomic, and genetic mechanisms underlying acclimatization and adaptation to OA conditions with coordinated and integrated studies of adults and larvae of sea urchins and mussels collected from each of two sites within each of the four regions. In common-garden experiments culture sea urchins and mussels, respectively, under different CO_2 and temperature regimes, and use genomic techniques to determine the tolerance of larvae to present and future OA conditions. (3) Determine evolutionary responses and adaptation potential to OA using genetic surveys of urchins and mussels across the 8 sites and relate detected variability to the oceanographic conditions. (4) Examine ecological responses to OA with transplants of mussels and urchins in the field and monitor growth rates and shell accretion rates in relation to oceanographic and physical conditions.

Related information:

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
_4_ Physiological Responses
_3_ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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Research Interests:

My research focuses primarily on climate change and its impact on ocean life. While individual projects conducted within my lab are quite diverse, and include both extensive field-based experiments, observations and sampling as well as laboratory-based manipulation experiments, our collective goals are focused in two areas: 1) to characterize surface ocean climate variability and change in the tropics and subtropics over the last 1000 years, and 2) to quantify the impacts of ocean climate variability, both past and future, natural and anthropogenically-forced, on the health of marine calcifying organisms and the ecosystems that depend on them.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects, titled "An Investigation of the Role of Nutrition in the Coral Calcification Response to Ocean Acidification" (NSF OPP 1041106 co-PIs D. McCorkle, A. Tarrant, S. de Putron) investigates the role of nutrition, or energetic status, in the coral calcification response to ocean acidification (and warming). We are using both laboratory manipulation experiments and quantification of coral samples collected at field sites across the tropical Pacific, to investigate the interactions amongst coral $CaCO_3$ production, coral energetics, availability of nutrients/food and environmental variability (specifically *in situ* Ω_{ar} and T). Our initial data, based on two experiments conducted in summer 2010, suggest that energetically replete corals produce more $CaCO_3$ than energetically depleted corals, independent of Ω_{ar} (range: 3.9-1.5) or T (range 22°C -29°C) (Drenkard et al., 2011, Barkley et al., 2011). For example, energetically replete corals reared at Ω_{ar} = 1.5 produced more $CaCO_3$ than energetically depleted corals reared at ambient Ω_{ar}. Our data collected from field corals support this observation: calcification rates (quantified by 3-D CAT scanning of intact skeletons) at low Ω_{ar}, high nutrient sites can be as high or higher than those of conspecifics at high Ω_{ar}, low nutrient sites. This research is just beginning and new laboratory and field experiments, as well as modeling studies (in collaboration with Dr Sarah Cooley at WHOI) are planned for the summer and fall 2011.

Another research project, titled "Ocean Acidification Impacts on Larval Shell Formation by Commercial Shellfish Species of New England: An Experimental Investigation" (NOAA Seagrant NA10OAR4170083 co-PI D. McCorkle) is just beginning. Our goal is to quantify the sensitivity of larval shell formation to changes in Ω_{ar}, focusing initially on four shellfish species that have commercial value in the New England fishery. Our initial data (collected for the bay scallop *A. irradians*) suggest significant negative effects on survival and shell development within the first 24 hours post-fertilization at Ω_{ar}<1.

Related information: Barkley, H., et al., Establishing links between basin scale climate variability and the growth of Atlantic corals: an experimental investigation, ASLO 2011, Aquatic Sciences Meeting, 13-18 February 2011, Puerto Rico; Drenkard E., et al., Feeding modulates the impact of ocean acidification on coral growth, ASLO 2011, Aquatic Sciences Meeting, 13-18 February 2011; McCorkle D.C., et al., Impact of ocean acidification on survival and early shell development by the bay scallop Argopectin irradians, World Aquaculture Society: Aquaculture 2010 - San Diego, California - March 1 - 5, 2010; De Putron S., et al. (2011) The impact of seawater saturation state and bicarbonate ion concentration on coral calcification, Coral Reefs, *in press;* Cantin N.C., et al., (2010) Coral growth declines as temperatures rise in the central Red Sea, Science, 2010;329(5989):322-325; Ries J.B., et al. (2010) The zooxanthellate temperate coral *Oculina arbuscula* exhibits a nonlinear calcification response to pCO_2-induced ocean acidification. Coral Reefs, DOI 10.1007/s00338-010-0632-3; Holcomb M.C., et al. (2010) Long-term effects of nutrient and CO_2 enrichment on the temperate coral *Astrangia poculata* (Ellis and Solander 1786), Journal of Experimental Marine Biology and Ecology, 386 (2010) 27–33; Cohen A.L. and Holcomb M.C (2009) "Why Corals Care about Ocean Acidification: Uncovering the Mechanism". IN: *The Future of Ocean Biogeochemistry in a High CO_2 World*, Oceanography, 22(4); Ries J.B., et al. (2009), Marine calcifiers exhibit mixed responses to CO_2-induced ocean acidification. Geology, no. 12; p. 1131–1134; doi: 10.1130/G30210A; Cohen A.L., et al. (2009), Compositional and morphological changes in the skeletons of juvenile corals reared in acidified seawater: insights into the biomineralization response to ocean acidification, Geochem. Geophys. Geosyst., 10, Q07005, doi:10.1029/2009GC002411.

Meeting scientific themes relevant to this research:

_X_ Paleo & Proxies/Modeling
_X__ Observations & Monitoring
_X__ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

Most of my work has centered on physiological interactions between marine invertebrates and symbiotic dinoflagellates with particular emphasis on nutrient interactions. Current work includes analysis of light limitation and turbidity on the skeletal architecture of scleractinian corals. I have a peripheral interest in calcification mechanisms in marine invertebrates, particularly reef-building corals.

Synopsis of current ocean acidification-relevant research or work:

I served as an NSF Program Director in BIO / IOS (Integrative Organismal Systems) from 2008 through 2010. My primary duty was to administer the Symbiosis, Defense and Self-recognition program. Proposals dealing with the physiology of corals and microbial / algal symbionts would be considered by this program, as well as a broad range of symbiosis / defense-related topics (plant pathology, microbial interactions, comparative immunology.) I was one of three representatives from the BIO directorate on the NSF Ocean Acidification team, working with other program directors from the GEO directorate and the Office of Polar Programs to facilitate the NSF solicitation on ocean acidification.

Related information:

Meeting scientific themes relevant to this research:
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___ Observations & Monitoring
_1__ Physiological Responses
__2_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:
My research uses oceanographic and social science approaches to forecast the total consequences of human-driven changes in the marine inorganic carbon cycle. Anthropogenic changes like ocean acidification will affect not only the marine environment but also the benefits, like economic revenue and protein supply, that marine ecosystems provide to human communities. This makes ocean acidification and other biogeochemical changes internationally policy-relevant, but these issues must be related to human communities to interest policymakers. Recently, I have assessed how ocean acidification could alter protein supply and economic revenue using ocean models and social science datasets. This research increasingly incorporates ecology, sociology, economics, resource management, risk assessment, and decision making under uncertainty. I am also interested in using more classical biogeochemical model/data assessments to examine chemical changes in nearshore and open-ocean regions, in particular, detection and attribution of statistically significant change from historical conditions.
Synopsis of current ocean acidification-relevant research or work:
- Examine ocean acidification's potential consequences on mollusk harvests
    - Combine coupled ocean model forecasts of future ocean conditions with mollusk harvest data to examine potential economic or nutritional consequences of environmental changes that result in mollusk harvest decreases. Co-investigators: S. Doney, H. Kite-Powell, N. Lucey (all WHOI).
- Study consequences of river outflow and mesoscale circulation features in Middle Atlantic Bight
    - Perform model-data studies using ROMS NENA, CESM, and historic data to examine accuracy of models in MAB region, leading towards developing initial/boundary conditions for studying the future consequences of environmental change in this coastal region. Co-investigators: K. Fennel (Dalhousie), S. Doney (WHOI)
- Develop reduced-form integrated assessment model (in development).
    - Model will incorporate biogeochemistry and economics to allow macro-level studies of ocean acidification's total impacts. Co-investigators: C. Moore, EPA; others.
- Develop decision-support tools for stakeholders with realistic scientific details. (in development)
    - Combine regional biogeochemical/ecological models with human decision information for W. Florida Shelf region to provide stakeholders with relevant information. Co-investigators: G. Morgan, I. Azevedo-Lima, M. Small (all CMU CDMC); S. Doney (WHOI).
- Ocean acidification scientist in Ocean Carbon and Biogeochemistry Project Office
    - Provide logistical support to OCB Ocean Acidification subcommittee; develop and distribute outreach and education materials about ocean acidification; maintain clearinghouse of ocean acidification information for media, policymakers; coordinate ocean acidification research & communication efforts in U.S. with international programs. www.whoi.edu/OCB-OA

Related information:
Feely, R.A., et al. (2009) *Oceanography* 22(4): 36-47.
Cooley, S.R., et al. (2009) *Oceanography* 22(4): 172-181.
Cooley, S.R., and S.C. Doney. 2009. *Environmental Research Letters*, 4, doi:10.1088/1748-9326/4/2/024007.

Meeting scientific themes relevant to this research:
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___ Observations & Monitoring
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Research Interests:

My research focuses on improving our understanding of the chemistry of carbon dioxide in seawater, with a current emphasis on the effects of ocean acidification. My laboratory has played a leading role in developing reference materials for the quality control of oceanic carbon dioxide measurements, and these materials are distributed extensively to scientists around the world.

In addition to this work on measurement quality control, we also participate in hydrographic cruises that are part of CLIAVR (a WCRP program addressing Climate Variability and Predictability) measuring total alkalinity and pH on open ocean samples, with a view to assessing the changes that have been occurring since such hydrographic sections were occupied during the WOCE program in the 1990s.

Finally, we are applying our knowledge of ocean CO_2 chemistry in collaborations with biologists that are aimed at studying the physiological and ecological consequences of changing the chemistry of the oceans by the addition of anthropogenic CO_2.

Synopsis of current ocean acidification-relevant research or work:

1. Preparation, certification, and distribution of reference materials for the measurement of total alkalinity, total dissolved inorganic carbon, and pH in seawater. (NSF OCE 0961242)
2. Ocean acidification exacerbated by coastal upwelling: monitoring of CO_2 and O_2 on the California shelf and effects on red sea urchins, abalone, and oysters. (V. Fabry, proj. director; G. Hofmann, R. Feely, J. Abell, A. Dickson — CA Ocean Protection Council R/OPCENV-09B)
3. Collection and analysis of seawater sample from the California Coast (CIMEC NA10OAR4320156)
4. MRI: Development of instrumentation to control seawater composition for ocean acidification research (NSF OCE 1039930)

These are all examples where my laboratory's expertise in CO_2 measurements is playing a role. In #1 we provide the OA community with measurement advice and calibration standards for these important measurements; in #2 we are working with others on a project addressing local concerns in California (our part involves seawater analyses, as well as development and operation of a system for controlling seawater composition for physiological experiments; in #3 the samples we collect are being used to validate a simple model (S.Alin & R.Feely) that predicts aragonite saturation state in the water column from the simple hydrographic parameters: S, t, $[O_2]$. Project #4 builds on experience from #2 and we aim to assemble a system that can control the compositions in multiple aquaria simultaneously, and vary the composition dynamically as needed.

Related information:
http://andrew.ucsd.edu/co2qc

Meeting scientific themes relevant to this research:

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_1_ Observations & Monitoring
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Research Interests:

Our research on ocean conservation issues has focused primarily on public and stakeholder awareness and attitudes toward value for ocean ecosystem services, threats to ocean health and the health of marine life, as well as solutions to address these problems. Primary questions motivating this research include: 1) How can the impacts of threats to ocean health be most effectively communicated to the public and stakeholders; 2) What barriers exist to engagement on ocean-related issues and how can we lower them; 3) Which solutions, personal and policy-oriented, can the public and stakeholders be motivated to support?

Synopsis of current ocean acidification-relevant research or work:

Our current research, titled "Ocean Acidification: Communicating for Understanding, Concern and Engagement," focuses on stakeholder and the public in the United State and the United Kingdom and examine awareness of and reactions to ocean acidification. The research included in-depth interviews, focus groups and national sample surveys in each country. The results of the research have implications for those working to communicate ocean acidification as a priority issue for research; as well as for those working in ocean resource management and conservation who seek support for ocean acidification mitigation and adaptation policies and strategies.

Related information:

Meeting scientific themes relevant to this research:

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Research Interests:
My research interests focus on carbon cycling and ocean acidification, specifically mechanisms controlling sources and sinks of anthropogenic CO_2 in the oceans, and impacts of CO_2 on marine ecosystems.

Synopsis of current ocean acidification-relevant research or work:
I have been using the CLIVAR/CO_2 Repeat Hydrography and North American Carbon Program cruise data sets in collaboration with modelers to determine the rates of acidification of open-ocean and coastal waters in the Pacific and to determine the relative contributions of anthropogenic CO_2 inputs, circulation, mixing, biological productivity, and remineralization on the acidification process. This year we'll be studying the combine impacts of ocean acidification and hypoxia along the Cascadia Margin between Canada and Mexico. This will allow us to make detailed observations throughout the Cascadia region focusing on areas of known recurring hypoxic conditions consistently observed through the past decade. We plan to conduct a full suite of high-quality measurements of inorganic carbon (total CO_2, alkalinity, pCO_2), oxygen, nutrients, salinity, and temperature. These measurements will form the core of the data set needed to extend the predictive relationships for Ω_{arag} and pH to water masses with hypoxic conditions.

I am a member of the OCB Scientific Steering Committee and Ocean Acidification Subcommittee, and the Interagency Working Group on Ocean Acidification (IWGOA) established by the Joint Subcommittee on Ocean Science and Technology (JSOST). I am also a member of the international SOLAS-IMBER Ocean Acidification Working Group (SIOA WG). The SIOA WG consists of representatives from the world's major ocean acidification research programs currently underway in in Australia, China, France, Germany, Japan, UK and USA and functions to coordinate research and information exchanges at the international level.

Related information:
Feely, R.A., S.C. Doney, and S.R. Cooley (2009): Ocean acidification: Present conditions and future changes in a high-CO_2 world. Oceanography, 22(4), 36–47.

Feely, R.A., V.J. Fabry, A. Dickson, J.-P. Gattuso, J. Bijma, U. Riebesell, S. Doney, C. Turley, T. Saino, K. Lee, K. Anthony, and J. Kleypas (2010): An international observational network for ocean acidification. In Proceedings of the "OceanObs'09: Sustained Ocean Observations and Information for Society" Conference (Vol. 2), Venice, Italy, 21–25 September 2009, Hall, J., D.E. Harrison, and D. Stammer, Eds., ESA Publication WPP-306, doi: 10.5270/OceanObs09.cwp.29.

Feely, R.A., S.R. Alin, J. Newton, C.L. Sabine, M. Warner, A. Devol, C. Krembs, and C. Maloy (2010): The combined effects of ocean acidification, mixing, and respiration on pH and carbonate saturation in an urbanized estuary. Estuar. Coast. Shelf Sci., 88, doi: 10.1016/j.ecss.2010.05.004, 442–449.

For more information visit our website at: http://www.pmel.noaa.gov/co2/

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
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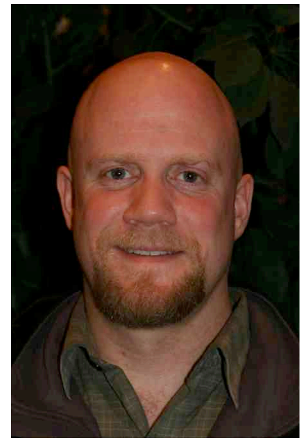

Research Interests:

My research interests are focused on the influence of environmental variables on the distribution, biology, and ecology of marine organisms. Specifically I have focused on the influence of temperature and inter-species interactions on the behavior and energetics of forage fish, groundfish, and crabs. I currently conduct stock assessments of crab stocks in the eastern Bering Sea incorporating environmental information. The Kodiak Laboratory houses a state of the art seawater system where experiment are conducted on environmental influences, habitat requirements, and species interactions specific to the larval and juvenile life histories of Lithodidae and Majidae crab, Gadidae, Pleuronectidae, and Sebastidae.

Synopsis of current ocean acidification-relevant research or work:

Initial pilot projects to ascertain the potential impact of ocean acidification on commercial crabs in Alaska indicated that lower pH from hydrochloric acid mediated pH changes negatively affected survival to and growth and calcium content of the first juvenile stage of blue king crab (*Paralithodes platypus*). Subsequently a CO_2 delivery system capable of short and long term studies on individual larval and adult scales was developed.

In 2010, Tanner crabs, *Chionoecetes bairdi*, were exposed to increased pCO_2 resulting in pH of 7.5, 7.8, and 8.1 to test the effects on growth and survival. Survival decreased 20%, wet weight mass growth was 40% lower, and carapace width growth was 20% lower in the most acidified treatment. In 2011, work on Tanner crab will continue on the effects on fecundity, embryo viability, embryo condition, hatching success, and embryo development time.

In 2010, red king crab, *Paralithodes camtschaticus*, were exposed to increased pCO_2 for three months to test the effects on late embryogenesis, larval condition, and larval survival. We crossed maternal treatment with larval treatment to examine interactions between the effects of increased pCO_2 at the embryo and larval stages. Acidified waters affected embryo morphology, decreased larval survival time, affected larval morphology, and resulted in larvae with higher calcium content.

Collaborative work continues with stock assessment scientists to model the potential population level impacts and economic impacts if survival and growth changes experimentally observed are realized in the eastern Bering Sea resulting in the loss of millions of dollars of revenue in coastal Alaskan communities.

Related information:

http://www.afsc.noaa.gov/kodiak/

Long, W.C., K.M. Swiney, and R.J. Foy. in Review. Effects of ocean acidification on late embryogenesis, and larvae condition and survival in red king crab.

Page, H., R. J. Foy, W.C. Long, K.M. Swiney. 2010. Effect of ocean acidification on juvenile Tanner crab, *Chionoecetes bairdi*, survival and growth. Ernest F. Hollings Undergraduate Scholar 2010 Symposium, August 2010. Washington, DC.

Blakeslee, M., and W.C. Long. 2011. Design and operation of a flow-through seawater acidification system for Ocean Acidification research at the NMFS Kodiak Laboratory. Alaska Marine Science Symposium, January 2011. Anchorage, Alaska.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
1 Physiological Responses
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___ Biogeochemistry & Modeling

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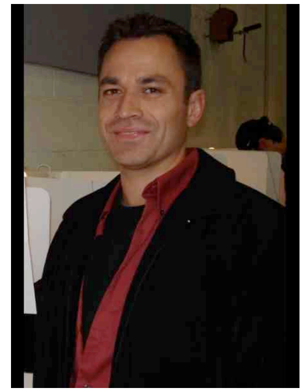

Research Interests:
I am currently in the final year of working on a PhD at the University of Southern California with Dave Hutchins on the effects of climate change on oceanic N_2-fixing cyanobacteria. One of the main priorities of my dissertation work is to document the effect of elevated pCO_2 on N_2 fixation in combination with other environmental factors that are expected to change simultaneously, such as light, phosphate and iron. Unrelated to topics in ocean acidification research, I have also studied with Jack DiTullio and Peter Sedwick at the College of Charleston where I completed my M.S. thesis work examining the half-saturation constant for growth with respect to iron under a range of irradiances in the alga *Phaeocystis antarctica*.

Synopsis of current ocean acidification-relevant research or work:
So far, I have tested the combined impacts of light and elevated pCO_2 on growth, CO_2- and N_2 fixation by *Trichodesmium erythraeum* and *Crocosphaera watsonii*. For instance, I showed that the effect of elevated pCO_2 on N_2 fixation by two strains of *Trichodesmium erythraeum* decreases with increasing irradiance. These findings have large implications for projections of global climate change effects on oceanic N_2 fixation, particularly because the majority of N_2 fixation by *Trichodesmium* occurs in well-lit surface layers of the ocean. I also documented that elevated pCO_2 stimulates N_2 fixation rates in some but not all strains of *Crocosphaera watsonii*. This finding also has important implications for models that project the impacts of climate change on oceanic N_2 fixation.

Related information:
Garcia et al. In review. Interactive effects of irradiance and CO_2 on CO_2- and N_2 fixation in the diazotroph *Trichodesmium erythraeum* (Cyanobacteria). Journal of Phycology.
Hutchins et al. 2009. Nutrient cycles and marine microbes in a CO_2-enriched ocean. Oceanography 22: 125-148.
Fu et al. 2008. Interactions between changing pCO_2, N_2 fixation, and Fe limitation in the marine unicellular cyanobacterium *Crocosphaera*. Limnol. Oceanogr. 53:2472-2484.
Hutchins et al. 2007. CO_2 control of *Trichodesmium* N_2-fixation, photosynthesis, growth rates, and elemental ratios: Implications for past, present, and future ocean biogeochemistry. Limnol. Oceanogr. 52:1293-1304.

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
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_1_ Biogeochemistry & Modeling

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Research Interests:

My lab addresses interdisciplinary questions at the interface of biomechanics and marine ecology. A primary focus is how the scaling of physical processes places bounds on organismal design and drives population or community pattern. Our group often targets problems where progress has been thwarted due to challenges in understanding linkages between biology and fluid properties, including aspects of flow and seawater chemistry.

Synopsis of current ocean acidification-relevant research or work:

Colleagues and I have established a research consortium at Bodega Marine Laboratory (BOAR: Bodega Ocean Acidification Research) involving marine ecologists, oceanographers, and marine geochemists. We have two NSF-funded projects underway, and are members of a multi-campus graduate training program in ocean acidification.

One current project, entitled "Ocean acidification in a California upwelling zone: A sentinel site for impacts on open-coast and estuarine foundation species" (NSF OCE-0927255; B. Gaylord, E.D. Sanford, T.M. Hill, and A.D. Russell), examines impacts of ocean acidification on California mussels (*Mytilus californianus*) and west-coast native oysters (*Ostrea lurida*). We employ a four-pronged approach including ocean monitoring (cruises, mooring-based sampling), geochemical analyses (trace metals, polymorphs), laboratory culturing of multiple life stages, and field experiments. In our mussel work, we demonstrate clear functional costs of seawater acidification. Larval mussels produce less tissue mass and smaller, thinner, and weaker shells; each of these responses has important implications for early post-settlement mortality. Findings for oysters indicate strong impacts of seawater acidification on larval growth, with effects extending long after exposure. Individuals subjected to acidified conditions exclusively during the larval phase continue to exhibit dramatically reduced growth months after entering juvenile life. These patterns arise both in laboratory trials and in field outplants. We continue to monitor seawater carbonate parameters on a permanent mooring located offshore of Bodega Marine Laboratory to inform experiments and extend results.

Another research project, entitled "Acclimation and adaptation to ocean acidification of key ecosystem components in the California Current System," (NSF OCE-1041089; B.A. Menge with 13 co-PIs), investigates ocean acidification impacts on mussels (*M. californianus*) and urchins (*Strongylocentrotus purpuratus*) within the context of local-to-biogeographic variation in carbonate chemistry. To date we have spawned urchins from multiple source populations along the west coast of the U.S., have reared their larvae under acidified conditions through settlement, and are assessing effects on survivorship, growth, morphology, and selection pressure.

Related information:

Gaylord B, TM Hill, ED Sanford, EA Lenz, LA Jacobs, KN Sato, AD Russell, A Hettinger. 2011. Functional impacts of ocean acidification in an ecologically critical foundation species. Journal of Experimental Biology, in press.
http://www-bml.ucdavis.edu/facresearch/gaylord.html
http://www-bml.ucdavis.edu/research_topics/boar.html

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Research Interests:
Primary research interest focus on monitoring and modeling the dynamics in surface ocean carbonate chemistry particularly within (sub)tropical waters with the aim of improving our understanding of the rate and spatial heterogeneity of ocean acidification. This includes modeling the regional seasonal dynamics and interannual variability through the application of *in-situ*-based (underway, discrete, and mooring) algorithms applied to satellite and synoptic modeling datasets. Moreover, we seek to understand how these regional dynamics in OA are reflected within the complex coral reef ecosystems and how local biogeochemical processes might feedback as a response to OA. Our ultimate objectives are to provide a means to discern which reef environments and under which prevailing local conditions might serve to better conifer resiliency to secular declines in carbonate mineral saturation state.

Synopsis of current ocean acidification-relevant research or work:
AOML/OCD and CIMAS are advancing the development of the *ocean acidification product suite (OAPS v0.5)* which provides regionally synoptic maps of surface carbonate chemistry. This experimental product is currently being distributed by NOAA Coral Reef Watch (CRW) and delivers a monthly x 0.25 degree synthesis of satellite and modeled environmental datasets to provide estimates of the distribution sea surface carbonate chemistry throughout Greater Caribbean Region. The satellite-based algorithms that drive this experimental model are derived from underway and discrete geochemical survey data [2008, *J. Geophys. Res.*, *113*, C10031, doi:10.1029/2007 JC004629]. Current efforts seek to improve the constraint of biological and vertical entrainment effects on the surface DIC fields. In addition, how the dynamics in oceanic carbonate chemistry revealed by the OAPS are reflected within local coral reef environments is the focus of the Atlantic Ocean Acidification Test-bed (AOAT). The AOAT in La Parguera, PR is an on-going project advanced by the NOAA Coral Reef Conservation Program which seeks to 1) establish a standardized approach and methodology for monitoring, assessing, and modeling the impacts of OA on coral reef ecosystems, 2) identify critical thresholds, impacts, and water chemistry trends necessary for developing ecological forecast, 3) characterize the spatial and temporal variability in carbonate chemistry in coral reef environments to better characterize the threat of OA, 4) provide data and information necessary to facilitate an early alert system based on ecological forecasting for OA stress to coral reef ecosystems. This joint effort by NOAA, the University of Miami/RSMAS (Rosenstiel School of Marine and Atmospheric Science) and the University of Puerto Rico Mayagüez (UPRM) has sought to serve as a nexus of federal and academic monitoring and research related to assessing the impacts of ocean acidification on coral reef ecosystems since 2008.

