Update Report

Period 2/1/2013 - 1/31/2014

Project R/OCEH-6 - Optical detection and characterization of pre-HAB populations of the fish-killing alga, Heterosigma akashiwo

STUDENTS SUPPORTED

Brugger, Sonia, sonia.brugger@yahoo.com, U.W., Oceanography, status new, field of study Oceanography, no advisor, degree type BS, degree date 2015-06-01, degree completed this period No Student Project Title Analysis of remotely sensed Heterosigma cell data Involvement with Sea Grant This Period Independent Undergrad Researcher Analyzed remote sensing data from the WSG-funded Heterosigma imager at American Gold Seafoods Post-Graduation Plans unknown
Coyle, Owen, ocoyle@uw.edu, University of Washington, Oceanography, status cont, field of study oceanography, advisor Grunbaum, degree type MS, degree date 2014-06-01, degree completed this period No Student Project Title Software and hardware development for low-cost in situ plankton imaging Involvement with Sea Grant This Period research assistantship Post-Graduation Plans faculty position
Katagirir, Colin, katagiri@ocean.washington.edu, U.W., Oceanography, status new, field of study Oceanography, no advisor, degree type BS, degree date 2014-06-01, degree completed this period No Student Project Title Life-stage transitions in Heterosigma cell cultures Involvement with Sea Grant This Period Independent Undergrad Researcher Cultured and observed Heterosigma cell cultures Post-Graduation Plans none
Pratt, Brendan, bkpratt@u.washington.edu, U.W., Oceanography, status new, field of study Oceanography, no advisor, degree type BS, degree date 2013-06-01, degree completed this period Yes Student Project Title Analysis of video data from underway protist sensors and ROV video feeds. Involvement with Sea Grant This Period Independent Undergraduate Researcher

Post-Graduation Plans none

Tobin, Elizabeth, etobin@u.washington.edu, University of Washington, Oceanography, status cont, field of study Algal biology, advisor Grunbaum, degree type PhD, degree date 2014-06-01, degree completed this period No
Student Project Title none

Involvement with Sea Grant This Period grad student (no salary support)

Post-Graduation Plans Faculty or government research position

CONFERENCES / PRESENTATIONS

Poster "Trait-based prediction of Harmful Algal Blooms Motility/demography tradeoffs in Heterosigma akashiwo". D. Grünbaum and Elizabeth Tobin. International Workshop on Trait-based approaches to Ocean Life, Royal Danish Academy of Science and Letters, Copenhagen, Denmark, public/profession presentation, 100 attendees, 2013-08-28
Invited seminar "Synergistic effects of memory and movement on population distributions of algae and fish." D. Grünbaum. Centre fpr Ocean Life, Danish Technical University, Charlottenlund, Denmark., public/profession presentation, 50 attendees, 2013-09-12
Invited seminar "Observations and modeling of temperature, light, and pH impacts on plankton movement Case studies from harmful algae and marine invertebrate larvae" D. Grünbaum. Advancement of Coupled Climate Ocean Ecosystem Models Group, KlimaCampus, University of Hamburg, Hamburg, Germany., public/profession presentation, 30 attendees, 2013-10-18
Invited seminar "Linking cognition and spatial memory to individual movements and population distributions." D. Grünbaum. Bristol Centre for Complexity Sciences, University of Bristol, Bristol, U.K., public/profession presentation, 50 attendees, 2013-11-05
Invited seminar "Observations and modeling of cell-level swimming in toxic phytoplankton Implications for Harmful Algal Bloom dynamics" D. Grünbaum. Aquatic Ecology Seminar, Department of Biology, Lund University, Lund, Sweden., public/profession presentation, 35 attendees, 2013-11-29
Invited talk "Scales of environmental change, environmental matching and the dynamics of phenotypic plasticity." D. Grünbaum and D. K. Padilla. Symposium A New Organismal Systems Biology How Animals Walk the Tightrope between Stability and Change. Soc. Integr. Comp. Biol. Annual Meeting, public/profession presentation, 50 attendees, 2014-01-05
Invited talk "Signs of movement Synergies of biomechanics, behavior and spatial ecology in ocean ecology applications." University of North Florida, public/profession presentation, 35 attendees, 2014-04-01

ADDITIONAL METRICS

K-12 Students Reached	Acres of degraded ecosystems restored as a result of Sea Grant activities
Curricula Developed	Resource Managers who use Ecosystem-Based Approaches to