Related information:
The OAPS v0.5 model output is available from download at http://coralreefwatch.noaa.gov
The time-series data from the AOAT is available from http://www.coral.noaa.gov

Meeting scientific themes relevant to this research:
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Research Interests:

Marine planktonic calcifiers such as coccolithophores, foraminifera, and pteropods play a fundamental role in the ocean carbon system, a role that may be modified substantially by rising atmospheric CO_2 and climate change. The overall goal of this project is to better constrain the magnitude of ocean acidification and climate change impacts on marine inorganic carbon dynamics, ocean carbon storage and atmospheric CO_2 levels over the next several decades to centuries.

Synopsis of current ocean acidification-relevant research or work:

Our primary numerical tool will be the new Community Earth System Model, version 1 (CESM, v.1), a variant of the widely used Community Climate System Model (CCSM) that includes fully interactive marine ecosystem and global carbon modules. Satellite observations will be integral to the project in terms of both model parameterization development and model-data evaluation.

The specific objectives are four fold:

1). Utilize historical satellite remote sensing (SeaWiFS; MODIS) and in situ data to characterize the biogeographic niche for marine calcifiers; i.e., the temperature, circulation and seawater chemistry "phase-space" for calcifiers;

2). Improve the existing CESM marine ecosystem module to incorporate more explicit ecological treatment of distinct biological calcifiers and modify biological calcification and carbonate dissolution rates so that they are sensitive to changing seawater chemistry;

3). Verify against satellite and in situ data the simulated fields of marine planktonic calcification including the spatial distributions and seasonal to decadal temporal variability;

4). Quantify the projected changes over the 21st century in the patterns and strength of marine biological calcification in a warmer, higher-CO_2 world and the resulting feedbacks on ocean carbon storage.

Related information:

Heinze, C., 2004, Simulating oceanic $CaCO_3$ export production in the greenhouse, *Geophys. Res. Lett.*, **31**, L16308, doi:10.1029/2004GL020613.

Orr, J.C., V.J. Fabry, O. Aumon, L. Boop, S.C. **Doney**, R.A. Feely, A. Gnanadesikan, N. Gruber, A. Ishida, F. Joos, R.M. Key, K. **Lindsay**, E. Maier-Reimer, R. Matear, P. Monfray, A. Mouchet, R.G. Najjar, G-K. Plattner, K.B. Rodgers, C.L. Sabine, J.L. Sarmiento, R. Schlitzer, R.D. Slater, I.J. Totterdell, M-F. Weirig, Y. Yamanaka, and A. Yool, 2005, Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms, *Nature*, **437**, 681–686.

Steinacher, M., F. Joos, T.L. Frölicher, L. Bopp, P. Cadule, V. Cocco, S.C. **Doney**, M. Gehlen, K. **Lindsay**, J.K. Moore, B. Schneider, and J. Segschneider, 2010, Projected 21st century decrease in marine productivity: a multi-model analysis, *Biogeosciences*, **7**, 979–1005.

Xu, N., D.M. **Glover** and S.C. **Doney**, 2010, Modeling the Potential Effects of Seasonal Variations in Seawater Carbonate Species on Calcification, *Eos Trans. AGU*, **91** (26), Ocean Sci. Meet. Suppl., Abstract IT35I-08.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_1_ Biogeochemistry & Modeling

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Research Interests:
The research I conduct at EPA focuses on application of quantitative ecological methods, especially those of theoretical and experimental population ecology, in risk assessment. Much of our recent effort has focused on marine mysids because of their legacy as a model system in ecotoxicology and their importance in marine food webs. Using this system, we have found that the short-term cohort studies of early life stages that figure so prominently into population research sometimes produce dramatically different descriptions of risk than those produced by studies of fully structured populations. This result is not surprising on theoretical grounds but is problematic because cohort studies have become the basis for published meta-analyses of ocean acidification effects on marine biodiversity. Thus, we are examining solutions to the observational and computational limitations that have impeded observation of intact populations. These solutions include applications of digital imaging technology, inverse demographic modeling, and information-theoretic inference. We use seawater CO_2 manipulations to test the sensitivity of these methods for detecting stressor effects on populations.

Synopsis of current ocean acidification-relevant research or work:
Our current ocean acidification-related work is motivated by the research objectives described above and by EPA's responsibilities under both the Clean Air Act and the Clean Water Act. Our laboratory setup uses a bubbling system with CO_2-enriched air and continuous seawater flow. Manipulated seawater is distributed into replicated mysid population tanks. We recently completed a 4-month experiment (~5 generation lengths) with ambient and elevated CO_2 treatments. Population structure was measured once per week via digital imaging and we are currently analyzing these measurements using inverse demographic analysis to determine which life history traits govern the population response. We used this approach successfully in a prior study of resource limitation effects that is currently in review.

We monitor pH in our experiments using glass electrode measurements at 5-minute intervals and twice-weekly calibrations with standard pH buffers. Twice during the recent 5 month experiment, we also measured dissolved inorganic carbon using a TOC analyzer. Our pH measurements confirm strong absolute differences between treatments, as well as expected daily and seasonal pH signals in the incoming seawater, but these data will be insufficiently accurate for determining actual pH and other carbonate system characteristics. To address this problem in future experiments, we plan to include occasional alkalinity titrations and spectrophotometric pH measurements. Finally, we are examining possibilities for acquisition of pCO_2 monitoring equipment that could be deployed alternately between EPA's survey vessel (O.S.V. Bold) and our seawater laboratory. A major challenge will be to assure quality in this chemistry work while at the same time maintaining rigor and quality in the ecological methods.

Related information:
[1]Grear, J.S., Doranne Borsay Horowitz and R. Gutjahr-Gobell. *Accepted* (in revision for MEPS) Mysid population responses to resource limitation differ from those predicted by cohort studies.

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
_2_ Observations & Monitoring
___ Physiological Responses
_1_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My research program deals with organism-environment interactions and is focused mainly on aquatic organisms with an emphasis on marine teleost fish. We apply molecular techniques, expression systems, biochemistry, electrophysiological measurements on isolated tissues and classical whole animal physiology in an attempt to gain an integrative understanding of organismal responses to environmental challenges. The past decade has unraveled a component of osmoregulation in marine fish, intestinal base secretion, with significant implications for acid-base balance. While interactions between acid-base balance and osmoregulation have long been recognized for freshwater organisms, compromises between these two vital processes in marine teleosts are just now coming into focus.

Synopsis of current ocean acidification-relevant research or work:

Ongoing NSF supported research (IOB 0743403) has revealed that intestinal base secretion, which is central to osmoregulation, has implications for acid-base balance and is compensated for by adjustments of branchial transport processes. Our studies of ion transport and acid-base balance, included the cloning and characterization of a number of HCO_3^- and H^+ transport proteins as well as epithelial carbonic anhydrase isoforms, have positioned us well to study physiological responses to rising CO_2 levels and ocean acidification. Ongoing work has demonstrated acid-base balance disturbances in the gulf toadfish at 750 but not 560 ppm CO_2. A near immediate respiratory acidosis (elevated partial pressure of CO_2) following onset of exposure to elevated CO_2 is rapidly compensated by increased plasma HCO_3^- levels restoring blood pH to control levels within hours. Intestinal base secretion rates are dependent on plasma HCO_3^- and blood partial pressure of CO_2 and are elevated in fish exposed to elevated ambient CO_2. Thus, the compensatory response to elevated CO_2 which involves retention of HCO_3^- results in increased HCO_3^- loss across the intestinal epithelium placing a greater demand on branchial transport processes. Compensatory mechanisms in the gill involve elevated HCO_3^- uptake rather than H^+ extrusion and are not limited by blood carbonic anhydrase levels. High rates of intestinal HCO_3^- secretion lead to high HCO_3^- concentrations (~100 mM) in marine fish intestinal fluids and the formation of $CaCO_3$ precipitates which are released to the environment via the rectum. We recently reported that piscine $CaCO_3$ production contributes up to 15% or more to global oceanic $CaCO_3$ production. Fish thus represent a case of potential increased $CaCO_3$ production in response to ocean acidification because elevated ambient CO_2 results in elevated plasma HCO_3^- and blood CO_2, which in turn results in elevated intestinal base secretion and therefore potential for greater $CaCO_3$ production. Ongoing and planned studies aim at testing this hypothesis as well as the possibility of acclimation to elevated CO_2.

Related information:

Wilson, R.W., Millero, F.J., Taylor, J.R., Walsh, P.J., Christensen, V., Jennings, S., Grosell. M. (2009): Contribution of fish to the marine inorganic carbon cycle. *Science* 323, 359-362.

(2010): The multifunctional gut of fish. In: Fish Physiology Vol 30. Eds: Grosell, Farrell & Brauner.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1_ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My research interests are focused on understanding the role of the ocean and in particular the role of marine carbonate chemistry in global climate change. Culture experiments with planktic foraminifers form an important tool of my research and help me to better understand the proxies used for paleoreconstructions. I am specifically interested in the validation and application of boron proxies for past seawater pH.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects aims at "Reconstructing deep-sea acidification during the Paleocene-Eocene Thermal Maximum," (NSF OCE 09-02992; collaborative research with J. Zachos, E. Thomas and R. Zeebe). Our goal is to quantify the extent of deep-sea acidification at that time using boron isotopes (Hönisch) and B/Ca (Zachos) in benthic foraminifers, foraminiferal assemblages (Thomas) and modeling (Zeebe). Although poor carbonate preservation prevents us from sampling the peak of the event, boron isotope data indicate a minimum pH decrease of -0.3 units in the South Atlantic. Data collection at sites in the Pacific and Indian Ocean is in progress and we have also added a few planktic samples.

"Validation of the B/Ca proxy for surface seawater pH and application to measure anthropogenic ocean acidification", (NSF OCE 07-51764; PI B. Hönisch) is also nearing completion. This study funds the graduate research of Katherine Allen, who has completed two sets of foraminifer culture experiments with subtropical/temperate and tropical planktic foraminifers to validate the novel B/Ca proxy. The data show pH and salinity effects on foraminiferal B/Ca but no temperature effect as previously suggested. The observed effects are significant in laboratory culture, where organisms can be grown over a wide range of physico-chemical conditions but it has become obvious that the relatively small pH variations of Pleistocene glacial cycles cannot be resolved with this proxy, at least not in the species calibrated to date.

"Ocean Acidification - Category 1: Calibration and application of the boron isotope seawater-pH indicator in deep-water corals", (NSF OCE 10-41133; PI B. Hönisch) is a new project that will calibrate the boron isotope and B/Ca proxies in live collected bamboo corals, and subsequently apply the calibration to fossil specimens of the past hundreds to thousands of years. Research has not yet started on this project.

In August 2010 I have also organized a "Workshop on Paleo-ocean Acidification and Carbon Cycle Perturbation Events", (NSF OCE 10-32374; PI B. Hönisch), the results of which we are currently summarizing in a synthesis paper.

Related information:

Hönisch, B., Hemming, N.G., Archer, D., Siddall, M., McManus, J.F., 2009, Atmospheric Carbon Dioxide Concentration over the Mid Pleistocene Transition, Science 324, p. 1551-1554.

Meeting scientific themes relevant to this research:

_1_ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

I'm a marine ecophysiologist and most often study benthic marine invertebrates. Currently, my lab group is interested in the physiological response of marine invertebrates, and their early life history stages, to conditions of present-day pH variability and to future ocean acidification (OA) events. The central focus of this particular project (ANT-0944201) is to examine the effects of OA on fertilization kinetics, embryos and larvae of a calcifying echinoderm in the coastal waters of Antarctica, the sea urchin *Sterechinus neumayeri*.

Synopsis of current ocean acidification-relevant research or work:

The effect of future OA is projected to be particularly threatening to calcifying marine organisms in coldwater, high latitude seas, making tolerance data on these organisms a critical research need in the Antarctic marine ecosystems. Due to a high magnesium (Mg) content of their calcitic hard parts, echinoderms, the focus of this project, are especially vulnerable to dissolution stress from OA because these organisms already exist in seawater that is often barely at the saturation level to support biogenic calcification. In this project we have employed several metrics to examine the physiological plasticity of urchin embryos and larvae to CO_2-acidified seawater, to mimic the OA scenario as defined by IPCC emission scenarios and by analyses of future acidification predicted for the Southern Ocean. Additionally, we have deployed autonomous pH sensors (SeaFETs constructed by our colleague Dr. Todd Martz at Scripps) to assess present-day variability in pH in McMurdo Sound. In a second element, we hope to learn about the biological consequences of developing under conditions of OA and further, whether embryos and larvae of *S. neumayeri* are affected by synergistic interactions of two converging climate change-related stressors –ocean acidification and ocean warming.

Using a portable CO_2 mixing/culturing system (see Fangue et al., 2010), sea urchins are raised in culture at the habitat temperature for *S. neumayeri* (-1.9 °C) at different CO_2 partial pressures that include a measured environmental level in the waters of McMurdo Sound (~380 uatm CO_2) and higher predicted future levels of atmospheric CO_2. We are currently processing the data from our first field season (October-December 2010) that includes the assessment of the effect of CO_2-acidified seawater on fertilization and the development of early embryos and larvae, morphometric analysis of the larval endoskeleton, respirometry, calcification assays on later stage echinopluteus larvae, and gene expression analysis using a DNA microarray.

Related information:

Hofmann lab website: http://hofmannlab.msi.ucsb.edu/

Fangue, N.A., M.J. O'Donnell, M.A. Sewell, P.G. Matson, A.C. MacPherson and G.E. Hofmann (2010) A laboratory-based experimental system for the study of ocean acidification effects on marine invertebrate larvae. *Limnol. Oceanogr.: Methods* 8: 441-452

Yu, P.C., P.G. Matson, T.R. Martz and G.E. Hofmann (2011) The ocean acidification seascape and its relationship to the performance of calcifying marine invertebrates: laboratory experiments on the development of urchin larvae framed by environmentally-relevant pCO_2/pH. *J. Exp. Mar. Biol. Ecol.* DOI: 10.1016/j.jembe.2011.02.016

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_2_Observations & Monitoring
_1_Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

A newly funded project in my lab (IOS 1021536) is focused on characterizing the response of larval purple sea urchins (*Strongylocentrotus purpuratus*) to the synergistic effects of two global climate change (GCC) related variables: ocean acidification (OA) and ocean warming (OW). The biological consequences of these complex and interacting environmental factors on marine organisms, particularly those that form calcium carbonate 'hard parts', is not clear. Thus, the central goal of this research is to estimate the vulnerability of purple sea urchins to the combinatorial effects of OA and OW and determine whether this species possesses the plasticity to compensate for the potentially deleterious impacts of GCC.

Synopsis of current ocean acidification-relevant research or work:

The philosophy driving this research is that the performance of marine organisms in future environments is more accurately modeled by simultaneously manipulating multiple variables expected to shift with GCC. Laboratory controlled experiments will be used to culture larval purple sea urchins under varying pCO_2 and temperature regimes that reflect future ocean conditions. Our overarching hypothesis is that the combinatorial effects of elevated pCO_2 (i.e. low pH and carbonate) and temperature will have a greater impact on urchin development and physiological function than either of these potential stressors applied independently. Our experimental approach is multi-disciplinary, with the aim of evaluating the consequences of OA and OW across levels of biological organization:

Evolutionary- Oceanographic measurements of temperature and pH are necessary to consider the range of conditions organisms experience in nature and how their evolutionary history might dictate responses to GCC. We have deployed autonomous sensors at near-shore benthic sites to characterize pH and temperature regimes currently experienced by purple sea urchins in California (Yu *et al*. 2011). We hypothesize that urchins inhabiting areas with larger fluctuations in pH and temperature will function better under a broader range of conditions, but will be living close to upper-level temperature and pH tolerance limits.

Organismal-Morphometric and survival analyses will be used to quantify whole organism level consequences of OA and OW. Our lab has already demonstrated that elevated pCO_2 significantly affects the size and shape of sea urchin larvae (O'Donnell *et al*. 2010). We hypothesize that additional impacts on larval growth will occur when cultured in the presence of both elevated pCO_2 and temperature.

Physiological-Microarray and RNA sequencing approaches to will be used to chart changes in the transcriptome (the cellular mRNA pool) of larval urchins exposed to elevated pCO_2 and temperature. Our previous research has shown that larval purple urchins respond to elevated pCO_2 with large-scale changes in gene expression (Todgham and Hofmann 2009). We hypothesize the addition of temperature stress will lead to shifts in the expressions of genes correlated with increased cellular damage, such as those involved in the cellular stress response, proteolysis and cell death.

Cellular-Respiration rate, lipid content, calcification rate and total protein content will be measured to estimate the metabolic costs associated with development under elevated pCO_2 and temperature regimes.

Related information:

Hofmann lab website: http://hofmannlab.msi.ucsb.edu/

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_2_Observations & Monitoring
_1_Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

- I'm a coastal physical oceanographer, with a current interest in understanding seasonal, inter-annual and decadal variability and trends in subarctic estuarine oceanography, chemistry, plankton and near-shore habitats, and in linkages with the adjacent ocean shelf waters. As director of the NOAA Kasitsna Bay Laboratory (KBL), I also help support ocean acidification research projects conducted at our facility by other agency and university partners. Our mission includes providing the science information and products that help coastal managers assess current and future climate change and ocean acidification impacts on coastal resources. Kachemak Bay provides a natural laboratory for these studies. It is a fjord located near the entrance of Cook Inlet, along the central Gulf of Alaska coast and most of the bay is designated as the Kachemak Bay National Estuarine Research Reserve (NERR). The productive Bay supports subsistence and recreational shellfish harvests, oyster mariculture and commercial and recreational fishing. Numerous sub-bays include both glacial and non-glacial watersheds (15 glaciers provide freshwater input) and there is regular upwelling of Gulf of Alaska shelf waters. Kachemak Bay is located at a biogeographic divide along the Gulf of Alaska and includes diverse coastal ecosystems (rocky intertidal, seagrass, kelp, and salt marsh communities). Low pH, undersaturated in carbonate waters are already found at shallow depths in the Gulf of Alaska, sparking immediate concerns about impacts on plankton, fish (through food), shellfish and coastal habitats.
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Synopsis of current ocean acidification-relevant research or work:
We have two ocean acidification research projects at Kasitsna Bay Laboratory. The first is a pilot study to assess spatial and temporal variability of ocean acidification in the subarctic estuary of Kachemak Bay, done in partnership with the University of Alaska Fairbanks (UAF). The goal of this study is to quantify seasonal and spatial variability in estuarine pH and carbonate chemistry, with a focus on the impacts of glacial water input, upwelling of ocean waters, and phytoplankton blooms. This information will help: 1) provide context for laboratory studies on species response to increasing acidification; 2) assess linkages with Gulf of Alaska ocean acidification patterns (being measured by shipboard surveys and at an upstream mooring – GAK1); and 3) guide deployment of future estuarine acidification monitoring systems. Our second ocean acidification project is a laboratory study to assess the impact of increasing acidification on larval Tanner crab, using an acidification treatment system. This project includes collaboration between UAF, KBL and the Kachemak Bay NERR. The laboratory study is being done by a UAF graduate student, who is a graduate research fellow with the Kachemak Bay NERR. Treatment system and study design are also being coordinated with the NOAA NMFS Kodiak Laboratory.

Related information:
KBL is a NOAA facility under the National Ocean Service, National Centers for Coastal Ocean Science - part of the Center for Coastal Fisheries and Habitat Research, which also operates a large laboratory in Beaufort, North Carolina. KBL is also operated as a collaboration between NOAA and UAF.

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
_2_ Physiological Responses
__3_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

I study phytoplankton physiology and ecology, focusing on nutrient limitations and nutrient acquisition mechanisms (including CO_2). In relation to ocean acidification, I study the CO_2 concentrating mechanisms (CCMs) of phytoplankton and effects of rising CO_2 on photosynthetic physiology. Phytoplankton operate a CCM to elevate the concentration of CO_2 around the primary carbon fixing enzyme, RubisCO, allowing this slow and inefficient enzyme to work at its maximal rate. It is widely hypothesized that the down-regulation of the CCM at high CO_2 is the ultimate cause of many other acclimations to high CO_2, such as increased photosynthesis or N_2 fixation. The goals of my work include: 1) understanding the molecular mechanism of the CCM in phytoplankton, 2) constraining energy savings from the down-regulation of the CCM to determine if the energy saved is sufficient to account for increased rates of photosynthesis, N_2 fixation, etc, 3) understanding the changes in photosynthetic physiology that may result from down-regulation of the CCM, and finally 4) integrating these results to predict how different groups of marine phytoplankton will respond to rising CO_2.

Synopsis of current ocean acidification-relevant research or work:

My major funded project on ocean acidification seeks to understand the: "Effects of pCO2 and pH on photosynthesis, respiration and growth in marine phytoplankton" (NSF EF 1041034, co-PIs: Francois Morel, Michael Bender; Princeton University). The primary goal of this project is to isolate energy sources that allow increased phytoplankton growth and photosynthesis at high CO_2. We hypothesize that increased CO_2 allows energetic savings from the CCM, while decreased pH may decrease dark respiration. Divergent phytoplankton taxa are under study as we believe that there will be varied energetic savings among the groups leading to differing responses to ocean acidification.

The interactions between nutrient limitation and CO_2 effects are also of interest. For example because iron limitation restricts energy generation, the energetic savings derived from CCM down-regulation may be especially important in HNLC regions.

I am also using newly available genetic transformation techniques to study the molecular basis of the CCM in model diatoms (in collaboration with C. Dupont, JCVI). We are manipulating putative CCM genes to determine if their repression or overexpression alters CCM function. Newly developed membrane inlet mass spectrometry methods are used to study carbon cycling in the diatoms to better understand the exact nature of the CCM.

Related information:

Hopkinson, B.M., C.L. Dupont, A.E. Allen, F.M.M. Morel. in press. Efficiency of the CO_2 concentrating mechanism of marine diatoms. *Proceedings of the National Acacdemy of Sciences USA*. doi:10.1073/pnas.1018062108.

Hopkinson, B.M., Y. Xu, D. Shi, P.J. McGinn, and F.M.M. Morel. 2010. The effect of CO_2 on the photosynthetic physiology of phytoplankton in the Gulf of Alaska. *Limnology and Oceanography* 55: 2011-2024.

Shi, D., Y. Xu, B.M. Hopkinson, F.M.M. Morel. 2010. Effect of ocean acidification on iron availability to marine phytoplankton. *Science* 327: 676-679.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1_ Physiological Responses
_2_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

I have been working for the past four years with various NOAA scientists to create a NOAA Ocean Acidification program. I was a lead author of the newly completed NOAA Ocean and Great Lakes Acidification Research Plan. I am also a NOAA representative to the interagency working group on OA convened as a result of the FOARAM Act. As soon as OA funding becomes available, I am prepared to oversee an extramural funding program focused on the ecosystem impacts of ocean acidification with a particular emphasis on the impacts on commercial and recreational fishery species and on species living in NOAA managed marine protected areas.

Synopsis of current ocean acidification-relevant research or work:

Related information:

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
____ Physiological Responses
____ Ecology & System Responses
____ Biogeochemistry & Modeling

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Research Interests:

My research focuses primarily on measurement, analysis, modeling and prediction of sound propagation in spatially and temporally varying ocean media, with emphasis on characterizing the soundscape in naval relevant environments. There are two areas of interest that motivates this research: 1) noise variability affects the performance of naval sonar systems and 2) sound, particularly from anthropogenic sources such as shipping and sonar, may affect the behavior of marine mammals. With this research, I seek to find methods for characterizing the acoustic environment that can be useful for optimizing system performance and to develop a model for characterizing the ocean soundscape on a regional scale that can be applied in studies on marine mammal behavioral responses to anthropogenic sound.

Synopsis of current ocean acidification-relevant research or work:

Sound propagating through the ocean is partially attenuated by a pH-dependent chemical relaxation process. Thus, it seems a reasonable assumption that ocean acidification will make seawater more acoustically transparent and has potential to increase received ambient noise levels, but an important question is: By how much? In our investigation, we were seeking to understand the sensitivity of ambient noise to ocean acidification by calculating changes in noise levels that could be expected with hypothetical changes in ocean pH. Using realistic environments based on climatology, we made a computational assessment of the expected change in received noise level due to changes in ocean pH using an ocean acidification model found in the literature at three receiver locations over a period of nearly three centuries. Model results indicate changes in noise level are expected to be very small (< 0.21 dB) across the 25-2000 Hz frequency band.

Related information:

Joseph, J. E. and Chiu, C.-S., "A computational assessment of the sensitivity of ambient noise level to ocean acidification," *J. Acoust. Soc. Am.*, 128(3), EL144-149, 2010
Reeder, D. B. and Chiu, C.-S., "Ocean acidification and its impact on ocean noise: Phenomenology and analysis," *J. Acoust. Soc. Am.*, 128(3), EL137-143, 2010

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_1_ Biogeochemistry & Modeling

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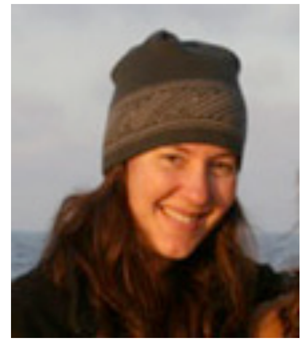

Research Interests:
My research interests are focused on monitoring and quantifying the impact of climate- and ocean acidification related changes to biogeochemical cycling. Specific strategies I apply toward this goal include 1) development of algorithms for prediction of carbon system parameters (*p*H, saturation state) from simple hydrographic data; 2) monitoring of carbon chemistry in vulnerable areas (e.g., Arctic and coastal margins); 3) using dissolved gas tracers to quantify community productivity rates to better understand mechanisms controlling biological CO_2 uptake, as well as potential vulnerabilities and feedbacks.

Synopsis of current ocean acidification-relevant research or work:

Development of algorithms for prediction of pH and saturation state from hydrographic data (with co-PIs R. Feely, S. Alin, and C. Sabine): The aim of this work is to develop robust empirical relationships that can be used to monitor carbon chemistry in areas of interest at greatly reduced cost. In coastal and high latitude regions, logistical/financial constraints prevent discrete sampling of carbon chemistry at all time/space scales of interest. We have developed algorithms for prediction of *p*H and saturation state for the Oregon coast (Juranek et al., 2010), the S. California bight region (Alin et al., in prep), and the NE Subarctic Pacific (Juranek et al., in prep). These relationships can be applied to glider/profiling float observations for highly-resolved estimates of *p*H and Ω that would be unattainable from ship-based surveys alone.

Observation and Prediction of Ocean Acidification in the Western Arctic Ocean – Impacts of Physical and Biogeochemical Processes on Carbonate Mineral States (NSF 1041102, co-PIs Mathis, Feely): The aim of this work is to better characterize the physical (sea-ice melt, terrestrial and riverine inputs, circulation) and biological (gross and net community production) controls on saturation state in the Western Arctic during late summer. Field work for this project begins 2011 and will continue through 2013. Planned measurements include discrete DIC and TA, nutrients, $\delta^{18}O_{water}$, triple O_2 isotope ($^{17}\Delta$) for gross primary production, discrete and underway O_2 /Ar for net community productivity, and discrete and underway *p*H (PI: R. Byrne) and underway *p*CO2 (PI: T. Takahashi).

Moored Observations of Ocean Acidification in the Northern Gulf of Alaska including Resurrection Bay and Prince William Sound (NPRB 1004, co-PIs J. Mathis, C. Sabine): This project includes funds for deployment of a mooring with a surface MAPCO2 and SAMI PH as well as a bottom SAMI pCO2 and pH in the N. Gulf of Alaska (GAK1). The mooring has a planned deployment of March 2011.

Related information:
Juranek, L.W., R.A. Feely, W.T. Peterson, S.R. Alin, B. Hales, K. Lee, C.L. Sabine, and J. Peterson (2009): A novel method for determination of aragonite saturation state on the continental shelf of central Oregon using multi-parameter relationships with hydrographic data. *Geophys. Res. Lett.*, 36, L24601, doi: 10.1029/2009GL040778.

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
_3_ Ecology & System Responses
_2_ Biogeochemistry & Modeling

Eric Kaltenbacher
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Research Interests:

My work focuses primarily on the development of sensors and instrumentation. I work closely with scientists to understand sensing needs and then strive to design an instrument that will meet those needs. My primary interest lies with applying optical phenomenology and technology to novel oceanographic sensors. In particular, topics with which I work most often include: 1) spectroscopy; 2) use and performance of long-pathlength optical cells; 3) fluorescence; 4) beam propagation; and 5) optical system modeling. As technology advances, I try to identify ways in which we can apply the latest devices and methods to the next generation of sensors to enable new facets in environmental research.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects, titled "Development of an In Situ Sensor for Hi-Resolution Measurement of Total Inorganic Carbon," (NSF OCE-1030019; PI L. Adornato, Co-PI R. Byrne) seeks to demonstrate in situ measurements of C_T. We are adapting one of our spectrophotometric elemental analysis systems (SEAS) for this measurement through optical reconfiguration and software modifications. We have completed the optical redesign and are currently testing the software operation in the lab. Field tests should commence sometime this spring/early summer. We strive to collect simultaneous pH and C_T data to enable calculation of total alkalinity and CO_2 fugacity.

Another research project, titled "Carbonate Ion Sensor Development," (NOAA NA09OAR4310067; PI R. Byrne; Co-PI L. Adornato) is focused on developing a sensor for in situ measurements of CO_3^{2-}. We are currently evaluating the optimal configuration for the optical cell to enable reliable measurements in the field and finalizing the control electronics. A completed instrument is expected late summer with field tests beginning this fall.

Related information:

Wang, Z.A., Xuewu Liu, Robert H. Byrne, Rik Wanninkhof, Renate Bernstein, Eric A. Kaltenbacher and James Patten. Simultaneous spectrophotometric flow-through measurements of pH, carbon dioxide fugacity and total inorganic carbon in seawater. *Analytica Chimica Acta* 596: 23-36 (2007)

Liu, X., Z.A. Wang, R.H. Byrne, E.A. Kaltenbacher and R.E. Bernstein "Spectrophotometric Measurements of pH In-Situ: Laboratory And Field Evaluations of Instrumental Performance." *Environmental Science and Technology* 40:5036-5044 (2006)

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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PI, NSF-MCB
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Research Interests:

Our research group studies the bacterial carbon concentrating mechanism, which is composed of membrane-bound transporters for inorganic carbon uptake and bacterial organelles called carboxysomes. Unlike the organelles of eukaryotes, carboxysomes consist entirely of protein. Hexameric and pentameric carboxysome shell proteins tile together to form an icosohedral-like external shell that is permeable to bicarbonate. This shell encapsulates carbonic anhydrase and RuBisCO and enhances CO_2 fixation by minimizing oxygen levels and increasing the amount of CO_2 surrounding RubisCO (see figure below). Our group focuses on the structural basis of function of carboxysomes, primarily in two model cyanobacterial systems, Prochlorococcus and *Synechecoccus elongatus* PCC7942. The *Prochlorococcus* project is supported by an NSF MCB Collaborative Research grant [Structural, Functional, and Ecological Characterization of the *Prochlorococcus* Carboxysome, the Ocean's Primary Molecular Module for Carbon Fixation] in collaboration with Claire Ting (Williams College) and Gordon Cannon and Sabine Heinhorst (University of Southern Mississippi).

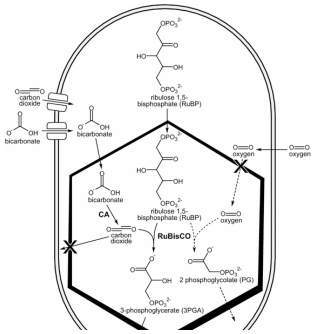
Synopsis of current ocean acidification-relevant research or work

While we are not currently working on ocean acidification-specific questions, we have several projects that are relevant or use approaches that have potential applications to ocean acidification research. For example, we are re-engineering the carboxysome to enhance CO_2 fixation in cyanobacteria and to gain new insights into the functions of individual components. In the context of these efforts, we are establishing methods to combine genetic manipulation of cyanobacteria with laboratory evolution of engineered strains followed by genome re-sequencing as a means to identify genetic changes that underly adaptation and contribute to enhanced CO_2 fixation. Other related projects in our laboratory include the redesign of halorhodopsin, a light activated chloride pump, to pump bicarbonate (a recently funded NSF MCB project) and the sequencing and bioinformatic analysis of 50 phylogenetically diverse cyanobacteria (a collaboration with the Pasteur Culture Collection).

We are also part of an interdisciplinary network of investigators studying the mechanistic aspects of biogeochemical carbon cycling in biological soil crusts. The goal is to understand the relationship between perturbation of environmental factors and the metabolic response of microbial systems. We are integrating biogeochemical, microbiological, (meta)genomic, (meta)transcriptomic, and metabolomic approaches to analyze isolates, lab consortia and community samples taken directly from the environment. We aim to develop a systems level view of the crust ecosystem and to define the limits of stability to a changing climate.

Kerfeld is also head of the JGI's Education program which develops tools to enable faculty and students to incorporate genomics and bioinformatics in undergraduate courses and research.

Related Information:



Meeting scientific themes relevant to this research:

___ PaleoProxies/Modeling
___ Observations & Monitoring
_X_Physiological Responses
_X_Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:
We are building regional collaborations among diverse entities to address physical, ecological, and social dimensions of ocean acidification research. The combined research capacity of universities, federal and state agencies, industry, and NGOs will be applied to address larger-scale and longer-term aspects of the OA problem. The response of commercial fisheries, shellfish aquaculture, and habitat-forming species to OA and associated stressors are key themes of these collaborations, as is the capacity for human adaptation to changing ocean condition. We are working to connect regional efforts to programs in other regions of the U.S. and elsewhere, for example, the UK Ocean Acidification Research Program.

Student training is critical to our approach. We are developing a new graduate training course at Friday Harbor Laboratories (see O'Donnell abstract) and have an IGERT proposal pending.

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:
My over-arching research objectives are to examine the causes and effects of coral reef degradation. I seek to increase understanding of local and global-scale stressors on reefs, and experimentally determine how factors such as changing ocean conditions (ocean acidification and sea-surface warming), extraction of fisheries resources, and other human perturbations affect coral reef organisms and community structure. My work informs resource managers about the mechanisms causing reef degradation and how management efforts may be improved to better govern and restore degraded reefs. Please visit the USGS Coral Reef Ecosystems Studies (CREST) website for more information: http://coastal.er.usgs.gov/crest/.

Synopsis of current ocean acidification-relevant research or work:
We have established long-term calcification monitoring stations at four sites throughout the Florida Keys, USA. From north to south, we are measuring coral and algal calcification at Fowey Rocks near Miami, Molasses Reef off Key Largo, Sombrero Reef off Marathon, and Pulaski Shoals in the Dry Tortugas. With aragonite saturation state continually declining, our objective is to document the predicted decreases in coral and crustose algal calcification over the next couple decades. Temperatures, however, are simultaneously increasing, so we need to evaluate any changes in growth rate and skeletogenesis in the context of ocean warming. We will generate region- and species-specific temperature-Sr/Ca calibration curves to augment our retrospective studies on coral cores from the Caribbean region (see CREST website above). Presently we are focusing on the massive starlet coral, *Siderastrea siderea*. We will correlate our growth measurements with *in situ* temperature measured continuously at our sites. We seek collaboration with modelers within this OA research community to correlate our data with modeled carbonate system parameters as well. Because of the subtropical location of our reefs, we see a pronounced seasonal cycle in coral growth rate, corresponding with seasonality in temperature, daily solar irradiance, and aragonite saturation state. We are directly measuring calcification rates (buoyant weight technique) and linear extension rates (Alizarin Red-S staining) of the corals, and hope to tease apart the relative influence of ocean chemistry, temperature, and solar irradiance on calcification rates through correlation analyses, modeling, and proxies.

We are also conducting further studies on the samples from the Kuffner et al. (2008) and Jokiel et al. (2008) mesocosm study at the Hawaii Institute of Marine Biology. We are presently examining corals from control and low aragonite-saturation state treatment mesocosms for differences in skeletal density, porosity, and Sr/Ca.

Related information:
Kuffner IB, Andersson AJ, Jokiel PL, Rodgers KS, Mackenzie FT (2008) Decreased abundance of crustose coralline algae due to ocean acidification. Nature Geosci 1:114-117

Jokiel PL, Rodgers KS, Kuffner IB, Andersson AJ, Cox EF, Mackenzie FT (2008) Ocean acidification and calcifying reef organisms: a mesocosm investigation. Coral Reefs 27:473-483

Meeting scientific themes relevant to this research:
_3_ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1_ Physiological Responses
_2_ Ecology & System Responses
___ Biogeochemistry & Modeling

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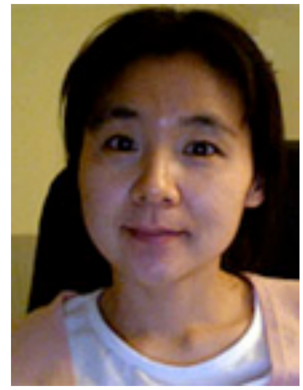

Research Interests:

My research focuses primarily on the interactions between climate change and ocean biogeochemical cycles. I aim to improve our ability to predict climate change and its interactions with marine ecosystems, which I hope to achieve through our improved understanding of the past and present-day climate systems and marine ecosystems. My principle research tools include analytical, statistical and numerical models combined with observations. In particular, I have developed a computationally efficient 3-D global ocean biogeochemistry model with which I carried out intensive model optimization and sensitivity analyses. I have recently used this model to study the control of atmospheric CO_2 concentration by ocean ventilation change, in relation to the glacial/interglacial carbon cycle. Another aspect of my research involves the use of fully coupled climate models to study the seasonal to multi-decadal variations in climate and ocean biogeochemical cycles.

Synopsis of current ocean acidification-relevant research or work:

The research project, entitled "Does the strength of the carbonate pump change with ocean stratification and acidification and how?" (NSF ANT-1040957; PI: Jorge Sarmiento; Co-PIs: Eun Young Kwon, John Dunne, J. R. Toggweiler; 2010. 11 ~ 2013. 10) poses a classic question of how the carbonate pump operates in the present-day ocean and how changes in ocean stratification and acidification will feed back on the future strength of the carbonate pump. Key questions to be addressed are (i) Does the strength of the carbonate pump change in response to ocean acidification and stratification? (ii) Is the $CaCO_3$ export more closely associated with the tightly recycling picoplankton and nanoplankton ecosystems than the blooming microplankton? (iii) What is the role of interactions between organic particle fluxes and the saturation state of seawater with respect to $CaCO_3$ minerals in the dissolution of $CaCO_3$ in the water column and sediments? We will address the above three questions in a unified model-observation framework where a suite of global models of the carbonate pump will be objectively assessed using a wide range of observations.

Related information:

Galbraith, E., E. Kwon, J. Sarmiento, *et al.*, The impact of climate variability on the distribution of radiocarbon in CM2Mc, a new earth system model, accepted in *Journal of Climate*.

Kwon, E., J. Sarmiento, J. R. Toggweiler, T. DeVries, The control of atmospheric CO_2 by ocean ventilation change: The effect of the oceanic storage of biogenic carbon, submitted to *Global Biogeochemical Cycles*.

Key, R. M., J. R. Toggweiler, J. Sarmiento, X. Lin, New look at the alkalinity distribution in the ocean, revised in *Global Biogeochemical Cycles*.

Toggweiler, J. R., R. M. Key, J. Sarmiento, Impact of rivers and the hydrological cycle on the carbon chemistry of the Atlantic Ocean, revised in *Global Biogeochemical Cycles*.

Meeting scientific themes relevant to this research:

_2_ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_1_ Biogeochemistry & Modeling

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Research Interests:

I am interested in how elevated CO2 will impact the sustainability of coral reef ecosystems. My research interests range from field studies exploring new techniques to measure community calcification rates on various spatial and temporal scales and establishing baseline carbonate chemistry and calcification rates to lab studies looking at the interaction of elevated CO2 with other environmental stresses on coral biology and ecology (photophysiology, algal symbiont type, respiration, calcification, skeletal growth, recruitment success). I am trying to discover the scope for acclimation amongst different coral taxa in order to better predict how corals and coral reef ecosystems may be impacted by climate change and ocean acidification.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects, titled **"**Application of a novel geochemical approach to the alkalinity anomaly method of estimating coral reef calcification: implications of ocean acidification (NSF 0825578, co-PI: D. Kadko)" seeks to develop at new method for estimating the residence of reef waters using the geochemical tracer Be-7 in environments where established methods based on salinity and water budgets do not offer sufficient precision. Field-work is being conducted in Bermuda, the Florida Reef Tract, and La Parguera, Puerto Rico. Preliminary results are encouraging and we are now focusing on obtaining estimates of calcification by other methods to compare with the alkalinity anomaly-Be-7 residence time rates.

Two other projects, titled "Climate change and coral reefs: integrating calcification, photosynthesis and symbiosis flexibility into species survival trajectories for Caribbean reef corals" (NSF 0547169, Co-PI: A. Baker) and Resiliency of corals to changing saturation state: a field study" (NSF 0550588, Co-PIs: P. Swart and F. Millero) are just wrapping up. The former project examined the importance the zooxanthellae taxanomic ID (clade C or D) on the outcome of induced bleaching under ambient and elevated CO2 conditions (390 vs 800 ppm). Our results show that while corals hosting clade D zooxanthellae exhibit great tolerance to thermal stress (paling but no mortality after 32C for eight weeks) it did not prevent the calcification rate from being depressed by 20-40%. The later project looked at whether two species of coral found in Florida Bay that exhibit tolerance to thermal and hyper salinity stress would be similarly tolerant to conditions of elevated CO2. *In situ* measurements of calcification, photosynthesis and respiration revealed that *Siderastrae radians* and *Solenastrae hyades* exhibit a sensitivity to elevated CO2 that is similar to that of many other species of coral, i.e. tolerance to other forms of environmental stress (temperature and salinity) does not necessarily convey tolerance to the stress of elevated CO2, as had been hypothesized.

Finally, a project titled "Small boat CO2 equilibrator and gradient – flux measurements of calcification" (NOAA, Co-PIs: D. Gledhill, W. McGillis and J. Corredor) is looking at two new methods for obtaining small-scale temporal and spatial resolution measurements of benthic primary production and calcification. This work is taking place at what we are calling the "Atlantic Ocean Acidification Test-Bed" AOAT in La Parguera, Puerto Rico. This project is leveraging the many other OA-related activities that are taking place in the same area, i.e. NSF and NOAA funded retrospective coral and foram pH reconstructions using B-11, the NOAA ICON and MAP-CO2 moorings, NSF funded SAMI pH and pCO2 sensor work, NSF Be-7 residence time measurements and USGS SHARQ enclosure deployment.

Related information:

Albright, R., B. Mason and C. Langdon (2008). Coral Reefs 27(3): 485-490.10.1007/s00338-008-0392-
Albright, R., B. Mason, M. Miller and C. Langdon (2010) Proc. Nat. Acad. Sci. **107**, DOI: 10.1073/pnas.100727310
Albright, R. and C. Langdon (2011). Global Change Biol.doi: 10.1111/j.1365-2486.2011.02404.x
McGillis, W. R., et al. (2011). Geophys. Res. Lett. 38, L03611, doi:10.1029/2010GL046179
Langdon, C., J. et al., ASLO 2011, http://www.sgmeet.com/aslo/sanjuan2011/viewabstract2.asp?AbstractID=8442
Venti, A., D. et al., ASLO 2011, http://www.sgmeet.com/aslo/sanjuan2011/viewabstract2.asp?AbstractID=8389

Meeting scientific themes relevant to this research:

___ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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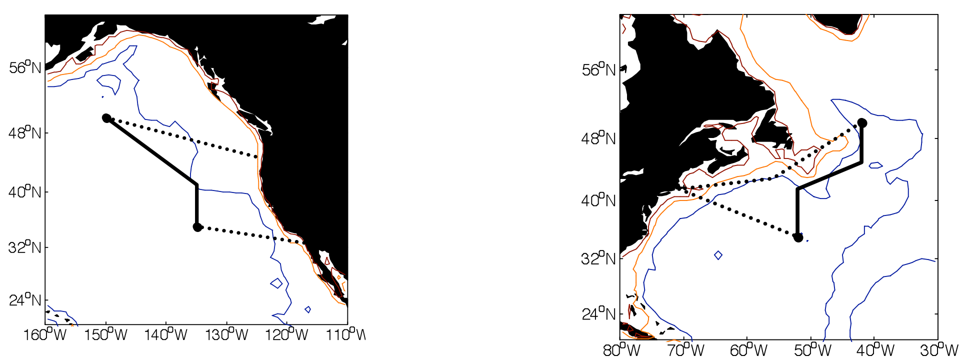
508-289-3713

Research Interests:
The focus of my research is on understanding the interaction of biological and physical processes leading to spatial and temporal variability in the distribution of zooplankton and micronekton, and the consequences of this variability to higher trophic levels. I am interested in these questions across temporal and spatial scales, including the influence of climatic processes. I am furthermore interested in the development and application of new technologies for the study of pelagic ecology, notably high-frequency acoustic scattering techniques. The ocean acidification-related project described below continues previous work conducted by myself and my co-PIs on pteropod distribution in the northwest Atlantic and Southern Oceans, as well as the ongoing development of acoustic methods for the quantification of pteropod abundance and size.

Synopsis of current ocean acidification-relevant research or work:
The primary objective of my current ocean acidification-related project (OCE-1041068; co-PIs A. Lavery, P. Wiebe, A. Wang) is to quantify the distribution, abundance, species composition, shell condition, and vertical migratory behavior of oceanic thecosome pteropods in the northwest Atlantic and northeast Pacific, and correlate these quantities to hydrography and concurrent measurements of carbonate chemistry, including vertical and horizontal distributions of aragonite saturation state. In particular, the project capitalizes on present-day variability in the depth distribution of aragonite saturation levels within and between the Atlantic and Pacific Oceans as a 'natural experiment' to address the hypotheses that pteropod vertical distribution, species composition, and abundance vary as the compensation depth becomes shallower. During August 2011 and 2012, two cruises will be conducted along survey transects covering portions of two WOCE/CLIVAR Repeat Hydrography transects (A20 and P17N) between 35 and 50°N in the northwest Atlantic and northeast Pacific (Figure 1). The surveys will involve a combination of station-work and underway measurements, and will employ a comprehensive array of instruments, including acoustic, optical, net, hydrographic, and carbonate chemistry sensors.

Related information:
www.whoi.edu/people/glawson

Figure 1. Transects to be surveyed in 2011 (Atlantic) and 2012 (Pacific):



Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
_2_ Observations & Monitoring
___ Physiological Responses
_1_ Ecology & System Responses
___ Biogeochemistry & Modeling

Cindy Lee
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Research Interests:

The distribution and behavior of biogenic organic compounds in the marine environment, and their role in the global carbon cycle. Most biogenic organic compounds are produced in surface waters by phytoplankton as a result of photosynthesis, are consumed by bacteria or zooplankton, and then enter the non-living particulate and dissolved carbon pools. Organic compounds are also affected by chemical and physical processes such as adsorption, photochemical degradation, and transport. I am interested in the rates and mechanisms of the transformation reactions that occur as organic compounds are affected by these processes. Much of my recent work has focused on particle production, transport and degradation. Ocean acidification will likely affect many of these processes.

Synopsis of current ocean acidification-relevant research or work:

My current project on ocean acidification is titled "Effects of ocean acidification on the formation and sinking of particle aggregates" (NSF 50904; co-PI Anja Engel) and is to investigate mechanisms of aggregation of marine particles that specifically relate to organic matter-ballast mineral interactions and their sensitivity to ocean acidification. Last year we conducted a chemostat experiment at the Alfred Wegener Institute in Bremerhaven, Germany where we grew the coccolithophore *Emiliania huxleyi* in controlled chemostats in the lab at CO_2 partial pressures of 180, 380 and 750 ppm. We sought to test three hypotheses: 1) Production of gel particles is sensitive to ocean acidification, and 2) Biomineral ballast (particularly $CaCO_3$) is an important factor in carbon export in the ocean, and 3) In addition to carbohydrates, gel particles also include proteins and lipids that will affect rate and mechanisms of organic matter aggregation in the ocean. The composition of gel particles in seawater will change at lower pH. We also developed a new technique for quantifying protein in gel particles (ASLO 2011 poster, Cisternas et al). We expect the chemical composition of gels to be different under different pH conditions. This summer we will be setting up mesocosms at Flax Pond, New York, to further investigate acidification effects on gel production and aggregate formation in a more natural setting, focusing on chemical composition. At the same time we will conduct auxiliary experiments on changes in organic composition of the marine microlayer in the tanks.

Related information:

Engel. A., Szlosek, J., Abramson, L., Liu, Z., and Lee, C. 2009. Investigating the effect of ballasting by $CaCO_3$ in *Emiliania huxleyi*: I. Formation, settling velocities and physical properties of aggregates. Deep-Sea Res. II, doi:10.1016/j.dsr2.2008.11.027

Engel, A., Abramson, L., Szlosek, J., Liu, Z., Stewart, G., Hirschberg, D., and Lee, C. 2009. Investigating the effect of ballasting by $CaCO_3$ in *Emiliania huxleyi*: II. Decomposition of particulate organic matter. Deep-Sea Res. II, doi:10.1016/j.dsr2.2008.11.028

Engel, A., J. Barcelos e Ramos, R. Geider, D.A. Hutchins, C. Lee, B. Rost1, R. Röttgers and F. Thingstad. 2010. Production and export of organic matter, Chapter 11, In**:** Guide to best practices for ocean acidification research and data reporting. Eds. U. Riebesell, V.J. Fabry, L. Hansson and J.-P. Gattuso, Luxembourg: Publications Office of the European Union.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_1_ Biogeochemistry & Modeling

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Research Interests:

- Calcium carbonate budgets of coral reefs with combined ocean acidification and global warming
- Species-specific calcification/growth response of scleractinian corals to combined acidification and warming
- Coral reef ecosystem function in a high-CO_2 world
- Variability of carbonate chemistry within and between coral reef environments
- Utilization of natural CO_2 gradients to elucidate real-world coral reef dynamics under varying CO_2 regimes

Synopsis of current ocean acidification-relevant research or work:
Current research is assessing carbonate budgets of coral reef communities across natural CO_2 gradients on the Florida Reef Tract. This includes integration of species-specific rates of coral calcification and growth, carbonate cement precipitation, and bioerosion. This research will be used to assess the future trajectory of differing coral reef habitats on the Florida Reef Tract with ocean acidification, providing information on areas that may serve as OA refugia (least susceptible) or, conversely, hotspots (most susceptible).

Related information:
Pertinent Publications

Manzello, D. P. 2010. Coral growth with thermal stress and ocean acidification: lessons from the eastern tropical Pacific. *Coral Reefs* **29**, 749-758. [URL: http://dx.doi.org/10.1007/s00338-010-0623-4]

Manzello, D. P. 2010. Ocean acidification hotspots: spatiotemporal dynamics of the seawater CO_2 system from eastern Pacific coral reefs. *Limnology and Oceanography* **55**, 239-248. [URL: http://wap.aslo.org/lo/pdf/vol_55/issue_1/0239.pdf]

Manzello, D. P. 2009. Reef development and resilience to acute (El Nino warming) and chronic (high-CO_2) disturbances in the eastern tropical Pacific: a real-world climate change model. *Proc. 11th International Coral Reef Symposium*, **25**, 1299-1304. [URL: http://www.nova.edu/ncri/11icrs/proceedings/files/m25-06.pdf]

Manzello, D. P., J. A. Kleypas, D. A. Budd, C. M. Eakin, P. W. Glynn, & C. Langdon. 2008. Poorly cemented coral reefs of the eastern tropical Pacific: possible insights into reef development in a high-CO_2 world. *Proc. Natl. Acad. Sci. U.S.A.* **105**, 10450-10455. [URL: http://dx.doi.org/10.1073/pnas.0712167105]

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_3__ Observations & Monitoring
_4___ Physiological Responses
_1__ Ecology & System Responses
_2__ Biogeochemistry & Modeling

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Research Interests:
Sediment geochemistry: The use of sediment and pore water measurements, with diagenetic models, to determine the rates of diagenetic processes and their influence on geochemical cycles and the sediment record. I have examined oxygen, metabolites, and the CO_2 system (concentrations, stable isotopes, and radiocarbon); and I have studied the transport processes affecting distributions of sedimentary components with both natural radiotracers and introduced tracers.
Marine carbonate chemistry: My past work has used measurements and models of solid and dissolved phase distributions in sediments to determine the occurrence, rate, and significance to biogeochemical cycles of metabolically driven calcite dissolution. We have demonstrated the occurrence of metabolic dissolution and shown that it may dissolve a significant fraction of the rain of calcite to the sea floor. My current work in sedimentary carbonate chemistry builds on these results with determination of the solubility of biogenic calcite. In addition, I am preparing an instrument for autonomous measurements of pH and TCO_2 in surface waters for long-term, temporally dense measurements of changes in the CO_2 system in seawater.

Synopsis of current ocean acidification-relevant research or work: My current, ocean acidification work is a study of the solubility of the calcite in planktonic foraminifera that been recovered from sediment cores. Pore water data have indicated that pore waters in some locations may reach equilibrium with a calcite phase that is more soluble than the abiogenic calcite measured by A. Mucci; the Mucci value is used to indicate calcite solubility throughout the oceans. We have collected 3 species of foraminifera, determined by W. Berger to have different susceptibilities to dissolution (G. ruber, G. sacculifer, and G. menardii), from depth transects of the Providence Channel (Bahamas) and Eastern Tropical Atlantic. We have measured the solubility of intact foraminifera through incubation in acidified seawater for 60-90 day periods. We have used two pre-treatments: sonication in distilled water, and sonication in the sequence: distilled water, methanol, dilute HNO_3, and distilled water. Results were similar with both pre-treatments and both equilibration times. With each set of incubations, we also measure the solubility of abiogenic, Iceland Spar calcite. We have found: (1) our measurements of Iceland Spar calcite agree (± 5%) with the Mucci solubility; (2) the solubility of the planktonic foraminifera is consistently higher than the Mucci solubility; (3) there are no consistent differences in solubility of the three species taken at sediments under similar water depths, although the bulk chemistry of the shells, as indicated by Mg/Ca, does differ; and (4) a (so far) limited comparison between pore water data and laboratory solubilities in the eastern tropical Atlantic shows good agreement between the 2 sets of data. Pore water data from a site under bottom waters with $\Omega_{calcite}$ (Mucci) = 1.30 and an apparent pore water equilibrium at Ω=1.15 ± 0.11 gave an experimental solubility (3 foram species) of 1.20 ± 0.02. Data from a site with bottom-water-Ω (Mucci) = 0.90 and an apparent pore water equilibrium value of 0.97 ± 0.07 gave an experimental solubility of 1.12 ± 0.02 (2 species). We are currently working to complete measurements over the 2 depth transects we are studying.

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_1__ Biogeochemistry & Modeling

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858-534-7466

Research Interests:

- Chemical sensor development, calibration, and validation
- Aqueous CO_2 chemistry
- Biogeochemical modeling

My research interests relate primarily to development of autonomous sensors for the marine CO_2 system. A goal is to design low power systems capable of extended operation on a variety of autonomous platforms (e.g. moorings, profiling floats). With such sensors, we hope to observe spatiotemporal scales of variability not easily quantified from shipboard data. Ultimately, such data will be used within the framework of physical-biogeochemical models to constrain processes such as net community production and export production. Such data can also be used to augment higher quality, but sparser, cruise data, effectively strengthening both data sets. A pre-requisite to this work is further development of systematic calibration and quality control protocols for the relatively immature field of autonomous sensors for aqueous CO_2 properties.

Synopsis of current ocean acidification-relevant research or work:
My group is developing autonomous pH sensors for moorings through NSF 0844394 "Evaluation and Adaptation of an Ion Sensitive Field Effect Transistor for Seawater pH Applications" and profiling floats through a NOPP award with MBARI (Ken Johnson, Lead PI), Honeywell, and UW. We are also in the early stages of a project to develop a dissolved inorganic carbon sensor for profiling floats through NSF 0961250 "Development of a Micro-Rosette Sensor for Total Dissolved Inorganic Carbon Measurement from Autonomous Lagrangian Ocean Profilers". To date we have constructed 45 pH sensor packages, known to several in the oceanography community as the "SeapHOx" and "SeaFET". These sensors, funded by 13 different groups collaborating with us, have been deployed around the world. To enhance sensor development, calibration, and inter-comparison work we are actively planning a large high-precision control tank at Scripps.

Related information:
http://martzlab.ucsd.edu/

Martz, T. R., J. G. Connery, and K. S. Johnson (**2010**). Testing the Honeywell Durafet® for seawater pH applications, *Limnology and Oceanography: Methods*, *8*, 172-184.

Yu, P. C., P. G. Matson, T. R. Martz, and G. E. Hofmann (**2011**). The ocean acidification seascape and its relationship to the performance of calcifying marine invertebrates: Laboratory experiments on the development of urchin larvae framed by environmentally-relevant pCO_2/pH, *Journal of Experimental Marine Biology and Ecology*, *In Press,* DOI: 10.1016/j.jembe.2011.02.016

Cullison-Gray, S. E., M. D. DeGrandpre, T. S. Moore, T. R. Martz, G. E. Friederich, and K. S. Johnson (**2011**). Applications of in situ pH measurements for inorganic carbon calculations, *Mar. Chem.*, *In Press,* DOI: 10.1016/j.marchem.2011.02.005

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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Research Interests:

The main focus of my research is the distribution, transformations and fate of carbon in the high latitude North Pacific. I have several funded projects in the Arctic Ocean, Bering Sea, and the Gulf of Alaska studying the impacts that physical and biogeochemical processes such as ocean acidification and sea ice loss have on the marine carbon cycle. These regions are critically important and may serve as a bellwether for our understanding of how changes in carbonate mineral saturation states will impact ecosystems. The waters of the North Pacific are preconditioned to have lower carbonate mineral saturation states due to ocean mixing patterns and colder water temperatures that increase CO_2 solubility. Recent observations in the arctic and sub-arctic North Pacific have already revealed areas of seasonal carbonate mineral suppression and aragonite undersaturations at the surface and near the bottom, while models project even larger areas of aragonite undersaturation in the coming decades.

Synopsis of current ocean acidification-relevant research or work:

I currently have projects funded around Alaska to better understand the controls and extent of ocean acidification and the impacts that biogeochemical factors such as primary production, sea ice melt, and terrestrial runoff have on carbonate mineral saturation states in the region. One of the projects (Observation and Prediction of Ocean Acidification in the Western Arctic Ocean - Impacts of Physical and Biogeochemical Processes on Carbonate Mineral States - NSF) will begin in the fall of 2011 and involve a cruise each year for four years to collect a suite carbon and biological rate measurements. This work will be done in conjunction with another of my NSF projects (An Interdisciplinary Monitoring Mooring in the Western Arctic Boundary Current: Climatic forcing and ecosystem response) to study the seasonal and interannual variability of water column biogeochemistry, including pH and pCO_2. I have another project (Biogeochemical Assessment of the North Aleutian Basin Ecosystem: Current Status and Vulnerability to Climate Change) funded by the BOEM to determine the controls on carbonate mineral saturations states in the Bering Sea. Data was collected in spring, summer, and fall in 2008 - 2010 across the eastern Bering Sea shelf for this work. In 2011, I will deploy a full suite of OA sensors at the surface and the bottom on the M2 mooring in the Bering Sea. Moving into the Gulf of Alaska, I am being supported by the Alaska Ocean Observing System (AOOS), to measure the full suite of carbon parameters along a time-series line twice each year (May and September) in the northern GOA. I have already collected data in 2008 – 2011 and this project will ideally go on indefinitely, allowing us to maintain a high latitude time-series for ocean acidification. This time series also includes a mooring with OA sensors at the surface and near the bottom. I also have a project in Glacier Bay funded by the National Parks Service to study the impacts of glacial discharge on ocean acidification and saturation states. This is a three year project that will begin in July of 2011. The full suite of carbon and hydrographic data will be collected monthly inside Glacier Bay. Finally, I have a project funded by the PCCRC to study the impacts of decreasing pH on larval and juvenile Pollock.

Related information:
More information about our work can be found at www.sfos.uaf.edu/oarc

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
_2_ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My research interests have focused primarily on marine chemical ecology and polar biology. A current area of my research involves the effects of ocean acidification on marine algae and invertebrates. To date, my studies have encompassed aspects of embryonic and larval development, juvenile to adult growth, calcification and reproductive success in temperate and subtropical barnacles and echinoderms. A major focus of my research has been antarctic marine invertebrate ecology. As such, I have become very interested in the potential impacts of ocean acidification on antarctic marine organisms and communities.

Synopsis of current ocean acidification-relevant research or work:

One of my current NSF programs, with Chuck Amsler and Robert Angus as co-investigators, involves an evaluation of the individual and combined effects of rising ocean acidification and sea surface temperatures on shallow-water calcified benthic organisms in western Antarctic Peninsular (WAP) marine communities. The goals are closely tied to my past and current NSF-funded studies into aspects of the energetics, population biology, and ecology of Antarctic benthic marine algae and invertebrates. The benthic flora and fauna of the shallow nearshore waters of the Antarctic Peninsula are uniquely vulnerable to the impacts of climate change. The Southern Ocean is predicted to become undersaturated in terms of both aragonite and calcite within 50 and 100 years, respectively, challenging calcification processes. Moreover, antarctic peninsular marine benthic organisms are essentially stenothermal, yet are being subjected to rising seawater temperatures. Adding to the problem, antarctic calcified benthic marine organisms are more vulnerable to ocean acidification than temperate and tropical species because they are generally weakly calcified. In a recent study I and colleagues found that post-mortem thalli of antarctic benthic crustose algae and shells of macroinvertebrates are highly susceptible to rapid dissolution under the predicted regime of ocean acidification. The present study will extend this important analysis to living benthic macroalgae and invertebrates. The proposed project employs both single-species and multi-species level approaches to evaluating the impacts of rising ocean acidification and seawater temperature on representative calcified and non-calcified macroalgae, on calcified and non-calcified mesograzers, and on a calcified macrograzer, all of which are important ecological players in the rich benthic communities. Multi-species analysis will focus on the diverse assemblage of amphipods and mesogastropods that are associated with dominant macroalgae that collectively play a key role in community dynamics along the WAP.

Related information:

McClintock, J. B., R. A. Angus, M. R. McDonald, C. D. Amsler, S. A. Catledge, Y. K. Vohra 2009. Rapid dissolution of shells of weakly calcified Antarctic benthic macroorganisms indicates high vulnerability to ocean acidification. Antarctic Science 21(05):449-456.

McDonald, M.R., McClintock, J.B., Amsler, C.D., Rittschof, D., Angus, .R.A., Orihuela, B., Lutostanski, K. 2009. Effects of ocean acidification over the life history of the barnacle Amphibalanus amphitrite. Marine Ecology Progress Series 385: 179–187.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
_1__ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

I am a chemical oceanographer / geochemist, with interests in:
Ocean acidification –culturing studies of OA impacts on a range of marine calcifying organisms, and field studies of the carbonate chemistry of coastal waters,
Benthic geochemistry – pore water and solid phase studies of sea floor organic matter decomposition, calcium carbonate dissolution, nitrogen cycling, and trace metal remobilization,
Ocean paleochemistry – field and culturing studies of the controls on benthic foraminiferal isotopic and elemental composition, and
Land-sea groundwater interactions – chemical and isotopic studies of groundwater discharge into estuaries and the coastal ocean.

Synopsis of current ocean acidification-relevant research or work:

Laboratory and field studies of the interacting influences of pCO_2, temperature, and nutritional status on coral calcification and growth (with Anne Cohen, and our students (Michael Holcomb, Liz Drenkard, Hannah Barkley), post-docs (Justin Ries, Neal Cantin), and colleagues (Samantha dePutron, Ann Tarrant)).

Laboratory studies of the impact of elevated pCO_2 on initial calcification and early development of a range of commercially important shellfish (with Anne Cohen, and post-doc Ries, graduate (Merdith White) and undergraduate (Maggie Sogin and Melissa Pinard) students, and colleagues at NOAA/NMFS (Lisa Milke, James Widman)).

Laboratory studies of the impact of elevated pCO_2 on survival and health of benthic foraminifera (with Joan Bernhard and post-doc Anna McIntyre-Wressnig).

Field studies of the controls on the carbonate chemistry of estuaries and the coastal ocean, emphasizing shellfish habitat, and coral reefs.

Related information:

Meeting scientific themes relevant to this research:

_3__ Paleo & Proxies/Modeling
_1__ Observations & Monitoring
_2__ Physiological Responses
_4__ Ecology & System Responses
__5_ Biogeochemistry & Modeling

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Research Interests:

As lead for OA research at the NWFSC, I work with a large number of collaborators on a variety of projects with the ultimate goal of understanding how OA will affect marine ecosystems, especially impacts to ecosystem services in the NE Pacific. I address this question experimentally by exploring the response of individual species to elevated CO_2, though modeling OA-caused changes to food webs, and with coupled biological/chemical monitoring to determine the carbon environment actually experienced by species of interest. My specific interests in this general program include the design of experimental OA systems, life-cycle based models, and fine-scale spatial and temporal mapping of pH in coastal habitats. I also have an interest in communicating OA science to the public.

Synopsis of current ocean acidification-relevant research or work:

I led the design and construction of an experimental system for OA research at the NWFSC lab in Seattle. The system has several unique features to more accurately and realistically mimic natural environments: 1) independently controls CO_2, DO and temperature for factorial experiments on interactions of OA, climate change and eutrophication, 2) dynamic control of all parameters to mimic natural patters at tidal, diurnal and other scales, 3) simulates pre-industrial conditions by removal of CO_2, 4) over-parameterization of carbon measurement for accurate and precise control, 5) large volume per treatment for simultaneous experiments on multiple species. In this system, we have conducted preliminary experiments on larval Pacific oyster, geoduck, krill (*E. pacifica*), and pinto abalone. In addition to continued work on these species, we have experiments planned in 2011 for larval Dungeness crabs, black rockfish, Olympia oyster, and copepods (*Calanus sp*.). The species experiments are conducted with multiple collaborators to look at complex response metrics such as sensory behavior, response to disease challenge and gene expression, in addition to standard metrics of growth and survival.

I have collaborated with Shallin Busch and others at the NWFSC on incorporating OA effects into an Ecopath/Ecosim model of Puget Sound. Inputs to the model were developed from a comprehensive literature survey and a data base we developed on the mineralogy of all species in the food web. I am also starting a new modeling project to explore how OA may affect Dungeness crab. The model will use the Species Life-cycle Analysis Modules (SLAM) modeling framework to look at population-level effects on changes to specific life stages and interactions with OA-affected predators, prey and habitat. The model will be parameterized with results from the OA experiments on Dungeness crab.

We have proposals pending for two projects on fine-scale spatial and temporal measurements of carbon chemistry in Puget Sound. The first project involves collection of pH and alkalinity data as a part of regular zooplankton collection transects in the Sound to correlate zooplankton abundance with saturation state. These data will inform experimental conditions in the lab and ecosystem-level food web models. A second project involves placing continuous pH sensors in habitats frequented by species of interest.

For outreach, I have been involved in setting up OA “discovery carts” at the Pacific Science Center and Seattle Aquarium, K-12 curriculum development and public lectures. With J. Stein and S. Busch, I organized a symposium on OA for the American Fisheries Society meeting in September, 2011.

Related information:

See West Coast chapter of NOAA OA research plan for summary of issues and research (http://www.pmel.noaa.gov/co2/story/NOAA+OA+Plan)

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_X_ Observations & Monitoring
_X_ Physiological Responses
_X_ Ecology & System Responses
_X_ Biogeochemistry & Modeling

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Research Interests:

My post-doctoral research at the University of Otago, New Zealand focused on the development of autonomous, pH-controlled culture systems for ocean acidification studies. The culture systems incorporate alkalinity and spectrophotometric pH measurements to continuously control (to within 0.02 pH units) and monitor the carbonate chemistry in up to 24 culture tanks. I developed and built several culture systems to study the impact of OA on marine organisms: (a) two ship-board systems, which recently returned from the Tasman Sea, (b) two trace-metal clean culture systems, (c) a 24-tank system for long-term cultures of subtidal communities, and (d) a 24-tank system capable of mimicking daily and seasonal changes in carbonate chemistry. These have been used for OA studies involving a wide range of New Zealand and Antarctic organisms, including phytoplankton, clams, sea urchins, and calcifying algae.

Synopsis of current ocean acidification-relevant research or work:

I am currently developing new electrochemical and colorimetric sensors for field measurements of the carbonate system. My lab is developing two sensors platforms to obtain high spatial- and temporal-scale measurements of carbonate, which we will use for OA research:

(a) Incorporation of new carbonate electrochemical sensors into sensing networks to obtain time-resolved 3D maps of carbonate within defined areas, i.e. localized coastal regions, calcifying sub-canopies, and tide pools. Real-time monitoring will allow us to investigate the regional differences in carbonate – both trends and variability – and the interactive effects of multiple environmental variables on calcification rates.

(b) Development of microsensors to measure gradients in ion fluxes near the surface of calcifying organisms, where pH, bicarbonate and carbonate concentrations co-vary greatly on distance scales of mm-to-cm. These sensors will allow us to investigate the regional impact of ocean acidification on the carbonate profile within the organism's diffusion boundary layer, which isolates it from the bulk seawater.

Related information:

C.M. McGraw, C. Cornwall, M.R. Reid, K. Currie, C.D. Hepburn, P.W. Boyd, C.L. Hurd, K.A. Hunter, An automated pH-controlled culture system for laboratory-based ocean acidification experiments, *L& O:Methods,* 8, 686–694, 2010.

C. Cornwall, C.D. Hepburn, D. Pritchard, K. Currie, C.M. McGraw, K.A. Hunter, C.L. Hurd, Differential responses of macroalgae with various carbon-use strategies to ocean acidification, *Accepted J. Phycol,* 7/2010.

V. Cummings, J. Hewitt, A.Van Rooyen, et al, Ocean acidification at high latitudes: potential effects on functioning of the Antarctic bivalve, *PLoS One 6(1): e16069,* 2011.

C.L. Hurd, C. Cornwall, K. Currie, C.D. Hepburn, C.M. McGraw, K.A. Hunter, P.W. Boyd, Calcifier-mediated pH fluctuations exceed projected changes due to ocean acidification, *Accepted by Global Change Biology,* 2/2011.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My research focuses on how variations in chemical variables (e.g., carbon dioxide) in the environment influence growth of different phytoplankton species and the consequences this has on the food web. Phytoplankton primary production is the building block of the marine food web, and variations in species composition can have dramatic effects upon grazers. Fundamental questions addressed in this research include: (1) How will pure cultures, 15 representative coastal and oceanic phytoplankton species, respond to an enriched carbon dioxide environment? (2) In combined, constructed-community, mixed cultures, which species will compete better in a high carbon dioxide environment and why? and (3) Are there changes in food quality of the phytoplankton resulting from shifts in species dominance? With this research, we hope to provide information about species dominance under an enriched carbon dioxide environment for food web-based models.

Synopsis of current ocean acidification-relevant research or work:

One of our current research projects entitled "Phytoplankton nutritional value for fishery-based food webs" (King, Wikfors, and Meseck) involves experiments with phytoplankton species that are relevant to the northern Atlantic and are key players in the planktonic ecosystem structure. This includes a coastal diatom (*Thalassiosira pseudonana*) and an oceanic diatom (*Thalassiosira oceanica*) as well as a dinoflagellate (*Alexandrium fundyense*) and a coccolithophore (*Emiliania huxleyi*). Diatoms represent a functional phytoplankton group at the base of the marine food web, especially with regard to the supply of omega-3 and omega-6 PUFAs for larval and juvenile fish nutrition. Dinoflagellates and coccolithophores both share an ecological niche and alternate in dominance with the coastal and oceanic diatoms, respectively, with their production having neutral or potentially negative influences on fisheries production (*A. fundyense* is toxic to most species). Representatives of all major microalgal classes, including cryptophytes, prasinophytes, cyanobacteria, chlorophytes, and raphidophytes will later be done. If, for example, low pH/high pCO_2 favors prasinophytes (which lack omega-3 fatty acid docosahexaenoic acid; DHA), prymnesiophytes (which lack eicosapentaenoic acid; EPA), or chlorophytes (which lack fatty acids with more than 18 C), the survival and reproductive success of commercially-important fish and shellfish may be affected. Experiments will initially be monospecific cultures and later mixed cultures will be used to evaluate competitive interactions between species. This research is just beginning with our post-doc Andrew King.

Related information

Meseck, S.L., et al. 2007. Nutrient interactions between phytoplankton and bacterioplankton under different carbon dioxide regimes. J. Appl. Phycol. 19:229-237.

Meseck, S.L. 2007. Controlling the growth of a cyanobacterial contaminant, *Synechoccus* sp., in a culture of *Tetraselmis chui* (PLY429) by varying pH: Implications for outdoor aquaculture production. Aquaculture, 273: 566-572.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
__3_ Observations & Monitoring
__2_ Physiological Responses
_1__ Ecology & System Responses
___ Biogeochemistry & Modeling

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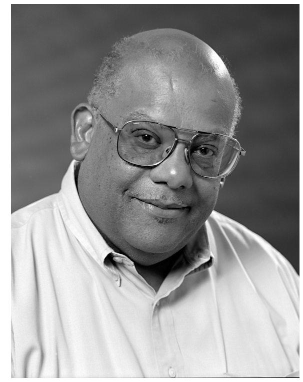

Research Interests:

My research interests have included international law and organization, particularly relating to the ocean; the design, processes, dynamics, and effectiveness of international environmental regimes; international science and technology policy; and the impacts of climate variability and climate change on societies and ecosystems at regional, national, and global spatial scales. I am particularly interested in the conditions under which science-based policies can be implemented to facilitate solutions to serious environmental problems. For the last fifteen years I have worked on developing climate and vulnerability impacts assessments at regional, national, and global spatial scales.

Synopsis of current ocean acidification-relevant research or work:

The implications of the combined effects of a warming and increasingly acidic ocean have been a major research interest of mine since the appearance of the two papers by Feely et al. (2004) and Sabine et al (2004). In 2007 I joined with Dick Feely and other colleagues at the University of Washington, other universities in the Pacific Northwest region, and two NOAA laboratories to develop a collaborative program of investigation which would be integrated from the research and monitoring to the impacts assessments, and concluding with policy identification and evaluation. At the policy end, the problem is treated as one of creating responses to multiple anthropogenic stresses on a global scale in which there is considerable regional and local variability. While this combination of stressors constitutes a serious global problem, we argue that it cannot be managed effectively at the global scale. The alternative we offer is the design of a path to creation of a regionally-focused global network for linking research and monitoring to development of policy options and evaluation of management strategies.

Related information:

Miles, Edward L. 2009. On the Increasing Vulnerability of the World Ocean to Multiple Stresses. Annual Review of Environment and Resources. 34: 18.1 – 18.25. DOI: 10.1146/annrev.environ.33.041707.110117.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
__1_ Observations & Monitoring
__3_ Physiological Responses
__2_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My research focuses on feeding, nutrition and physiology of marine bivalve molluscs with an emphasis on larval and early postlarval stages. Early developmental stages of marine molluscs may be particularly vulnerable to changes in pCO_2 and pH as they rely on calcite and/or aragonite to build their protective shells. Early life stages are generally more sensitive to stressors than adults and they also need to meet the energetic cost of metamorphosis. Alterations in pCO_2 levels may not only have a direct effect on shell formation, but also induce physiological changes as a result of altered water chemistry and associated stresses. These stresses have the potential to impact larval growth and development, metamorphic success and ultimately recruitment of these economically and ecologically important species.

Synopsis of current ocean acidification-relevant research or work:

I am involved in two proposed ocean acidification research projects. The first project involves the examination of the larvae of the surf clam, *Spisula solidissima*, through metamorphosis under different pCO_2 concentrations. Two different experiments will be conducted from the same cohort. A short term (48-72h post fertilization) experiment will examine biomineralization of the newly developed shell and viability of the larvae. The longer term (~21 days) experiment will rear animals through metamorphosis and examine growth, survival and metamorphic success as well as larval respiration rate and lipid class composition as measures of physiological condition.

The second proposed project I am participating in will examine effects of different pCO_2 levels on phytoplankton species representative of nutritional functional groups important to the ecosystem structure of the north Atlantic. The effect of pCO_2/pH on growth rate, elemental composition (C,N,P), intracellular pH, and fatty acid composition will be examined; my involvement is centering around the fatty acid characterization. The success of certain functional groups or changes in biochemical composition could alter the nutritional value of the phytoplankton community as a whole and have potential impacts on food web dynamics.

Related information:

Milke, L.M., V.M. Bricelj and C.C. Parrish (2006). Comparison of early life stages of the bay scallop, *Argopecten irradians*: effects of microalgal diets on scallop growth and biochemical composition. Aquaculture, 260: 272-289.

Milke, L.M., V.M. Bricelj and C.C. Parrish (2004). Growth of postlarval sea scallops, *Placopecten magellanicus*, on microalgal diets, with emphasis on the nutritional role of lipids and fatty acids. Aquaculture, 234(1-4): 293-317.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
__1_ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:
My interest and expertise is in reef coral population ecology and so with respect to OA, I am interested in population-level impacts (as opposed to calcification per se), particularly on early life stages of spawning species. Macroalgae are also important determinants of coral settlement success in reef environments and their dynamics may also be susceptible to CO_2-induced changes. This potential interaction of CO_2 impacts on reef macroalgae with cascading effects on coral recruitment is also an interest.

Synopsis of current ocean acidification-relevant research or work:
Future work is theoretically funded to conduct factorial temperature x CO_2 exposure treatments throughout the pelagic larval stage of several Caribbean spawning coral species. Preliminary work suggests that pelagic stages of coral (and other invert) larvae are less sensitive to CO_2 exposure, but other published work shows that at least some species are sensitive to warm temperatures as low as 30oC. We will attempt to culture the full (~ week long) pelagic stage of various spawning species under crossed conditions to quantify survivorship. If sufficient numbers of larvae survive these treatments, we will assay settlement success as well.

An additional project component will be observational measurements of colonization and productivity of reef macroalgae (including calcareous and non-calcareous species) at field sites where carbon chemistry is already being monitored in the Florida Keys (Manzello, NOAA/AOML) and Puerto Rico (Gledhill, NOAA/AOML). These measurements are intended as field baseline characterizations.

Related information:
Previous work has demonstrated that early life stages of ESA-listed elkhorn coral are affected by mid-century CO_2 levels, including impaired fertilization success, impaired settlement success, and reduced post-settlement growth rates. These cumulated impairments are estimated to potentially reduce coral recruitment by more than half by mid-century.

Albright R, Mason B, Miller M, Langdon C. (2010) Ocean acidification compromises recruitment success of the threatened Caribbean coral, *Acropora palmata*. Proc Nat Acad Sci 107: 20400–20404.

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1.5_ Physiological Responses
_1.5_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My current extramurally funded research interests include; marine cellular biomineralization and shell formation in oysters, which lead to the discovery and subsequent publication in *Science*, that the oyster's own blood cells or leukocytes nucleate and deliver calcium carbonate crystals to form the mineralized component of shell. The structural characterization of these nanoscale crystals, within living cells to determine their phase (either amorphous or crystalline) and their crystalline axis of orientation after deposition is one of our research questions under investigation. Through ONR sponsorship, my group *Okeanos* conducts research on the signal transduction mechanisms of biofouling in marine invertebrates which lead to our innovation of a novel marine antifouling coating strategy, termed fouling deterrence, in which the organism's own endocrine molecules when covalently bound to a polymeric coating, to deter settlement. Our lab (http://www.clemson.edu/okeanos/) in partnership with Nikon Instruments invented a laser scanning confocal *macro*-scope, which was launched as a product in 2010. I teach graduate students and faculty by offering several specialized courses of instruction on both optical and electron microscopy and limited spectroscopic techniques (EDS, Raman, and others).

Synopsis of current ocean acidification-relevant research or work:

To fully understand and appreciate the consequences of ocean acidification to shell forming mollusks, a realistic cellular biology understanding about how these organisms actually construct their shells is necessary. Towards this aim, our previous work has shown that the nucleation and growth of calcium carbonate crystals occurs via an *intracellular* mechanism in oysters, specifically within cells which circulate in the hemolymph. It is well known that the mineralization of calcium carbonate generates free hydrogen ions which must be either neutralized or removed for mineralization to proceed. Oyster hemolymph pH is ~7.4 and yet these cells mineralize, the implication being that these cells have evolved the capacity to regulate their acid-base balance, which may prove to be an important adaptive mechanism in ocean acidification. We have also discovered that nanocrystalline ceramics were innovated and evolved from specialized refractive (REF) cells over a billion years ago. These cells produce calcite crystals by intracellular means and deliver them to the mineralization front. Subsequently, we have found that oyster cells also organize nanoscale shell composites thus enabling simultaneous production and self-organization of organic and mineralized phases resulting in the extraordinarily strong nanocrystalline ceramic that forms the complex multi-lamellar oyster shell. We are now studying how large cellular aggregations are organized by microtubules, collagen and *folian,* and how these macromolecules participate in the cellular deposition of polycrystalline assemblies. Our studies of metallic implants in oysters have also revealed that a thin membrane covers implants, the fibers of which organize cellular movements and migrations. Cadherins are involved in cellular adhesion and the key cellular events involved in mineralization occur within a 3 to 15 hour time frame. The *transformative aspects* of this research are: a new understanding of molluscan shell formation from a cellular biology perspective which will further our understanding of the impact of ocean acidification on mollusks that inhabit estuarine, littoral and oceanic zones of the world ocean.

Related information:
Papers online at: http//www.clemson.edu/okeanos

We are hosting two sessions on Shell Formation and Marine Biofouling at the NSA Meeting, 27-31 March 2011

Meeting scientific themes relevant to this research:

- ✓ Physiological Responses
- ✓ Ecology & System Responses
- ✓ Biogeochemistry & Modeling

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Research Interests:

One of the greatest **challenges** in understanding and forecasting the consequences of ocean acidification is the scaling of biotic responses to the community and ecosystem level. Studies that combine small-scale laboratory experiments on single species with mesocosm experiments of multi-species and food-web interactions will provide the greatest opportunity for scaling the biotic response. Ideal studies include at least three trophic levels, such as bacteria, phytoplankton and zooplankton.

Synopsis of current ocean acidification-relevant research or work:

A new **Ocean Acidification Experimental Facility** has been constructed at the UW Friday Harbor Laboratories with financial support from NSF FSML, Educational Foundation of America (EFA) and UW. The facility consists of a dock with nine large volume mesocosms, an indoor lab for small-scale experiments and a complete carbonate system analytical lab (pH, DIC, alkalinity, P_{CO2}). The mesocosms were designed after the system built at Pohang, South Korea by Kitack Lee and colleagues (see Kim et al., 2008) are 3 m in height and 1 m diameter and contain 2,400 ltr. Both the mesocosms and small-scale experiments have the capability of temperature control as well as CO_2.

The objective of **mesocosm experiments** is to study responses at the community level. Besides the carbonate system chemistry, this requires some basic information on three biological trophic levels: bacteria, phytoplankton and zooplankton. We are planning to conduct the first experiment at FHL over three weeks in June 2011. This experiment will include experimentalists with expertise in several areas. These include James Murray (chemistry), Bob Morris (microbiology), Evelyn Lessard (zooplankton) and Robin Kodner (phytoplankton). The detailed specifics of the experiments are still evolving but the experiment will probably consist of three mesocosms at present day CO_2 (~390 ppm), three at 2X CO_2 (780 ppm) and three at 3X CO_2 (1170). The CO_2 will be kept close to the target levels and not allowed to drift down during the experiments. Impacts on community composition, species interactions, metabolism, gene expression and biogeochemical cycling, will be evaluated by using a combination of traditional, molecular and emerging technologies.

The **data set** will consist of core physical properties, light and nutrients. We will measure basic biological stocks and rates. Some novel experiments are planned where mesocosms are spiked with ^{13}C and ^{18}O to compare different approaches to estimate net and gross biological production.

The **expected outcome** is that the results from these first "proof of concept" experiments will enable us to be in a better position to apply for long term support from NSF. As these experiments will be conducted in conjunction with an ocean acidification class at FHL we can demonstrate how this synergy between research and education would work as part of an IGERT or STC type proposal. We will begin to learn how ocean acidification will impact biological food-web interactions in Puget Sound.

In addition we have been funded by the **World University Network (WUN)** to conduct a targeted workshop on Ocean Acidification from 29 August to 2 September 2011 at the University of Washington's Friday Harbor Laboratories (FHL). The purpose of this workshop will be to bring together students and researchers (including early career researchers and postgraduate students) from within the WUN to present their latest results and to develop a plan for future international research and educational collaboration. The expertise and facilities that exist among the WUN Universities offer an unparalleled opportunity to initiate a new program for international exchange.

Related information:

Kim J-M., Shin K., Lee K., Park B-K. 2008. In Situ ecosystem-based carbon dioxide perturbation experiments: Design and performance evaluation of a mesocosm facility. Limnology and Oceanography: Methods 6, 208-217.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
__x_ Physiological Responses
__x_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My research focuses on the effects of environmental variability on marine and estuarine organisms and ecosystems. I use mathematical models to examine changes in the distribution, abundance, and ultimately population biology of marine organisms in a variety of ecosystems. Because natural resource management motivates my research interests, much of my research has focused on fishes and their food resources. Recently my research has broadened to investigate the effects of acidification on estuarine ecosystems, in particular the behavior and trophic interactions among estuarine fish and their prey. While laboratory experiments suggest that the effects of acidification on fish growth and mortality are minimal, acidification has been shown to have significant effects on olfactory processes that control predatory avoidance, prey capture, and perhaps other behavior. In addition to examining the effects of ocean acidification on individual fish, I hope to examine the effects of this stressor at multiple trophic levels to further understand the ecosystem consequences of ocean acidification. Estuaries are highly variable physical environments and ocean acidification compounds the environmental stresses estuarine organisms already face.

Synopsis of current ocean acidification-relevant research or work:

A relatively small group of people including myself are developing a research program on ocean acidification in the EPA. Our research at AED, will focus on the effects of acidification on ecosystem services as EPA focuses more and more on broad sustainability issues. A laboratory system to manipulate pH with CO_2 has been developed and preliminary experiments to estimate vital rates have been conducted on the mysid *Americamysis bahia* (see Jason Grear abstract). We are expanding our research to study *Neomysis americana,* a common mysid species in Narragansett Bay, and several species of juvenile fish that feed upon *Neomysis americana* as well as phytoplankton dynamics. Ultimately we hope to conduct mesocosm experiments to elucidate the potential ecosystem effects of ocean acidification on estuarine organisms. We have also requested equipment that can be used to monitor pCO_2 and pH in the field, as information on natural variability in pH is lacking, but needed for regulation by the EPA.

Related information:

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
_2_ Observations & Monitoring
___ Physiological Responses
_1_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My primary interest is to understand how ecological interactions will be mediated by growth under acidified conditions. This includes looking at susceptibility to predation due to altered material properties and alterations in species response to acidification with variation in food supply. I concentrate on intertidal and shallow subtidal temperate organisms such as limpets and mussels. I also devote a great deal of effort to developing experimental systems and help to train undergraduate and graduate students in their use for ecological experimentation.

Synopsis of current ocean acidification-relevant research or work:

1) A primary project is to develop and deliver an upcoming graduate course on experimental approaches to OA research, to be offered at the University of Washington's Friday Harbor Labs in June and July 2011 (With Terrie Klinger). Effective ocean acidification research requires biologists and ecologists to adhere to standard operating practices to manipulate carbonate chemistry in an experimental setting. These operating practices necessitate that biologists and ecologists acquire new skills, especially with regard to analytical chemistry, experimental design, and analysis. Few graduate students possess the full suite of biological/ecological, chemical analytical, and technical skills to perform successful experiments, and opportunities to learn these skills in the U.S. are rare to absent. To address this need, we will offer a 5-week intensive residential graduate in which students learn the technical, chemical analytical, and experimental design skills necessary for ocean acidification research.

2) I am overseeing the design and construction of a multi-user acidification research facility at FHL. This includes an analytical chemistry lab for onsite monitoring of experimental conditions and isolated experimental chambers providing independent control of temperature and carbonate chemistry. The facility is intended to serve investigators and students from around the U.S.

3) Specific research projects include an investigation of growth in intertidal limpets to determine whether response to acidification is dependent on the feeding condition of these animals; and an investigation of the effects of acidification on the material properties of biological structures (NSF EF 1041213; Emily Carrington PI; described in more detail in Carrington's abstract in this volume).

Related information:
Information about the summer course: http://tinyurl.com/FHL-OA

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_2_ Physiological Responses
_1_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

I am a biological oceanographer and I am interested in phytoplankton molecular and physiological ecology, production and dynamics of marine polymer gels, and their roles in the ecosystem dynamics and biogeochemical processes. My research focuses on using systems approaches to understanding the molecular responses of diatoms to environmental changes, specifically ocean acidification and climate change; and the roles that marine polymer microgels play in the water column in the Arctic Ocean, where changes are occurring fastest than anywhere on Earth. My long-term goal is to understand the coupling between phytoplankton environmental responses, microgels production and their dynamics. Presently, very little is known about how exposure to corrosive water affects the production and dynamics of microgels. Theoretically anticipated impacts are likely to strongly affect the bioavailability of this massive reservoir of carbon.

Synopsis of current ocean acidification-relevant research or work:

One of my current projects is a "*Collaborative proposal: A systems biology approach of diatom response to ocean acidification and climate change* (OCE0928561 to M.V. Orellana and N.S. Baliga; OCE0927238 to E.V. Armbrust). This project focuses on understanding carbon cycle and carbon sequestration using systems biology approaches. Our goal is to characterize – at a molecular and cellular level - the response of diatoms to ocean acidification and climate change. Our broader goal is to understand the contribution by diatoms to carbon cycling at a biogeochemical level. We expect *to generate a predictive model of the global expression of all genes in the diatom Thalassiosira pseudonana, to forecast the diatom's response to projected environmental scenarios for the 21st century (higher CO_2 and temperatures, lower pH) and to anticipate how these changes will affect the ability of diatoms to sequester carbon in the oceans*. To accomplish this goal we are using high-throughput microarray technology, and we are measuring the dynamic gene regulatory response of *T. pseudonana* to increased CO_2 levels, in order to learn the molecular mechanisms by which its existing genetic program permits adaptation to changes in its environment. This allows us to describe the environment-dependent control of critical cellular processes, and to begin to build a model of the global gene regulatory network for this organism.

Another research project, "Collaborative proposal***: Marine*** *Microgels: A Microlayer Source of Summer CCN in High Arctic Open Leads" (ARC- 0707513 to P.A. Matrai and 0707555, to M.V. Orellana)* focuses on understanding the roles that marine polymer gels secreted by phytoplankton play in cloud formation and their responses to climate change.

Related information:

J. Ashworth, A. Lee, E.V. Armbrust, N.S. Baliga,& M.V. Orellana. Molecular responses of diatoms to rising CO_2 levels and ocean acidification. ASLO. Puerto Rico (2011).
Orellana, M.V., T.W. Petersen, A.H. Diercks, S. Donohue, P. Verdugo and G. van-den Engh. Marine Microgels: Optical and Proteomic Fingerprint. Mar. Chem., 105: 229-239. (2007)
Chin, W., M.V. Orellana and P. Verdugo. Formation of microgels by spontaneous assembly of dissolved marine biopolymers. Nature 391:568-572 (1998).

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
__1_ Physiological Responses
_2_ Ecology & System Responses
_3 Biogeochemistry & Modeling

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Research Interests:

My interests are focused on the biological and ecological impacts of ocean acidification with the goal of understanding how harvested and protected marine species may be affected. I am interested in the physiological effects of ocean acidification on marine organisms and the resulting ecosystem impacts of these effects. I am also interested in utilizing the results of the research conducted in these areas to help determine what management actions may be taken to help organisms, and the ecosystems they are components of, be more resilient or adapt to ocean acidification.

Synopsis of current ocean acidification-relevant research or work:

I am involved with planning and managing ocean acidification research within NOAA and across Federal Agencies. I am a member of the Interagency Working Group on Ocean Acidification which is charged with planning and coordinating U.S. Federal ocean acidification research and monitoring activities, assessment, adaptation and mitigation strategies, and communication. This working group has developed a report on federally funded ocean acidification research and monitoring activities and recently completed a draft strategic plan for Federal research and monitoring on ocean acidification. I also am assisting with the development of the U.S. National Ocean Council strategic action plan for Resiliency and Adaptation to Climate Change and Ocean Acidification. In addition, I contribute to the planning of ocean acidification activities across NOAA and currently manage the ocean acidification research program within the NOAA National Marine Fisheries Service (NMFS). In this capacity I coordinate and help set priorities for NMFS research which is focused on investigating the impacts of ocean acidification on living marine resources. Research is conducted to assess the physiological effects on key species and the resulting ecosystem impacts.

Related information:

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_3_ Observations & Monitoring
_2_ Physiological Responses
_1_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My research focuses primarily on large-scale marine community ecology and conservation, including fundamental questions in diversity theory. My interests in large-scale processes are driven by questions of 1) how anthropogenic and natural forcing alters marine communities, 2) how diversity in marine ecosystems is generated and maintained, 3) coral reef ecology and physiology, and 4) how #1-3 can be integrated into relevant and realistic environmental policy; this often involves teaming with economists to value ecosystem goods and services affected by (primarily anthropogenic) ecosystem forcing. The overall goal of my research is to identify mechanisms and patterns important to the maintenance of ecosystem function, and assess how policy makers and managers may use these mechanisms and patterns to help maintain functional ecosystems. Thus, ocean acidification is a nexus among all of my major research interests.

Synopsis of current ocean acidification-relevant research or work:

My current research focuses on how coral reefs are likely to be affected by ocean acidification on a global scale. To do this, I am developing a spatially-explicit model of coral reefs that projects the extent of future coral reef area. Inputs to the model include: 1) spatially explicit projections of water temperature (including annual and monthly variability) and ocean chemistry, 2) regionally-explicit estimates of coral growth rates, bleaching probabilities, and hurricane frequency, and 3) global estimates of the probability and rate of symbiont switching and evolution. Output will include, for several climate scenarios, a spatially-explicit, probabilistic assessment of live coral reef cover on an annual basis between 2011 and 2300.

This ecological model is being developed in tandem with an economic model designed to estimate the impact of changes in coral reef health on several components of coral reef value (collaborators: Elena Besedin and Ellen Post). These components include values for recreation (tourism, SCUBA diving, snorkeling, recreational fishing, etc.), commercial fishing, and shoreline protection provided by coral reefs. Estimates of the impact of ocean acidification on recreational values of coral reefs will be based on a meta-regression of studies of willingness to pay (WTP); methods to estimate impacts on commercial fishing and shoreline protection values are currently in development.

The combined ecological-economic model will be used to incorporate the effects of ocean acidification into estimates of the social cost of carbon (SCC). The SCC is a measure of the economic benefit from a marginal reduction in CO_2 emissions, estimates of which do not currently include the effects of ocean acidification on ecosystem goods and services (also see abstract by Chris Moore). This omission may lead to a large underestimate of the SCC and consequently of the benefits from regulations that reduce CO_2 emissions. Final model output will be communicated to EPA for potential incorporation into SCC estimates used in cost-benefit analyses required for large federal environmental regulations.

Related information:

The modeling team (ecology & economics) is interested in incorporating other ecosystem goods and services related to ocean acidification into the SCC. Future projects may include estimating the SCC component of commercial fisheries, and of shellfisheries (including aquaculture) on a global scale.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_2_ Observations & Monitoring
___ Physiological Responses
_1_ Ecology & System Responses
_3_ Biogeochemistry & Modeling

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Research Interests:
Functioning of the biological carbon pump, specifically carbon flux, in a changing world:
I seek to gain a ***mechanistic*** understanding of processes which determine the flux of carbon in marine systems, now, and in the future. Predictive modeling is only possible with a mechanistic understanding as empirical relationships may change under future conditions. Currently much of my research focuses on the impact of ***ocean acidification*** (OA) on carbon flux and cycling. One project investigates potential changes in the efficiency of the soft tissue pump due to altered aggregation rates or aggregate characteristics, e.g. decreased sinking velocities. The second project on ocean acidification concentrates consequences of altered carbonate chemistry for the release and utilization of dissolved organic matter.

Synopsis of current ocean acidification-relevant research or work:

1. NSF: OCE-0926711 (Co-PI Alldredge): "*Will Ocean Acidification Diminish Particle Aggregation and Mineral Scavenging, Thus Weakening the Biological Pump?*" This project which is in its second year studies the impact of an altered carbonate system on (a) the formation of Transparent Exopolymer Particles (TEP) and on (b) aggregation rate and sinking velocity of particles: Large, rapidly sinking aggregates provide one of the most important pathways for the sedimentation of particulate organic carbon to the deep ocean. TEP are essential for aggregation as they are sticky and abundant. Thus changes in the formation rate or characteristics of TEP will noticeably impact the efficiency of the biological carbon pump. TEP form abiotically from dissolved precursors released by phytoplankton and bacteria. The release and the formation rate, as well as their stickiness and thereby their aggregation rate are expected to be sensitive to ocean acidification (OA).
2. NSF: OCE-1041038 (Co-PIs C. Carlson & M. Brzezinski): "*Will high CO_2 conditions affect production, partitioning and fate of organic matter?*" This newly funded project investigates the production and microbial degradation of dissolved organic matter (DOM) under OA conditions. Elevated pCO_2 is expected to impact the partitioning of carbon between the particulate and the dissolved carbon pool during photosynthesis. Changes in the quality and quantity of DOM released by phytoplankton may potentially affect its bioavailability negatively. An accumulation of DOM in the surface ocean is hypothesized to result in increased downward transport of DOM to the deep ocean due to physical forcing.

Related information:
Arnosti C, Grossart H-P, Mühling M, Joint I, Passow U (in revision) Dynamics of extracellular enzyme activities under changed atmospheric pCO_2: A mesocosm investigation. Aquatic Microbial Ecology

Feng, Y., C. Hare, K. Leblanc, J. Rose, Y. Zhang, G. DiTullio, P. Lee, S. Wilhelm, J. Rowe, J. Sun, N. Nemcek, C. Gueguen, U. Passow, I. Benner, C. Brown, and D. Hutchins, Effects of increased pCO2 and temperature on the North Atlantic spring bloom. I. The phytoplankton community and biogeochemical response. Marine Ecology Progress Series, 2009. 388: p. 13-25.

Grossart, H.P., M. Allgaier, U. Passow, and U. Riebesell, Testing the effect of CO2 concentration on the dynamics of marine heterotrophic bacterioplankton. Limnology and Oceanography, 2006. 51(1): p. 1-11.

Meeting scientific themes relevant to this research:
__5_ Paleo & Proxies/Modeling
_4__ Observations & Monitoring
_3__ Physiological Responses
_2__ Ecology & System Responses
__1_ Biogeochemistry & Modeling

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Research Interests:

My principal research interests lie in the fields of biogeochemistry, chemical oceanography and paleoceanography. The goal of my research is to use the chemical and isotopic records enclosed in wide range of earth materials to study present and past biogeochemical processes. This research spans a wide range of temporal (seasons to millions of years) and spatial (molecular to global) scales. An over-arching goal of this research is to understand the processes and feedbacks operating in the earth System and how they relate to global changes in climate and tectonics. In addition, I am interested in natural and anthropogenically induced perturbations that affect biogeochemical processes and their impact on humans and the environment.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects, titled "Ocean Acidification Category 2: Calcification in low saturation seawater: What can we learn from organisms in the proximity of low pH, undersaturated submarine springs?" (NSF OCE 1040952) is a field based project to investigate long-term adaptations or coral reef systems to low carbonate saturation and low pH. Work is taking place at a series of natural springs in Mexico where discharging water pH ranges from 8.07 to 7.25 (at the various springs). We are conducting field surveys to map the chemical (pH, DIC, Alk, $pCO_{2,}$ nutrients, DOC, major and trace elements) and physical (temperature, salinity, turbidity, spring discharge rates) characteristics of the water around springs and describing population and community patterns (species distribution and abundance) and clacification rates along the pH gradient. We will also conduct recruitment and colonization studies. Results will shed light on community and ecosystem responses to long term exposure to elevated CO_2 and potential interactions with nutrients, trace metals, and other environmental variables.

Another research project, titled "Enhancing Opportunities for Ocean Acidification Research and Education at the University of California, Santa Cruz," (NOAA, West Coast & Polar Regions Undersea Research Center) seeks to set up the facilities needed to conduct culturing OA research at UCSC and acquire a preliminary set of data that demonstrates the success and importance of the facility. Specifically, a culturing facility to grow important organisms that characterize the Monterey Bay ecosystem at different CO_2 levels will be set at the Longs Marine Laboratory (LML). Two demonstration projects will be carried out one testing the response of cold water solitary corals to OA and the synergetic effects of CO_2 and energetic resources ("food") availability on these corals and the second project will investigate the response of phytoplankton that constitute the base of the food web and support.

A third research project, titled "Acidification of California coastal waters: A geologic record of natural and anthropogenic pH variability," (Coastal Environmental Quality Initiative Co-PIs A. Russell and T. Hill) will produce paleo-pH records using B/Ca ratios from the CA coastal zone for the recent past, and will address the question of how different California coastal environments respond to climate change.

I am also serving on the planning committee for the Third Symposium on the Ocean in a High CO_2 World, to be held in Monterey CA on 24-27 September 2012.

Related information:
http://pmc.ucsc.edu/~apaytan/index.html

Meeting scientific themes relevant to this research:
_2_ Paleo & Proxies/Modeling
___ Observations & Monitoring
_3_ Physiological Responses
_1_ Ecology & System Responses
___ Biogeochemistry & Modeling

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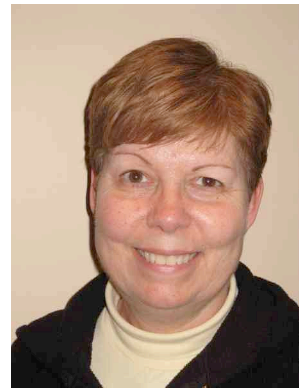

Research Interests:

My research uses field and laboratory studies to examine the effects of environmental factors on marine fish species. I have conducted studies on spawning, predation, habitat selection, and predator avoidance of juvenile and adult fish where behavior, growth, and survival were measured. Characterizing the effect of ocean acidification on early life-history stages of marine fish is a new research collaboration with colleagues,Chris Chambers and Matt Poach and Dan Wieczorek.

Synopsis of current ocean acidification-relevant research or work:

We will be conducting an experimental assessment of responses of key finfish species to increased CO_2 and associated increased acidity of marine and estuarine waters. Our focus is on responses expressed in the early life-stages of representative species. Early life-stages were chosen because the eventual level of recruitment to the adult stage is set during early life and these life-stages are likely to be most sensitive to environmental variations. Further, due to a limited amount of published information on the response of finfish to high CO_2 levels in their environment, we are compelled to underpin our approach with the expectation that the responses of finfish to high CO_2 levels may be subtle, interactive, and expressed in a number of different ways. To date, we have 1) identified a number of commercially and ecologically important finfish taxa to be used in our experiments that, collectively, cover a broad subset of ecological and life-history types for our region, 2) assembled an extensive list of sensitive response variables to be used as bio-indicators of responses to high CO_2 levels, and 3) adopted an experimental design (5 × 5 factorial) that has a sufficient range and density of treatment levels of two factors (CO_2 levels and water temperatures) to estimate the functional form of fish responses and to test for possible interactive effects. With colleagues, we have designed and constructed a controlled CO_2 -temperature flow-through experimental system for exposing fish eggs and larvae. We expect to first implement the system using winter flounder as our test subject this spring, followed by summer flounder then black sea bass.

Related information:

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1_ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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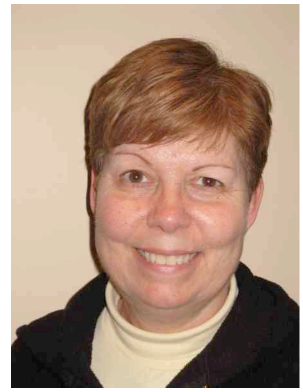

Research Interests:

My research background is on conducting field and laboratory studies that examine the effects of environmental factors such as ocean acidification on marine fish species. As a member of the member of the Ocean Acidification research implementation team, I am responsible for coordinating research efforts in the Northeast Fisheries Science Center. As part of NOAA, we are part of an effort to develop and implement a comprehensive monitoring and research plan for effectively characterizing the consequences of ocean acidification as mandated by The Federal Ocean Acidification Research and Monitoring (FOARAM) Act of 2009.

Synopsis of current ocean acidification-relevant research or work:

The Northeast Fisheries Science Center (NEFSC) follows the priorities established by the NOAA ocean acidification implementation team 1) monitoring, 2) ecosystem response, 3) modeling, 4) data synthesis, 5) human dimensions and 6) outreach (Feely et al. 2010). Monitoring efforts were started with developing baseline data collected during MARMAP (1977-1978) and continue with comparative data collected on the EcoMon seasonal surveys in 2010. Further data will be collected on the NEFSC's trawl surveys with the installation of pCO2 sensors on the R/V Bigelow. Modeling approaches will use this information to assess effects on species, system-level productivity and ecosystem structure and function. Research began with developing and implementing experimental protocols and identifying priority species based on their potential vulnerability to ocean acidification. A broad research effort is currently directed toward several taxa including phytoplankton, shellfish and fish. Our fish research will be directed to early life history stages that are more vulnerable to environmental stresses. Commercially important calcareous species (shellfish) were chosen because of their economic value and because these species are likely to suffer direct effects of reduced $CaCO_3$ availability. Planktonic species, representing both calcifying and non-calcifying groups and several diatoms are focal species as they are the basis of most marine productivity. Identification of taxa that are likely to be "winners" under projected OA scenarios and how these taxa could modify trophic structure has fundamental implications to fishery production.

In FY 2010, analytical ocean acidification laboratories and experimental systems were established at the Milford, CT and Sandy Hook, NJ in order to match expertise resident at each laboratory (e.g., fish culture at the Sandy Hook and phytoplankton and shellfish culture at Milford). Experiments were conducted at the Milford laboratory on a phytoplankton monoculture and preliminary work was done to determine the pH of blue crab hemocytes. A NMFS-wide ocean acidification meeting was held August 30-September 1, 2010 in Seattle to communicate research results and plans and foster further collaborations among the three northern NMFS science centers (Alaska, Northwest and Northeast) which have a joint research proposal in place.

Related information:

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_X_ Observations & Monitoring
_X_ Physiological Responses
_X_ Ecology & System Responses
_X__ Biogeochemistry & Modeling

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Research Interests:

My research interests focus mainly on the physiological response of marine organisms subjected to significant variation of one or more abiotic factors. My lab is currently addressing how organisms have adapted to cope with both acute perturbations, which can often be measured through changes in regulation of gene expression, and persistent environmental changes, frequently marked by changes at the level of protein function. We are currently focusing on the genomic response of marine invertebrates to environmental perturbations and seasonal changes in habitat temperature, oxygen levels and environmental pH. By analysis of these pathways, we aim to better understand how stress-response pathways, cellular energy demands, and cell-cycle control integrate to determine the limits of physiological plasticity.

Synopsis of current ocean acidification-relevant research or work:

In this collaborative project, titled *"Identifying adaptive responses of polar fishes in a vulnerable ecosystem"* (NSF ANT-1040945, Antarctic Organisms and Ecosystems; co-PI J. Dudycha), we are combining approaches from the fields of organismal physiology, functional genomics, and evolutionary biology in order to assess the impacts of global climate change on a vulnerable ecosystem. We are currently examining the interacting and potentially synergistic influence of two oceanographic features –ocean acidification and the projected rise in mean surface seawater temperatures– on the performance of a dominant faunal group of the Antarctic ecosystem, fishes of the suborder Notothenioidei. Using both field and laboratory-based approaches, we will examine the combined impacts elevated temperature and a high CO_2 environment will have on the metabolic oxygen demand, acid/ base homeostasis, and the capacity to mount an effective cellular stress response of an important group of fishes that have displayed incredibly narrow physiological limits in previous single stressor studies.

Given the propensity for both adaptive and potentially mal-adaptive traits found among these organisms, and their narrow physiological limits, this system provides a unique opportunity to examine physiological trade-offs associated with acclimation to a multi-stressor environment consistent with future atmospheric CO_2 projections. As an extension of the functional measurements, this study will use evolutionary genetics as a means to map variation in physiological responses onto the phylogeny of these fishes in order to gain insight into the potential for adaptation for fishes inhabiting specific niches.

This research is just beginning, and our first field season is scheduled for October 2011.

Related information:

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1__ Physiological Responses
_2__ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests: I am interested in monitoring carbon parameters in the Hudson-Raritan Estuary and the Mid-Atlantic Bight to provide baseline data as well as to determine current variability (e.g. daily and seasonally). I am especially interested in cataloging the carbon parameters of cold pool water from formation to dissipation and of coastal upwelling along the New Jersey coastline.

Synopsis of current ocean acidification-relevant research or work: At the present time, I am leading the effort to establish a regional ocean acidification laboratory at Sandy Hook. I am also assisting colleagues (Phelan,Chambers and Wieczorek) at Sandy Hook with creating experimental systems to test the effects of ocean acidification on marine organisms. Over the past year, the laboratory at Sandy Hook has acquired the equipment, supplies, and expertise necessary to measure seawater pH, dissolved inorganic carbon, and alkalinity. The current focus is on increasing measurement efficiency and sample throughput. An experimental system that can provide 5 CO_2 and 5 temperature treatments has also been constructed and is currently being tested.

Related information:

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_2_ Observations & Monitoring
___ Physiological Responses
_3_ Ecology & System Responses
_1_ Biogeochemistry & Modeling

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Research Interests:

Our research focuses primarily on ecology of coral reef benthic communities, population dynamics and physiology of corals and macroalgae, and their eco-physiological response to local and global human stressors. Coral reef ecosystems are incredibly biologically diverse and productive marine ecosystems but are also severely threatened as large declines in live coral cover have been documented in both the Pacific and the Caribbean basins. On local or regional scales overfishing, pollution, sedimentation and disease outbreaks are believed to affect the composition of reef communities ultimately leading to a reduction in live reef-building coral and reef-cementing coralline algae and an increase in the abundance of fleshy turf or macroalgae. Globally increases in sea surface temperature and subsequent coral bleaching has resulted in massive coral mortality events around the world. Other global stressors such as increasing storm frequency and intensity, sea level rise and ocean acidification are also expected to have detrimental effects on coral reef ecosystems in the coming decades. Numerous studies have examined the independent effects of many of these stressors using experiments and observations but we know much less about how resilient reefs are to ocean acidification.

Synopsis of current ocean acidification-relevant research or work:

Our current research seeks to examine the feedbacks between benthic algae and corals and their natural chemical environment in intact ecosystems (PI J. Smith, T. Martz, F. Rohwer, S. Sandin. R. Brainard). We are working in the remote Line Islands of the Central Pacific, with the largest efforts concentrated on Palmyra Atoll, to relate community structure on the reef floor with natural spatio-temporal variability in carbonate chemistry within the boundary layers where biological activity (i.e. respiration, photosynthesis, and calcification) is occurring. Daily fluctuations in pH and dissolved oxygen have been constrained for 8 months and the amplitude of the diurnal variation and daily mean is site-dependent and may be related to water depth, irradiance, physical oceanography, and community assemblage (photo-autotrophs vs. mixotrophs or autotrophs) in the immediate area. Likewise, net calcification rates measured on out-planted plates at these sites is strongly positively correlated with daily pH. This research was conducted on consecutive research cruises, the first supported by NOAA and the second by the Scripps Institution of Oceanography and San Diego State University, which just returned in November 2010; select data are presented in the slides.

Another research project focuses on the physiological responses of key reef building calcifying algae (and their fleshy competitors for space) to global warming and ocean acidification using mesocosm studies (PI J. Smith, S. Hamilton). This research explores changes in growth, photophysiology, calcification, morphology, and mineralogy in response to rising temperatures and CO_2 enrichment. The project's working hypothesis is that carbon-limited algae exposed to high-CO_2 marine conditions would benefit from enhanced photosynthesis and productivity, whereas calcifying algae (e.g. coralline algae and *Halimeda*) would experience reduced calcification rates as a consequence of lowered calcium carbonate saturation states. Thus far, this project has shown that algae have species-specific responses to CO_2-caused acidification, although most calcified species respond negatively while some fleshy species (e.g. Caulerpa) have increased productivity.

Related information:

Martz, T., N. N. Price, G. Hoffman. Perturbation time of the marine CO_2 system. *Geophysical Research Letters*. In Review.

Price, N. N., S. Hamilton, J. Tootell, J. E. Smith. Species-specific consequences of ocean acidification for the calcareous tropical green algae *Halimeda*. *Marine Ecology Progress Series*. In Review.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_3_ Observations & Monitoring
_2_ Physiological Responses
_1_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My work focuses on identifying, evaluating, and developing approaches to address ocean acidification (OA) and climate change under the Clean Water Act 303(d) program. The goal of the Clean Water Act (CWA) is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Section 303(d) of the CWA and its implementing regulations (40 CFR 130.2 and 130.7) establish the Listing and Total Maximum Daily Load (TMDL) programs. These programs are primarily State-led with oversight from the U.S. Environmental Protection Agency (EPA). States, Territories, and authorized Tribes are required to develop lists of "water-quality limited segments" every two years (e.g. 2010, 2012). These 303(d) lists include segments that do not meet their applicable water quality standard (WQS), which could include a water quality criteria (WQC) for a particular pollutant (e.g., pH) and/or a designated use (e.g., fishable), even after technology-based CWA permit requirements are in place. The CWA also requires States to develop a pollutant "budget," or TMDL, for every water body/pollutant combination on their 303(d) list. Both the 303(d) lists and the TMDLs are approved by EPA.

To list a coastal water segment impaired by OA on the 303(d) list, States need data showing that an applicable WQS is not being met. Currently, the majority of coastal States only have marine pH WQC to assess OA and it usually includes a natural condition provision (e.g., pH shall not be changed at any time more than 0.2 units from that which occurs naturally). I am interested in identifying and evaluating techniques that can determine past and present pH levels for 303(d) listing. Also, I am interested in collaborating with other programs, such as the NOAA National Data Buoy Center, to create a National database that is searchable by State, monitoring program, and parameter (e.g., pH), with easy data access options. Such a database would help improve States' efforts to locate and solicit external OA-related data for assessment and 303(d) listing purposes.

Synopsis of current ocean acidification-relevant research or work:

I am currently identifying and tracking OA-related monitoring and research efforts that could be useful to States for future 303(d) listing of OA-related impairments. I am also investigating methodologies, such as models and remote sensing, that could provide data on past, present, or future OA-related assessment parameters, particularly marine pH. I am also involved with projects that are using atmosphere-ocean general circulation models (AOGCM) and regional climate models (RCM) in combination with watershed models to project future delivery of different pollutants. Currently, these projects focus on projecting future temperature, precipitation, flow, and pathogen loadings within freshwater systems, but they could also be used to estimate carbon deposition in marine systems. In doing so, these models could potentially assist with future OA assessment efforts for 303(d) listing and the development of "carbon" TMDLs for any waters listed as a result of OA-related impairments.

Related information:

Ruf, C., Reichert, J.M., Strebler, N., Lewicki, C., Kleine, J., King, A., and Hanley, E. 2011. Ocean Acidification and the Clean Water Act 303(d) Program. *In* Proceedings of the Impaired Waters Symposium 2011, Miami, FL, 12-13 January 2011. Water Environment Federation, Alexandria, VA 22314. pp. 47-72.

US EPA. 2010. Integrated Reporting and Listing Decisions Related to Ocean Acidification. Memorandum from Denise Keehner, Director, Office of Wetlands, Oceans, and Watersheds, Washington, D.C., November 15, 2010. Available at: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/oa_memo_nov2010.cfm.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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Research Interests:

I am a marine geologist in the Department of Marine Sciences at UNC – Chapel Hill. My research is focused on investigating global changes in the temperature and chemistry (carbonate chemistry, Mg/Ca ratios, red-ox state) of the oceans, and how these changes have impacted the viability and evolution of calcifying marine organisms. I explore these relationships over both geological and human timescales (Precambrian to future). My basic approach is to combine field studies with complementary laboratory experiments, which enables me to directly explore how changes in oceanic state have impacted marine calcifiers throughout the geologic past, and to predict how they will impact these organisms in the near future. This inherently interdisciplinary research draws from the fields of paleoceanography, paleobiology, carbonate sedimentology, carbonate geochemistry, isotope geochemistry, and biomineralization.

Ocean acidification constitutes one of the greatest chemical changes that the oceans will face over the coming centuries. The fossil and sedimentological records also provide compelling evidence that ocean acidification has played an important role in the evolution of marine calcifiers and carbonate sediments throughout the geologic past. Because of its dual relevance over both future and ancient timescales, ocean acidification has become an important focus of my research program in global oceanic change.

Synopsis of current ocean acidification-relevant research or work:

- Investigating the effects of $CaCO_3$ saturation state & temperature on the calcification rate and skeletal properties of benthic calcifiers (funded by NSF BIO-OCE #1031995)
- Geochemical and petrographic investigation of a novel calcite-aragonite sea transition in terminal Proterozoic time (funded by American Chemical Society #50214-DNI8)
- Reconstructing the impact of thermo-chemical changes in Carribbean seawater on coral extension rates over the past century
- Developing the $\delta^{11}B$-seawater pH proxy in various marine calcifiers
- Direct and indirect chemical analysis of the calcifying media of marine calcifiers

Related information:

Castillo, K.D., Ries, J.B., Weiss, J.M., 2010, Declining coral skeletal extension for forereef colonies of Siderastrea siderea on the Mesoamerican Barrier Reef System. PLoS ONE, 6 (2): e14615. PDF

Ries, J.B., Cohen, A.L., McCorkle, D.C., 2010, A nonlinear calcification response to CO_2-induced ocean acidification by the coral *Oculina arbuscula*, Coral Reefs 29: 661-674. PDF

Ries, J.B., Cohen, A.L., McCorkle, D.C. 2009. Marine calcifiers exhibit mixed responses to CO_2-induced ocean acidification. Geology, 37 (12):1131-1134. PDF

http://www.unc.edu/~jries/index.html

Meeting scientific themes relevant to this research:

_2_ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1_ Physiological Responses
_4_ Ecology & System Responses
_3_ Biogeochemistry & Modeling

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727 803-8747 x3005

Research Interests:

Much of my research career has focused on carbon in its various forms and I have been interested in how organic and inorganic carbon plays a role in the formation of $CaCO_3$, how organisms can transform carbon into its different forms and the "fingerprint" left behind in $CaCO_3$ shells etc., and carbon sequestration. Recently, my research has focused on carbon and carbon fluxes in seawater, specifically on the West Florida shelf and Arctic and how this information can provide insight into these quickly changing ecosystems.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects, titled "Response of Florida Shelf Ecosystems to Climate Change" (USGS with collaborators: P. Knorr, R. Byrne, X. Liu, D. Gledhill, K. Daly, P. Coble, C. Smith, K. Yates and J. Kleypas) has three OA relevant tasks: 1) "Monitoring and modeling Florida shelf carbonate chemistry", 2) "Effects of increased CO_2 on calcification and carbonate sediment contributions of *Halimeda* and larger foraminifera", and 3) "Changing conditions in Florida shellfish beds". The first task has focused on collecting high resolution seawater carbon data to set a baseline for further investigations on the shelf ecosystem. During the first two years, in collaboration with R. Byrne and X. Liu, we had three cruises that used the multiparameter inorganic carbon analyzer (MICA) flow- through system, developed by USF. Data were collected ~ every 2 min, providing over 1900 records each cruise. This year, in collaboration with Kendra Daly, we will be collecting data approximately every other month on alternate track lines. These cruises are providing information on evaluating spatial and temporal variability of carbon fluxes and carbonate saturation state on the shelf. The second project task is a laboratory study to look at how changes in pCO_2 and saturation state affect test ultrastructure in two prolific carbonate sediment producers living on the Florida shelf. This project is being lead by my USF Ph.D. student Paul Knorr, who will be defending in 2012. The third project task focuses on Florida estuaries and evaluates 25-30 years of historical water quality data from shellfish beds. Working with the State of Florida Department of Agriculture and Consumer Affairs, we are specifically looking at how pH, temperature, and salinity have changed in the estuaries as a response of changes in atmospheric CO_2 and other variables. Finally, Joanie Kleypas and I just finished a "mini project" within this project, in which we made "CO2calc", a user friendly seawater carbon calculator that can be used on PC, Mac, or iPhone. This program allows for large batch processing, which is particularly useful for analyzing the MICA data from this project and the Arctic project (see next project).

Another research project, titled "Arctic research related to ocean acidification" (USGS Co-PI K. Yates, collaborators: J. Lisle, R. Byrne, X. Liu, P. Knorr) is in its second year. This research is focused on acquiring high resolution carbon chemistry of the Arctic Ocean (Beaufort Sea/Canada Basin) to, among other goals, determine the spatial variability of saturation state and pCO_2 air-sea flux. Using the MICA (see above), over 25,000 samples of pH, TCO_2, and pCO_2sw were measured along a track line of approx 9300km. Similar to the subtropical project on the West Florida Shelf, we are also interested in delineating the controls of the saturation state, air-sea flux, and investigating their spatial variability. In 2011 we will collect data during a 7-week cruise within the Canada Basin.

I am a senior scientist at the USGS-St. Petersburg, where there are three other "groups" of scientists within my office working on ocean acidification issues.

Related information:

For information and publications see: http://coastal.er.usgs.gov/flash and http://coastal.er.usgs.gov/ocean-acidification/
For downloads of CO2calc: http://pubs.usgs.gov/of/2010/1280/

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
__X_ Observations & Monitoring
__X Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Ecologist; Senior Litigation and Policy Analyst
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202-566-1220

Research Interests:

Under the authority of the Clean Water Act Section 303(d) program, I am working to develop tools and methods that States and EPA Regions can use to assess and monitor ocean acidification (OA) impacts and, in the future, work on approaches to develop "carbon" pollution plans (TMDLs). I am also working with other EPA Offices (Air and Climate Office; Office of Research and Development) to apply output from national climate models to predict the water quality pollutant consequences of carbon-driven precipitation and temperature changes at the watershed scale. In the future we are hoping to include OA modeling and impacts. As part of assessing the impacts of OA, I am interested in helping States develop, identify and apply biological measures of OA impairment, including development of biocriteria. I am also interested in ways to encourage States to focus their efforts on OA-vulnerable waters (e.g., waters with coral reefs, marine fisheries, shellfish resources) that already are listed for other pollutants (e.g., nutrients) in order to promote ecological restoration.

Synopsis of current ocean acidification-relevant research or work

The goal of the Clean Water Act (CWA) is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Section 303(d) of the CWA and its implementing regulations (40 CFR 130.2 and 130.7) establish the Listing and Total Maximum Daily Load (TMDL) programs.   States are required to develop "lists" of "water-quality limited segments" every two years that will not meet water quality standards for a particular pollutant ("impaired water"). Currently, about 40,000 waters are listed nationwide as impaired, but only a handful are listed for OA impacts. I was the lead author of EPA's November 15, 2010 Memorandum describing how States and EPA Regions can move forward, where information exists, to assess coastal waters for OA water quality impairments (see http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/oa_memo_nov2010.cfm). I am working on identifying ways to develop more detailed listing guidance based on future OA research that provides States the basis for improved monitoring and assessment methods, and information/data from other Federal and academic efforts.   Finally, I am working with EPA Air & ORD Offices to apply national climate models to predict the water quality pollutant consequences of carbon-driven precipitation and temperature changes at the watershed scale, and am hoping to incorporate OA modeling and impacts in future scenarios.

Related information:

Ruf, C., Reichert, J.M., Strebler, N., Lewicki, C., Kleine, J., King, A., and Hanley, E. 2011. Ocean Acidification and the Clean Water Act 303(d) Program. *In* Proceedings of the Impaired Waters Symposium 2011, Miami, FL, 12-13 January 2011. Water Environment Federation, Alexandria, VA 22314. pp. 47-72.

US EPA. 2010. Integrated Reporting and Listing Decisions Related to Ocean Acidification. Memorandum from Denise Keehner, Director, Office of Wetlands, Oceans, and Watersheds, Washington, D.C., November 15, 2010. Available at: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/oa_memo_nov2010.cfm.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_X__ Observations & Monitoring
___ Physiological Responses
_X__Ecology & System Responses
X_ Biogeochemistry & Modeling

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Research Interests:

My research interests lie in the realm of zooplankton ecology and fisheries oceanography. I have been studying the population dynamics of planktonic copepods, particularly in the genus *Calanus*. I have also been involved in research on the biological and physical factors influencing recruitment into harvested marine fish and invertebrates. Overarching questions related my ocean acidification research are: (1) is the planktonic copepod, *Calanus finmarchicus*, a keystone species in marine food webs of the Gulf of Maine? (2) What are the contributions of advective transport and local production in sustaining this species in coastal waters of the northwest Atlantic? and (3) Will anticipated changes due to climate forcing result in effective disappearance *C. finmarchicus* in the Gulf of Maine, where it is at the southern edge of its subarctic range?

Synopsis of current ocean acidification-relevant research or work:

While attention concerning impacts of predicted acidification of the world's oceans has focused on calcifying organisms, non-calcifying plankton may also be vulnerable. With support from a recent NSF ocean acidification award, we will evaluate the potential for impacts of ocean acidification on the reproductive success of three species of planktonic copepods in the genus *Calanus* that are prominent in high latitude oceans. *C. finmarchicus* dominates the mesozooplankton biomass across much of the coastal and deep North Atlantic Ocean. *C. glacialis* and the larger *C. hyperboreus* are among the most abundant planktonic copepods in the Arctic Ocean. Preliminary results in our laboratory indicate that hatching success of *C. finmarchicus* is substantially reduced at increased seawater CO_2 concentrations corresponding to pH levels between 7.9 and 7.5. Predictions of likely decline of surface pH levels to 7.7-7.8 over the next century raise questions about impacts on *Calanus* population dynamics if these preliminary results are confirmed. *C. finmarchicus*, for example, is presently at the southern edge of its range in the Gulf of Maine. We will collect *C. finmarchicus* females from the Gulf of Maine and, with the assistance of Canadian colleagues, *C. glacialis* and *C. hyperboreus* females from the deep lower St. Lawrence Estuary. We will conduct laboratory experiments in which hatching success, development and growth of *Calanus* nauplius stages are measured in controls of natural seawater and at a series of treatments in which CO_2 concentrations, pH and temperature are rigorously controlled to represent possible future states of the northern ocean. We will measure present surface and deep pCO_2 and pH across the Gulf of Maine, including its deep basins, during a research cruise. We will evaluate the hypothesis that predicted levels of CO_2 increase in the northern ocean will impact population dynamics of the *Calanus* species. Using the results from the research cruise and a recently developed 1-D, Individual-Based life cycle model, we will explore in detail scenarios of impact of higher temperature and lower surface and deep pH on population dynamics of *C. finmarchicus* in the Gulf of Maine.

Related information:

Johnson, C., J. Runge, A. Bucklin, K. A. Curtis, E. Durbin, J. A. Hare, L. S. Incze, J. Link, G. Melvin, T. O'Brien and L. Van Guelpen. 2011. Biodiversity and ecosystem function in the Gulf of Maine: pattern and role of zooplankton and pelagic nekton. PLoS One. 6: 1-18.

Runge, J.A., S. Plourde, P. Joly, E. Durbin and B. Niehoff. 2006. Characteristics of egg production of the planktonic copepod, *Calanus finmarchicus,* on Georges Bank: 1994-1999. Deep-Sea Res. II. 53: 3618-2631.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_X_ Observations & Monitoring
_X_ Physiological Responses
_X_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My broad research interests are in the fields of biological oceanography, marine plankton ecology, plankton physiology, and marine biogeochemical cycling, with focus on how climate change impacts these processes. Specifically, I am interested in the effects of ocean acidification on plankton community composition, food web dynamics, and carbon and nitrogen cycling. My research goals are to determine how increased carbon dioxide (CO_2) affects: 1) viral, bacterial, phytoplankton, and zooplankton biomass and community structure, 2) rates of algal photosynthesis and nitrogen uptake and incorporation, 3) carbon fixation enzyme activity (i.e., RuBisCO, PEPC, CA activity), and 4) zooplankton feeding, respiration, and nutrient excretion rates. I aim to expand on my past and current research and continue to challenge myself to initiate diverse, multidisciplinary ocean acidification projects in order to answer large-scale questions with ecological, physiological, and biogeochemical implications.

Synopsis of current ocean acidification-relevant research or work:

Currently, I have been conducting a combination of laboratory and field experiments to determine the effects of increased CO_2 on plankton communities and biogeochemical cycling in the Western Antarctic Peninsula (WAP) region. This season, my team conducted two, 14-day mesocosm experiments at Palmer Station (for seasonal comparison) and one mesocosm experiment during the Palmer LTER cruise in January. In an additional cruise experiment, Antarctic krill (*Euphausia superba*) were incubated with natural plankton assemblages acclimated to variable CO_2 concentrations to determine effects of increased CO_2 on krill feeding, nutrient excretion rates, and metabolic enzyme activity. In the laboratory at Rutgers University, I am overseeing the senior honors thesis projects of two undergraduate students, which will determine effects of increased CO_2 on the growth, nutrient utilization, and physiology of multiple Antarctic algal cultures including *Phaeocystis antarctica* and a variety of diatoms.

In an upcoming project, for which we are currently in the process of securing funding, I am in collaboration with geo-engineering company Atmocean, Inc. to place wave-driven upwelling pumps in the coastal Mid-Atlantic Bight during periods of strong stratification to stimulate phytoplankton blooms. There are increasing pressures to utilize coastal systems with a variety of geo-engineering initiatives that range from extracting energy, harvesting biological resources, and sequestering atmospheric carbon in the ocean. The ultimate goals of this project are to promote bloom formation and identify (on a cellular level) the genetic/enzymatic triggers of phytoplankton competitive exclusion due to fluctuations in nutrient supply, monitor bottom up forcing through multiple trophic levels, quantify potential CO_2 sequestration during long-term utilization of this technology, determine ecological side effects of artificial upwelling, and finally weigh those advantages or disadvantages with relevance to environmental, economical, and societal issues.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_3_ Physiological Responses
_1_ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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206-526-4809

Research Interests:

My research addresses the role of the ocean in the global carbon cycle. In particular, my work centers on interpreting ocean inorganic carbon measurements and understanding the geochemical aspects of ocean acidification. This includes understanding the air-sea exchange of CO_2 at the ocean surface, examining the basin-scale distributions of both natural and anthropogenic carbon in the ocean's interior, understanding multiple tracer relationships (e.g. anthropogenic CO_2 and dissolved oxygen), evaluating ocean carbon cycle GCMs with data-based global carbon distributions, and examining carbonate and organic matter re-mineralization within the open ocean and in coastal environments.

Synopsis of current ocean acidification-relevant research or work:

The overarching goal of the NOAA Ocean Acidification Research Program is to monitor the trends in ocean acidification, to predict how ecosystems will respond to chemical changes brought on by burning fossil fuels and to provide information that managers can use to address acidification issues. The existing global oceanic carbon observatory network of repeat hydrographic surveys, time-series stations (ship-based and moored) and ship-based underway surface observations in the Atlantic, Pacific and Indian Oceans provide a strong foundation of carbonate chemistry observations to begin addressing the problem of ocean acidification.

I am working with a number of colleagues to develop an ocean acidification observational network by enhancing the capabilities of existing autonomous analytical systems to measure two carbon parameters and related ancillary parameters. Ocean acidification moorings are being deployed in three types of environments: open-ocean, coastal waters and near coral reefs. We are also developing new sensors for these moorings, including a robust moored dissolved inorganic carbon sensor. We are integrating pCO_2 and pH sensors into a wave powered autonomous surface vehicle (carbon wave glider) that will allow us to make ocean acidification measurements in places that are difficult to reach with conventional vessels. This network of observations will provide a better understanding of the time and space scales of variability in ocean carbon chemistry and biology and provide the observational basis for developing predictive models for future changes in ocean acidification and its consequences for marine ecosystems.

I am also part of the open-ocean and coastal survey efforts, coral reef calcification studies and several other collaborative efforts to measure ocean acidification. I am a member of the OCB scientific steering committee and the Interagency Working Group on Ocean Acidification (IWGOA) established by the Joint Subcommittee on Ocean Science and Technology (JSOST). Finally, I am a coordinating lead author on chapter 6 (Carbon and Biogeochemistry) of the working group 1 IPCC 5th assessment report, which includes sections on ocean acidification.

Related information:

For more information visit our website at: http://www.pmel.noaa.gov/co2/

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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Research Interests:

I study plankton food web dynamics, microbial ecology and biogeochemical cycling. I am interested in how natural and anthropogenic processes (i.e. ocean acidification) impact eukaryote diversity, plankton trophic dynamics and subsequently biogeochemical cycling. To address these research questions I employ molecular (i.e. DNA-fingerprinting techniques, qPCR) combined with traditional methods (microscopy & culture) in laboratory-based experimental trials and in the field.

Synopsis of current ocean acidification-relevant research or work:

Our project is entitled "Experimental studies to understand and evaluate acclimation of marine plankton assemblages to increased CO_2 and temperature" (NSF OCE 0962309; co-PIs D.Caron, D. Hutchins and F. Fu). Our ability to predict specific responses is somewhat limited because of the tremendous taxonomic complexity of microbial assemblages and the limitations of the methodological and experimental tools presently available to test specific hypotheses. Research to study community level effects due to a changing CO_2/temperature regime often involve short-term field incubations that subject organisms to simulated 'greenhouse' conditions. A central question for understanding global climate change is whether the trends and patterns that are observed in communities during short-term manipulations can be extrapolated to the responses of fully acclimated plankton communities over decadal or longer timescales.

Our specific project objectives are 1) to examine how protistan communities restructure in response to increased seawater CO_2 concentrations and temperature in semi-continuous field incubation experiments; 2) to evaluate if the dominant algal species that are isolated from either ambient or increased CO_2 and temperature treatments in our field experiments will re-establish dominance under the same conditions in acclimated laboratory culture competition studies.

Changes in community structure of natural protistan assemblages in our experimental treatments are followed using image-based methods (i.e. microscopy) in combination with state-of the art molecular tools (DNA fingerprinting). We hypothesize that change in CO_2 and temperature selects for some algal members that are inconspicuous under ambient conditions (members of the 'rare biosphere'). The unique aspect of our experimental approach is the combined use of field incubations that encompass entire natural microbial assemblages, with a series of laboratory culture competition trials that focus on the same groups of algae after extended acclimation, to evaluate the validity of short-term experiments that examine changing CO_2 and temperature. We just started our second field season and have at this time successfully completed field and lab trials with dinoflagellate-dominated communities from Southern Californian waters.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
3__ Physiological Responses
1__ Ecology & System Responses
2__ Biogeochemistry & Modeling

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(301)-286-9891

Research Interests:

My research focuses primarily on ecosystem dynamics and carbon cycling research in the high latitude regions of the North Atlantic using a combination of numerical models, satellite data, and *in situ* measurements. I am also interested in the role that phytoplankton dynamics have in the seasonal and interannual variability of carbon in the ocean. Primary questions motivating this research include: 1) what are the relative roles of advection and enhanced regional uptake on the storage of anthropogenic CO_2; 2) what is the impact of different phytoplankton functional groups on the seasonal uptake of atmospheric CO_2; 3) what are the major physical and biological driving mechanisms for the seasonal, interannual, and decadal variations of surface ocean pCO_2 and sea-air CO_2 flux? Can accurate satellite-based algorithms of surface ocean pCO_2 be developed for these oceanic regions; and 4) what is the predicted impact of anthropogenic and climate-driven (e.g., NAO, AMO) biogeochemical and carbon cycle changes in the regional primary production and fisheries. With this research I seek to determine how the long-term predicted ocean carbon changes impact on ocean acidification (pH, calcite/aragonite saturation states).

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects, titled “Assessment and Impact of Carbon Variability in the Nordic Seas” (10-CARBON10-9, NASA ROSES-2010, Program Element A.5: Carbon Cycle Science; co-PIs C. R. McClain, S. Häkkinen, A. Olsen, A. Omar, I. Skjelvan, M. Chierici, J. Olafsson, N. Metzl, and G. Reverdin) seeks to examine the physical-biogeochemical interactions that alter the ocean carbon uptake in the Nordic Seas, and its impact on ocean acidification. This research has just started and benefits from previous carbon study with our European co-investigators in the subpolar North Atlantic (SPNA).

Related information:

Signorini, S. R., et al., 2011. The role of phytoplankton dynamics in the seasonal variability of carbon in the subpolar North Atlantic – A modeling study. Accepted by *Geoscientific Model Development* as a discussion paper.

Olsen, A., et al., 2011. Changes in intermediate water masses drive decadal changes in the carbon sink and ocean acidification in the surface Subpolar North Atlantic, 1994-2004. Manuscript in preparation.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_2__ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_1__ Biogeochemistry & Modeling

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Research Interests:
My research focuses on understanding the physiological mechanisms of stress tolerance in marine organisms and the role of energy homeostasis – a fundamental requirement for survival and stress tolerance – in these mechanisms. Marine mollusks are excellent models for these studies due to their metabolic flexibility, abundance and important role in estuarine and coastal ecosystems. I investigate the effects of environmental stressors (including ocean acidification, temperature, pollution and hypoxia) on bioenergetics of marine mollusks, with an emphasis on interactive effects of multiple stressors under the environmentally realistic scenarios. These studies have broad implications for stress physiology and environmental research because stress-induced disturbance of energy homeostasis determines limits for both short-term and long-term survival of organisms and their populations and provides common ground for understanding and integrating responses to a variety of environmental stressors regardless of their nature.

Synopsis of current ocean acidification-relevant research or work:
One of my current research projects (NSF IOS-0951079 "LiT: Effects of Temperature and Elevated CO_2 Levels on Biomineralization and Metabolic Physiology of Marine Bivalves", co-PI Dr. Elia Beniash, University of Pittsburgh) explores the effects of elevated temperature and CO_2 levels on biomineralization, growth and energy metabolism of three common bivalve species with different shell mineralogy - eastern oysters (*Crassostrea virginica*), hard shell clams (*Mercenaria mercenaria*) and blue mussels (*Mytilus edulis*) with calcitic, aragonitic and mixed shells, respectively. The goals of this research are to: 1) determine the effects of elevated CO_2 and temperature on shell formation, chemical composition, mineralogy, structural and mechanical properties in three selected mollusk species; 2) measure the expression of biomineralization-related genes in response to elevated temperature and CO_2 levels; and 3) determine the effects of high CO_2 and temperature on survivability, growth and metabolic physiology of juveniles and adults of these species. This study will elucidate the potential mechanisms involved in temperature- and CO_2-induced modulation of physiology and biomineralization of mollusks, advance our understanding of the sensitivity of several key bivalves species – the major calcifiers in estuarine and coastal ecosystems of the eastern United States – to ocean warming and acidification, and support scientifically-based assessment of the consequences of global climate change in marine ecosystems.

Related information:
Beniash E., Ivanina A., Lieb N.S., Kurochkin I., Sokolova I.M. 2010. Elevated levels of carbon dioxide affect metabolism and shell formation in oysters *Crassostrea virginica* (Gmelin). *Mar Ecol Prog Ser* 419:95-108.

Tomanek L., Zuzow M.J., Ivanina A.V., Beniash E., Sokolova I.M. 2011. Proteomic response to elevated P_{CO2} level in eastern oysters *Crassostrea virginica*: evidence for oxidative stress. *J Exp Biol* (accepted).

Lannig G., Eilers S., Pörtner H.O., Sokolova I.M., Bock C. 2010. Impact of ocean acidification on energy metabolism of oyster, *Crassostrea gigas* – Changes in metabolic pathways and thermal response. *Marine Drugs 8*(8), 2318-2339.

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1__ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My current research focus is on characterizing the natural variability and global trends in coastal ocean carbon chemistry. Specifically, I am interested in using interdisciplinary approaches to explore how local and regional biogeochemical mechanisms drive variations in ocean carbon chemistry across time and space, with a particular interest in informing our understanding of ocean acidification impacts in ecologically and economically important systems such as coastal margins.

Synopsis of current ocean acidification-relevant research or work:

I am working with Drs. Richard Feely and Chris Sabine to expand our global CO_2 network by adding high-frequency pH and other biogeochemical sensors (O_2, chlorophyll, turbidity) to mooring platforms to better understand natural variability of ocean acidification over daily to seasonal cycles. We are now measuring ocean acidification chemistry on 5 moorings in coastal margins of the Pacific and Atlantic Oceans and the Gulf of Mexico and on 1 mooring in the open ocean. Initial data suggest $p$$CO_2$ and pH in the coastal systems is highly variable on short time scales (hours to days) and differs considerably between locations. The major goals of my postdoctoral research are to contribute to a better understanding of the temporal and spatial variability of ocean carbon chemistry and expand the observational basis for developing predictions of future changes in ocean acidification and its consequences for marine ecosystems.

I am also interested in how science can inform management and policy discussions. Between completing my PhD and starting a postdoctoral position, I worked in Washington DC as a Sea Grant Knauss Marine Policy Fellow and Congressional Affairs Specialist at NOAA for 3 years covering ocean and atmospheric research topics, especially climate change, addressed by the U.S. Congress. I was intimately involved in the effort to pass the Federal Ocean Acidification Research and Monitoring Act. I continue to pursue my interests in science policy and outreach through contributions to the NOAA Ocean and Great Lakes Acidification Research Plan and engaging in opportunities to share ocean acidification information with educators, students, and journalists.

Related information:

http://www.pmel.noaa.gov/co2/story/Strategy+for+OA+Observations

Feely, R.A., R. Wanninkhof, J. Stein, M.F. Sigler, E. Jewett, F. Arzayus, D.K. Gledhill, and A.J. Sutton (2010): NOAA Ocean and Great Lakes Acidification Research Plan. NOAA Special Report, April 2010, 143 pp.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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Research Interests:

For accurate characterization of global environmental changes, baseline information is needed. The purpose of this study is to provide a global surface ocean baseline for pH and ($CO_3^{=}$) concentration in surface waters of the global ocean computed in a single uniform pH scale using an extensive pCO_2, alkalinity and TCO_2 (=DIC) database observed for past several decades. This should serve as a reference level, against which the future and past changes may be referenced.

We have three decades of the pCO_2 and DIC data (Takahashi et al., 2009), which are based on David Keeling's (and successor Pieter Tans at ERL/NOAA) WMO manometric CO_2 standard, the well-calibrated alkalinity and DIC data from the WOCE program (Dickson, et al., 2003) and from the time-series stations including BATS, HOT and ESTOC. These data will allow establishment of a global ocean pH and ($CO_3^{=}$) baseline anchored firmly to the international CO_2 standards common to the atmospheric and oceanic CO_2 measurements. The pCO_2 and DIC data obtained in different years will be corrected to a reference year 2000, and a climatological distribution of monthly mean pH in the "total hydrogen ion scale" and carbonate ion concentrations ($CO_3^{=}$) will be computed using the dissociation constants for carbonic and boric acids by Lueker et al. (2000) and Dickson (1990). This will serve as a world ocean baseline distribution for the characterization of future ocean acidification. In some data-rich areas of the North Atlantic, North Pacific and Southern Ocean, the rate of change may be determined.

Synopsis of current ocean acidification-relevant research or work:

Because of calibration problems associated with direct pH measurements, an observation-based global ocean pH distribution map is not possible; presently the information is based on ocean GCM studies without land interactions. Our analysis of the alkalinity data shows, however, that its distribution differs from the open oceans in the broad regions of land interactions such as the Bay of Bengal, Arabian Sea, Gulf of Alaska and Bering Sea. The distribution of alkalinity is further complicated by lateral and vertical mixing of water types. Using the alkalinity, TCO_2 and pCO_2 data, regionally and seasonally resolved distributions of pH, $CO_3^{=}$ and saturation levels of aragonite and calcite are computed. Over the global oceans, the pH (in the total H^+ scale) varies from 7.95 to 8.22, and in high latitude waters, the pH varies seasonally by as much as 0.15. The aragonite saturation level drops from 450% in tropical warm waters to near saturation in high-latitude waters in winter.

Related information:

Takahashi, T. et al. (2009). Climatological mean and decadal changes in surface ocean pCO_2, and net sea-air CO_2 flux over the global oceans. Deep-Sea Res. II, doi: 10.1016/j.dsr2.2008.12.009.

Le Quéré, C., Takahashi, T., Buitenhuis, E. T., Rodenbeck, C. and Sutherland, S. C. (2010). Impact of climate change and variability on the global oceanic sink of CO_2, Global Biogeochem. Cycles, 24, GB4007, doi:10.1029/2009GB003599.

LDEO database is available at <http://www.ldeo.columbia.edu/res/pi/CO2/>

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_1_ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_2_ Biogeochemistry & Modeling

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Research Interests:
Our research interests are to characterize present-day pH and DO regimes in coastal upwelling ecosystems and place the observed variability in the context of marine organism pH and DO exposure histories with particular emphasis on invertebrate larvae. Our ultimate goals are to integrate natural variability with anthropogenically driven pH changes to produce more robust predictions regarding larval exposure and sensitivity to recent pH and DO trends.

Synopsis of current ocean acidification-relevant research or work:

The Levin Lab currently has two NSF-funded ocean acidification research projects. The first, NSF-OCE 0927445 (PI: Lisa Levin; co-PI: Todd Martz), is entitled "Macrophyte-induced variability in coastal ocean pH and consequences for invertebrate larvae." The main objective of this project is to address the interplay between anthropogenically driven pH changes and the inherently variable coastal ocean, and directly test the implications for invertebrate larvae. In order to characterize the carbonate chemistry of the inherently variable coastal ocean we are conducting a series of autonomous sensor deployments with the use of SeapHOx packages (DO, pH, T, S, pressure). The observed natural variability is being incorporated into laboratory and *in situ* transplant experiments to test how pH and DO levels, variability regimes, and physiologically-relevant thresholds affect the health of marine invertebrate larvae.

The second project, NSF-OCE 1040162 (PI: Lisa Levin and Ariel Anbar (ASU); co-PI: Achim Herrmann (ASU) and Gwyneth Gordon (ASU)), is entitled "Development of geochemical proxies to evaluate larval pH-exposure history." The focus is on proxy development to determine pH exposure history for living organisms in their larval state. Mytilid mussel species and market squid larvae will be exposed to known pH, DO and temperature conditions through laboratory rearing experiments and *in situ* outplanting of lab-spawned larvae. Analyses of carbonate shells or statoliths will be conducted with SIMS ($\delta^{11}B$), multicollecter ($\delta^{44}Ca$, $\delta^{238}U$) and laser ablation (B, Cu, U, Pb, Mo) ICP-MS in order to identify pH-induced signatures and to determine species or taxon-specific vital effects. The retention of larval shell and statoliths after recruitment may ultimately allow us to test the importance of larval pH and O_2 exposure to subsequent survival and population persistence.

Related information:
http://levin.ucsd.edu/
http://martzlab.ucsd.edu/data.html
http://osprey.bco-dmo.org/project.cfm?flag=view&id=130&sortby=project

Meeting scientific themes relevant to this research:
_1__ Paleo & Proxies/Modeling
_2__ Observations & Monitoring
___ Physiological Responses
_3__ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

My research focuses on understanding the physiological consequences of ocean acidification for deep-sea animals. Deep-sea animals have evolved in a relatively stable biochemical environment, and are subject to minimal diel and seasonal changes in water chemistry, compared to shallower marine ecosystems. Thus, deep-sea animals are suspected to be highly sensitive to environmental acidification. Our lab group at MBARI, headed by Jim Barry, is primarily interested in how varying degrees of environmental hypercapnia affect deep-sea animals (1) metabolically, (2) enzymatically/ biochemically, (3) structurally, (4) nutritionally, and (5) developmentally. Secondarily, we are interested to make comparisons of deep-sea animals to their shallower-water relatives; how do their physiological responses to environmental acidification differ? We will ultimately use our findings to predict larger-scale ecosystem effects.

Synopsis of current ocean acidification-relevant research or work:

Our lab group is right now focused on the deep-sea urchin *Allocentrotus fragilis*. We have developed a Benthic Respirometer System (BRS) as a collaborative project amongst a team of MBARI engineers and scientists, led by Jim Barry. The BRS allows us to measure oxygen consumption of these animals in situ. Furthermore, this system allows a treatment (CO_2-saturated seawater, or hyperoxic seawater, thus far) to be pumped into the eight experimental chambers. A variety of complementary lab-based studies using a gas-controlled aquarium system (Barry et al. 2008) are underway, and we have recently completed a detailed time-course of blood acid-base chemistry over a month-long exposure, similar to that done for the deep-sea crab *Chionoecetes tanneri* in our lab (Pane & Barry 2007, Pane et al. 2008). Results show *A. fragilis* to have very limited physiological ability to compensate for the systemic acidosis brought on by environmental acidification. The mechanisms responsible for this limitation include insufficient ionic regulation ability, and low blood buffering capacity.

Related information:

Barry, J.P., Lovera, C., Okuda, C., Nelson, E., Pane, E. (2008). A gas-controlled aquarium system for ocean acidification studies. IEEE Xplore, 978-4244-2126-08/08

Pane, E.F., Grosell, M., Barry J.P. (2008). Hypercapnic tolerance of deep- and shallow-living crabs. Aquatic Biology, 4: 23-32.

Pane, E.F., Barry, J.P. (2007). Inefficient acid-base regulation in the deep-sea decapod crab (*Chionoecetes tanneri*) during short-term hypercapnia. Mar. Ecol. Prog. Ser., 334:1-9.

MBARI's Benthic Ecology Lab: http://www.mbari.org/benthic/

MBARI scientists will be involved in the Third International Symposium on the Ocean in a High CO_2 World, taking place in Monterey, CA in late September 2012. http://www.highco2-iii.org/

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_3_ Observations & Monitoring
_1_ Physiological Responses
_2_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

Our research attempts to characterize the physiological responses of marine organisms to acute and chronic environmental stress. In our studies we integrate the responses to these stresses at several levels of biological organization, ranging from gene transcript and protein at the molecular level to growth and aerobic performance at the organismal level. Our research teams, involving Dr. J. Stillman's lab of San Francisco State University and our lab at Cal Poly, have studied the physiological responses of marine crustacean and mollusk species to thermal stress, hypercapnia and ocean acidification. Our work aims at characterizing the molecular changes and how they affect whole organism performance in order to predict how future climate change may affect populations.

Synopsis of current ocean acidification-relevant research or work:

Our current research project, titled "Synergistic effects of temperature and pH variability on physiology, transcriptome and proteome of porcelain crabs," (NSF CRI-OA 1041227; co-PIs J. Stillman and L. Tomanek) studies the physiological responses of larvae and adult porcelain crabs to a range of constant and fluctuating temperatures as well as pH values. Currently we are rearing larvae under various combinations of temperature and pH.

In a recent publication, we presented our findings of the proteomic response of eastern oysters *Crassostera virginica* to hypercapnic conditions that are typical for estuaries during the summer (Tomanek et al., 2011). The levels of P_{CO2} were higher than they are predicted to occur in the open ocean within a century, nevertheless it was the first time a proteomic comparison was conducted on marine organisms exposed to prolonged exposure to high P_{CO2}. Our findings suggest that hypercapnia causes increasing levels of oxidative stress. Our work on the proteomic response of mussels of the genus *Mytilus* to acute heat stress suggests that the production of reactive oxygen species (ROS) induced by environmental stress causes a switch in metabolism from pro-oxidant NADH- to ROS-scavenging NADPH-producing pathways (Tomanek and Zuzow, 2010). We hypothesized that these changes are due to post-translational modifications of enzymes involved in energy metabolism, which we have now confirmed.

A major focus of our lab is to analyze the proteomes of marine organisms in response to environmental stress. We are collaborating with several other groups to apply proteomics to other questions in ecological physiology (Tomanek, 2011).

Related information:

Tomanek, L. (2011). Environmental proteomics: Changes in the proteome of marine organisms in response to environmental stress, pollutants, infection, symbiosis and development. *Ann Rev Marine Sciences* **3**, 373-399.
Tomanek, L. and Zuzow, M. J. (2010). The proteomic response of the mussel congeners *Mytilus galloprovincialis* and *M. trossulus* to acute heat stress: implications for thermal tolerance and metabolic costs of thermal stress. *J Exp Biol* **213**, 3559-3574.
Tomanek, L., Zuzow, M. J., Ivanina, A. V., Beniash, E. and Sokolova, I. M. (2011). Proteomic response to elevated P_{CO2} level in eastern oysters *Crassostrea virginica*: evidence for oxidative stress. *J Exp Biol* **in press**.

Lab website: http://www.calpoly.edu/~bio/EPL/index.html

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
_1_ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests:

I do not conduct research, but I am involved in promoting global cooperation among ocean scientists to advance ocean science worldwide. My organization is involved in all areas of ocean science. Apart from managing the organization, I spent a great deal of my time on the issues of ocean acidification, data publication, and capacity building.

Synopsis of current ocean acidification-relevant research or work:

My work related to ocean acidification involves serving as the lead staff person for the two past and one planned symposia on The Ocean in a High-CO2 World, and the PI on the NSF grant for the planned symposium, scheduled for 24-27 September 2012. I will present a few slides showing the program for the symposium, the topics, and speakers who have agreed to make presentations in the plenary sessions.

Related information:

Symposium Web site: www.highco2-iii.org

Meeting scientific themes relevant to this research:

_1__ Paleo & Proxies/Modeling
_1__ Observations & Monitoring
_1__ Physiological Responses
_1__ Ecology & System Responses
_1__ Biogeochemistry & Modeling

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Research Interests:
My interests are focused on bivalves in coastal and estuarine habitats and include:

- Mechanisms of bivalve responses to changing carbonate chemistry
- Natural variability of systems versus tolerances of organisms
- The role of oyster reefs in estuarine carbonate chemistry
- Controls on mineral and organic components of biocalcification
- Linking population models and carbonate chemistry models

Synopsis of current ocean acidification-relevant research or work:

I am leading a newly NSF funded project to measure the response of several marine bivalves (of different shell mineralogy and nativity) in response to changes in individual carbonate system parameters. Although we know that increased acidity is detrimental to larval and post-larval bivalves, we currently lack an in depth understanding of what components of the carbonate system are affecting these organisms. Utilizing a unique experimental system, my colleagues and I will expose bivalves to unique combinations of carbonate parameters to tease apart whether, for example, pH or mineral saturation state is affecting several measures of growth and survival.

I am currently completing work on a previously funded NSF project examining the interaction between sediment carbonate chemistry and newly settled marine bivalves. With Mark Green we have measured shell growth, mortality, and recruitment dynamics in response to sediment carbonate chemistry and I am currently working on parameterizing a stage-based population model to link the measured life history traits to sediment carbonate chemistry conditions of the sediments where these organisms are found.

Related information:

Waldbusser GG, Bergschneider H, Green MA (2010) Size-dependent pH effect on calcification in post-larval hard clam *Mercenaria spp*. Mar Ecol-Progr Ser 417:171-182

Waldbusser GG, Voigt EP, Bergschneider H, Green MA, Newell RIE (2010) Biocalcification in the eastern oyster (*Crassostrea virginica*) in relation to long-term trends in Chesapeake Bay pH. Estuaries and Coasts DOI: 10.1007/s12237-010-9307-0

Green, MA, GG Waldbusser, SL Reilly, K Emerson, S O'Donnell (2009) Death by dissolution: Sediment saturation state as a mortality factor for juvenile bivalves. Limnol Oceanogr 54:1037-1047.

<u>In Review or Preparation</u>

Kelly, RP, MM Foley, WS Fisher, RA Feely, BS Halpern, GG Waldbusser, MR Caldwell (Submitted) Mitigating local causes of ocean acidification with existing laws.

Green, MA, GG Waldbusser, L Hubazc, E Cathcart, J Hall. (in revision) Carbonate mineral saturation state as a recruitment cue for settling bivalves in marine muds.

Waldbusser, GG and MA Green (in prep) Linking populations and sediment carbonate chemistry: A case study of *Mercenaria spp*.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
__X_ Physiological Responses
__X_ Ecology & System Responses
_X_ Biogeochemistry & Modeling

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Marine Chemistry and Geochemistry
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Research Interests:

My research focuses on the carbonate (CO_2) system in rivers and coastal oceans. Under the global climate change and Ocean Acidification, these systems are experiencing rapid changes. My long-term research goal is to understand how these global changes are going to affect dissolved inorganic carbon (DIC), CO_2, and alkalinity (Alk) fluxes to and from these systems, and how the changes in these inorganic carbon fluxes in turn would affect the global carbon cycle and the climate. This line of research is often limited by scarce long-term CO_2 system measurements in rivers and coastal oceans and rivers. My current research is motivated to primarily focus on: 1) Improving our observing capacity by developing in-situ sensor technology to measure the carbonate system parameters (pH, DIC, pCO$_2$, and Alk) on fixed (e.g. buoys) and mobile (e.g. AUVs) platforms; 2) Establishing long-term time series measurements of the carbonate system in many river systems around the globe; 3) Studying effects of Ocean Acidification on marine chemistry and biology in natural environments.

Synopsis of current ocean acidification-relevant research or work:

My current ocean acidification research is titled 'Horizontal and Vertical Distribution of Thecosome Pteropods in Relation to Carbonate Chemistry in the Northwest Atlantic and Northeast Pacific' (NSF OCE 1041068; PI: G. Lawson; co-PIs P. Wiebe, Z.A. Wang, and A. Lavery). Thecosome pteropods form an aragonite (i.e., calcium carbonate) shell and are thus highly sensitive to the water column's changing carbonate chemistry under ocean acidification, and particularly to the shoaling of the 'aragonite compensation depth' at which seawater becomes corrosive to aragonite. Through survey work employing a suite of sophisticated devices to sample pteropods and carbonate chemistry simultaneously, our project will capitalize on present-day variability in the aragonite compensation depth within and between the Atlantic and Pacific Oceans as a 'natural experiment' to address the hypothesis that pteropod vertical distribution, species composition, and abundance vary as the compensation depth becomes shallower; in this way, we seek to use current spatial differences in ocean chemistry to understand the likely impacts of future changes predicted to occur under continued ocean acidification.

Related information:

Wang, Z. A. et al. (2011). Distributions of the marine CO_2 system along the US Atlantic and Gulf of Mexico coast. *To be submitted*.

Wang, Z. A. et al. (2007). Simultaneous spectrophotometric flow-through measurements of pH, carbon dioxide fugacity, and total inorganic carbon in seawater. *Analytica Chimica Acta* **596**: 23-36.

Wang, Z. A. et al. (2005). The southeastern continental shelf of the United States as an atmospheric CO2 source and an exporter of inorganic carbon to the ocean. *Continental Shelf Research* **25**: 1917-1941.

Wang, Z.A. and Cai, W.J. (2004). Carbon dioxide degassing and inorganic carbon export from a marsh-dominated estuary (the Duplin River): A marsh CO2 pump. *Limnology and Oceanography* **49**: 341-354.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
_√_ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
___ Biogeochemistry & Modeling

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305-361-4379

Research Interests:

My main interest is ocean carbon cycle research with focus on quantifying the uptake of anthropogenic CO_2 by the world's ocean. The research has a strong observational emphasis with involvement in the CLIVAR/CO2 repeat hydrography survey, and the NOAA "CO_2 on ships of opportunity" program. The former is focused on decadal repeat transects in all major ocean basins to determine natural and man-induced changes in the ocean. The latter involves 6 partners maintaining automated CO_2 instrumentation on 17 research and merchant ships to determined spatial and temporal changes in surface water pCO_2.

The data has been instrumental to determine decadal changes in anthropogenic CO_2 inventories and to improve the estimates of air-sea CO_2 fluxes. This has involved several data synthesis efforts including CARINA (CARbon IN the Atlantic) for sub-surface data, and the Surface Ocean Carbon Atlas (SOCAT) for the global surface water pCO_2 data.

Synopsis of current ocean acidification-relevant research or work:

As part of the ocean acidification efforts sponsored by the NOAA Climate Program Office we are starting an ambitious monitoring project to determine variability and trends in surface CO_2 levels in the coastal ocean along the Gulf Coast and East Coast of the USA. The project involves academic and NOAA investigators. Our specific component is focused on determining spatial trends from autonomous equipment on ships. The core measurements are the underway pCO_2 observations but they are being augmented with a suite of biogeochemical sensors (e.g. O_2, nitrate, and pH) to elucidate the controls of surface water CO_2/pH levels. The ships include several NOAA fisheries vessels involved in stock assessments offering the opportunity to relate possible impacts of ocean acidification on higher trophic levels.

Related information:
Pertinent websites:
AOML ocean carbon and ship of opportunity data: http://www.aoml.noaa.gov/ocd/gcc/index.php
AOML CO2 flux map graphical interface:
http://cwcgom.aoml.noaa.gov/erddap/griddap/aomlcarbonfluxes.graph
CARINA data site: http://cdiac.ornl.gov/oceans/CARINA/
SOCAT information: http://ioc3.unesco.org/ioccp/SOCAT

Meeting scientific themes relevant to this research:
___ Paleo & Proxies/Modeling
1. Observations & Monitoring
___ Physiological Responses
3. Ecology & System Responses
2. Biogeochemistry & Modeling

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Research Interests:

How does altered pCO_2 impact the cellular physiology and ecology of microalgae, including different endosymbiotic dinoflagellates (*Symbiodinium* spp.), species responsible for harmful algal blooms (e.g. raphidophytes and dinoflagellates), and species involved in nitrogen fixation (e.g. *Trichodesmium*). Beyond the microalgae, I am also interested in how ocean acidification impacts the physiology, ecology and biogeochemistry of reef building corals, and the role of potential interactive impacts of combined physical changes due to climate change (e.g. elevated CO_2 and temperature).

Synopsis of current ocean acidification-relevant research or work:

My most current research project, "Collaborative research–Ocean Acidification Category 1: Interactive effects of temperature, nutrients, and ocean acidification on coral physiology and calcification" (NSF 104090; co-PIs Andrea Grottoli, and Wei-Jun Cai) is designed to first investigate the combined impact of ocean acidification and thermal stress on several species of Pacific corals in a controlled laboratory setting. The second goal of this project is to investigate how elevated nitrogen and phosphorus may alleviate or exacerbate the noted impacts of CO_2 and temperature noted in the initial part of the project. Research tools in this project will include the assessment of coral energy reserves and metabolic demand, symbiotic algal diversity and physiology, coral calcification, as well as direct measurement of the internal coral pH and carbonate concentration via microprobes, and seawater chemistry.

Related information:

Brading, P., Warner, M.E., Davey, P., Smith, D.J., Achterberg, E.P., and D.J. Suggett. 2011. Differential effects of ocean acidification on growth and photosynthesis among phylotypes of *Symbiodinium* (Dinophyceae). Limnology and Oceanography. In press.

Meeting scientific themes relevant to this research:

___ Paleo & Proxies/Modeling
___ Observations & Monitoring
__1_ Physiological Responses
_2__ Ecology & System Responses
__3_ Biogeochemistry & Modeling

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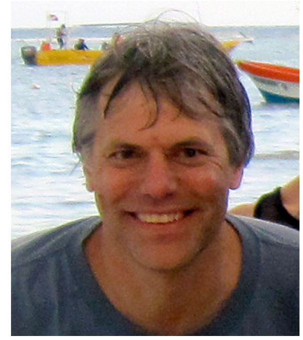

Research Interests (Tim Wootton):

My research focuses generally on understanding and predicting the effects of environmental impacts (including ocean acidification) on natural ecosystems characterized by complex networks of interactions. This work includes implementing field experiments to better understand indirect effects in ecological communities, developing methods to estimate the strengths of interactions among species, and applying/experimentally testing dynamic models of ecosystems. A central activity in this program has been to develop extensive (18 yr) time series of multi-species dynamics in parallel with measurements of local oceanic conditions (11 yr) to facilitate model development using ecosystem dynamics.

Synopsis of current ocean acidification-relevant research or work:

Our recent discovery of a sustained, rapid decline in ocean pH, and associated changes in species dynamics, has prompted Cathy Pfister (U. Chicago) and me to further investigate these patterns. Our activities address several areas: 1) More thoroughly characterizing the DIC/pH/TA at our site and extending the time series *[pH continues to decline rapidly; our initial pH measures are consistent with spectrophometric pH/DIC/TA]*. 2) Characterizing pH levels over larger spatial scales *[similar low pH values and rapid regional declines]*. 3) Assembling time series of multiple physical/chemical variables relevant to test causal hypotheses for rapid pH decline *[popular explanations-- upwelling, freshwater input, acid precipitation, and DOC input --are not supported]*. 4) Exploring whether similar changes have occurred historically by using the unique resources available at our site--Makah tribe middens (up to 2300 yr bp) and researcher-archived material (up to 40 yr bp) *[mussel shells are up to 50% thinner now compared 1000-2300 years ago and exhibit unprecedented changes in $d^{13}C$ (-0.71 / 11 yr), but not $d^{18}O$, as pH has declined; ongoing studies of trace/rare earth elements]*. 5) Developing functional links between pH / temperature change and detailed species replacement dynamics from the multi-species time series dataset to identify key action points of pH and predict long term consequences for species composition in a framework that incorporates species interactions *[species replacements associated with pH declines; predicted shifts in dominance from large calcifiers to fleshy algae; species removal changes functional relationships; hence understanding/predicting effects of pH decline in ecosystems must incorporate species interactions]*. 6) Guided by ecosystem change with declining pH we see in nature (#5), we are doing targeted experiments to probe underlying mechanism. We are repeating "classic" field experiments at our site under current low pH conditions, and implementing lab experiments manipulating pCO_2. One project is focusing on coralline algae performance and interactions with competitors and grazers, lead by graduate student Sophie McCoy. *[Other projects will explore interactions among calcifying consumers and their calcified or non-calcified prey, and the role of pH on byssal thread attachment strength].*

Related information:

http://woottonlab.uchicago.edu, http://pfisterlab.uchicago.edu

Wootton, J. T., Pfister, C. A., Forester, J. D. 2008. Dynamical patterns and ecological impacts of ocean pH in a high-resolution, multi-year dataset. *Proceedings of the National Academy of Science* 105:18848-18853.

Meeting scientific themes relevant to this research:

__4_ Paleo & Proxies/Modeling
__2_ Observations & Monitoring
__5_ Physiological Responses
__1_ Ecology & System Responses
__3_ Biogeochemistry & Modeling

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Research Interests:

My research focuses on measuring in situ rates of benthic community productivity, calcification, and carbonate sediment dissolution relative to changing seawater chemistry resulting from increased atmospheric CO_2, *in situ* perturbation experiments to quantify the effects of ocean acidification on these processes, and measurement of carbonate system parameters in coastal and marine ecosystems. Understanding the impact of climate change and ocean acidification on the balance between community processes is critical for predicting the potential resiliency and fate of coastal and marine ecosystems. My work spans from the tropics to the Arctic Ocean. Primary questions motivating this research include: 1) what are current and past rates of community production and calcification/dissolution in coastal ecosystems, 2) what are the pCO_2, $[CO_3^{2-}]$, and mineral saturation state thresholds for biogenic calcification and dissolution, 3) will coral reefs be able to keep up with rising sea level in the face of increased atmospheric CO_2, and 4) what is the range of variation (diurnal, seasonal, and spatial) in carbonate system parameters in coastal and marine ecosystems.

Synopsis of current ocean acidification-relevant research or work:

One of my current research projects, titled “Coral reef community calcification and metabolism” provides baseline community calcification rates, carbonate sediment accumulation rates, and the first *in situ* measurements of pCO_2 and $[CO_3^{2-}]$ thresholds for calcification and dissolution in Florida Bay, Biscayne National Park, the U.S. Virgin Islands, Hawaii, and Puerto Rico. Results indicate that considerable carbonate sediment dissolution is already occurring in many coastal ecosystems. Measured dissolution thresholds are consistent with dissolution thresholds determined in laboratory and modeling studies, and sediment accumulation rates in many locations are not keeping up with sea level rise. We are currently in the process of measuring historical coral growth and calcification rates in coral cores from these locations and reconstructing historical seawater pH from the pre-industrial period to present through use of boron isotopes (collaborator R. Moyer, USGS Mendenhall Fellow) for comparison to modern rates.

A second element of my project provides baseline data on diurnal variation in coastal carbonate system parameters in these same locations and in Tampa Bay, Dry Tortugas, Bahamas, and Tobago. Results indicate the biological, chemical, and physical controls on diurnal variation; and that the diurnal range of variation can exceed the seasonal range, and may exceed the annual range in open marine systems.

Another research project titled “Arctic Ocean Acidification” is focused on acquisition of high-resolution (spatial and temporal) measurement of carbonate system parameters, air:sea pCO_2 gas fluxes, and basic seawater chemistry throughout the Arctic Ocean (co-PI, L. Robbins, USGS). We completed our first 5-week field expedition and collected a high-resolution data set of over 25,000 measurements along 10,000 kilometers of track lines in the Arctic Ocean. Preliminary results show the spatial variation in seawater carbonate system parameters and carbonate mineral saturation states, and the effect of ice cover on pCO_2 concentration and CO_2 gas flux.

Related information:

Yates, K.K. and Moyer, R.P. 2010. Effects of ocean acidification and sea-level rise on coral reefs. U.S. Geological Survey Fact Sheet 2010-3091, http://pubs.usgs.gov/fs/2010/3091/ . **Robbins, L.L., Yates, K.K., Feely, R., and Fabry, V.J.** 2010. Monitoring and assessment of ocean acidification in the Arctic Ocean: a scoping paper. U.S. Geological Survey Open-File Report 2010-1227, http://pubs.usgs.gov/of/2010/1227/ . Other references are available from http://coastal.er.usgs.gov/ocean-acidification/ and http://coastal.er.usgs.gov/crest/research-themes/community-metabolism.html .

Meeting scientific themes relevant to this research:

__4_ Paleo & Proxies/Modeling
__2_ Observations & Monitoring
___ Physiological Responses
__3_ Ecology & System Responses
__1_ Biogeochemistry & Modeling

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Research Interests:

My research focuses primarily on 1) past (paleo) ocean acidification events and impacts on planktonic and benthic foraminifera and other marine calcifiers, and 2) the calibration of proxies. In particular, I am interested in the nature and consequences of extreme ocean acidification during the Paleocene-Eocene Thermal Maximum (PETM; 55 Mya), as well as less severe episodes of acidification during the Eocene.

Synopsis of current ocean acidification-relevant research or work:

A current project (NSF OCE- 0903014, co-investigators; Richard Zeebe, Bärbel Hönisch, and Ellen Thomas) is designed to quantify the changes in ocean pH and $[CO_3^{2-}]$ during the PETM. The project is utilizing B based proxies of these two parameters as recorded in planktonic and benthic foraminifera from deep sea cores. Both B isotopes and B/Ca are being measured in foraminifer shells. We are also calibrating B/Ca in modern representative and descendents of the species of benthic foraminifers that were common in the Eocene. The data will be used to test simulations of changes in saturation state, particularly of the surface ocean for which there are currently no quantitative estimates of acidification. The best fit simulations of the acidification event suggest as much as a 50% reduction in omega in the surface ocean.

A second related project (multi-institutional/investigator Biocomplexity project) has documented the scale and rate of acidification and subsequent recovery during the PETM. We found that 4500-6000 Pg C was released over a period of <10 k.y. resulting in massive shoaling of the CCD. Recovery took well over 100 k.y. and involved a phase of oversaturation.

Related information:

Bowen, G.J. and J.C. Zachos, 2010, Rapid carbon sequestration at the termination of the Paleocene-Eocene thermal maximum. Nature Geosciences. doi:10.1038/ngeo1014

Zeebe, R.E., J. C. Zachos & G. R. Dickens, 2009, Carbon dioxide forcing alone insufficient to explain Palaeocene–Eocene Thermal Maximum warming. Nature | doi:10.1038/ngeo578.

Zachos, J. C., U. Röhl, S. A.Schellenberg, A. Sluijs, D. A. Hodell, D. C. Kelly, E. Thomas, M. Nicolo, I. Raffi, L. J. Lourens, H. McCarren, D. Kroon, 2005, Rapid Acidification of the Ocean During the Paleocene-Eocene Thermal Maximum. Science, v.308, p.1611-1615.

http://www.es.ucsc.edu/personnel/Zachos/index.html

Meeting scientific themes relevant to this research:

_1_ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
_2_ Ecology & System Responses
___ Biogeochemistry & Modeling

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Research Interests: Ocean Acidification: Past, present, future. Seawater CO2 chemistry, Carbon cycle modeling, biogeochemistry, paleo-proxies, past carbon cycle and climate perturbations, fossil fuel neutralization, carbon sequestration, sediment dissolution,

Synopsis of current ocean acidification-relevant research or work:

- National Science Foundation. "Early Detection of Ocean Acidification Effects on Marine Calcification and Deep-Sea Carbonate Dissolution." NSF: OCE07-51959, PI: Zeebe, R. E., 03/2008-02/2012.
- National Science Foundation. "Collaborative Research: Reconstructing deep sea acidification during the Paleocene-Eocene Thermal Maximum." NSF: OCE09-02869. (4 Institutions), PIs: Zachos, JC, Hoenisch, B, Thomas, E, Zeebe, RE. 07/2009-06/2011.
- National Science Foundation. "Collaborative Research: Dynamics of carbon release and sequestration; Case studies of two early Eocene hyperthermals." NSF: EAR06-28394 (10 Institutions), Zachos, JC, Zeebe, RE et al. 09/2006-03/2011.

Related information:

- Zeebe, R. E., J. C. Zachos, K. Caldeira, and T. Tyrrell, "Oceans: Carbon Emissions and Acidification", Science (Perspectives), p. 51, vol. 321 (2008).
- Ilyina, T., Zeebe, R.E., Maier-Reimer, E., Heinze, C., "Early Detection of Ocean Acidification Effects on Marine Calcification", Global Biogeochemical Cycles (2009).
- Ilyina, T., Zeebe, R.E., Brewer, P.G., "Future ocean increasingly transparent to low-frequency sound owing to carbon dioxide emissions", Nature Geoscience (2010).
- Zeebe, R. E. and J. C. Zachos., "Reversed deep-sea carbonate ion basin-gradient during Paleocene-Eocene Thermal Maximum.", Paleoceanography, PA3201, vol. 22 (2007).
- Zachos, J. C., G. R. Dickens, and R. E. Zeebe, "An early Cenozoic perspective on greenhouse warming and carbon-cycle dynamics.", Nature, p. 279, vol. 451, (2008).
- Zeebe, R. E., Zachos, J. C., and G. R. Dickens., "Carbon dioxide forcing alone insufficient to explain Paleocene-Eocene Thermal Maximum warming", Nature Geoscience (2009).
- Stuecker, M. F., and Zeebe, R. E, "Ocean chemistry and atmospheric CO2 sensitivity to carbon perturbations throughout the Cenozoic", Geophys. Res. Lett., p. , vol. 37, (2010).
- Uchikawa, J. and R.E. Zeebe, "Examining possible effects of seawater pH decline on foraminiferal stable isotopes during the Paleocene-Eocene Thermal Maximum", Paleoceanography, PA2216, vol. 25, (2010).
- Komar, N. and R. E. Zeebe, "Changes in oceanic calcium from enhanced weathering did not affect calcium-based proxies during the Paleocene-Eocene Thermal Maximum", Paleoceanography, in revision (2011).

Meeting scientific themes relevant to this research:
_1_ Paleo & Proxies/Modeling
___ Observations & Monitoring
___ Physiological Responses
___ Ecology & System Responses
_1_ Biogeochemistry & Modeling