Management

HACCP - Number of people with new certifications

Volunteer Hours

Cumulative Clean Marina Program - certifications

PATENTS AND ECONOMIC BENEFITS

No Benefits Reported This Period

TOOLS, TECH, AND INFORMATION SERVICES

No Tools, Tech, or Information Services Reported This Period

HAZARD RESILIENCE IN COASTAL COMMUNITIES

No Communities Reported This Period

ADDITIONAL MEASURES

Safe and sustainable seafood

Number of stakeholders modifying practices
Actual (2/1/2013 - 1/31/2014)
Anticipated (2/1/2014 - 1/31/2015)

Number of fishers using new techniques
Actual (2/1/2013 - 1/31/2014)
Anticipated (2/1/2014 - 1/31/2015)

Sustainable Coastal Development
Actual (2/1/2013 - 1/31/2014)
Anticipated (2/1/2014 - 1/31/2015)

Coastal Ecosystems
Actual (2/1/2013 - 1/31/2014)
Anticipated (2/1/2014 - 1/31/2015)

PARTNERS

Partner Name American Gold Seafoods
Partner Name Chief Kitsap Academy, type Academic Institution, scale Tribal
Partner Name Ocean Inquiry Project
Partner Name Quartermaster Harbor Yacht Club
Partner Name Rensel Associates Aquatic Sciences
Partner Name Society for Integrative and Comparative Biology
Partner Name University of Washington
Partner Name Wallingford Imaging Systems

IMPACTS AND ACCOMPLISHMENTS

Title Washington Sea Grant research develops a low-cost monitoring technology to detect harmful algae before it blooms

Type impact

Relevance, Response, Results Relevance The toxic algae Heterosigma and Alexandrium are common and costly sources of harmful algal blooms (HABs) in Puget Sound. Alexandrium, is a dinoflagellate whose toxin can accumulate in shellfish and cause paralytic shellfish poisoning in humans and other animals. Heterosigma is a microscopic raphidophyte that relies upon its vigorous swimming ability to aggregate into toxic blooms that kill fish and other marine life. Response Washington Sea Grant-funded researchers developed and deployed high-resolution, low-cost, low-power micro-imaging technology using embedded computers and high-definition cameras to detect, quantify and characterize swimming algal cells. The imagers can work autonomously, storing data onboard, or be integrated into sensor networks, streaming real-time data to an online server. Results In field tests, prototype imagers distinguished Alexandrium chains and quantified their abundance and swimming velocities. They enabled the team to publish new observations of Heterosigma cells emerging from sediment to water column. When conditions became supportive, resting cells could emerge and divide within hours, suggesting a tradeoff between swimming speed and efficient transition to the water column, both of which are metabolically demanding. The research team developed a numerical model based on this tradeoff that predicts the conditions under which different Heterosigma strains are likely to dominate HAB populations and under which no strains will likely bloom.

Recap WSG research develops new imaging technology for monitoring harmful Alexandrium and Heterosigma algae and a new model for predicting when and where Heterosigma will form HABs, substantially increasing the ability to prepare for harmful blooms.

Comments Primary Focus Area OCEH (SSSS) Secondary Focus Area OCEH (HCE), COCC (HRCC) Associated Goals Improve understanding and management of emerging and cumulative threats to ocean and coastal health (SSSS Supply). Improve understanding and management of emerging and cumulative threats to ocean and coastal health (HCE Science). Improve understanding of coastal hazards and environmental change and develop tools and approaches for observation, prediction, planning and adaptation (HRCC, Capacity).

Related Partners , , , , , ,

PUBLICATIONS

Title Ocean acidification induces budding in larval sea urchins.

Type Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year 2013 Uploaded File none URL none

Abstract Ocean acidification (OA), the reduction of ocean pH due to hydration of

atmospheric CO2, is known to affect growth and survival of marine invertebrate larvae. Survival and transport of vulnerable planktonic larval stages play important roles in determining population dynamics and community structures in coastal ecosystems. Here, we show that larvae of the purple urchin, Strongylocentrotus purpuratus, underwent high-frequency budding (release of blastula-like particles) when exposed to elevated pCO(2) level (> 700 mu atm). Budding was observed in > 50 % of the population and was synchronized over short periods of time (24 h), suggesting this phenomenon may be previously overlooked. Although budding can be a mechanism through which larval echinoids asexually reproduce, here, the released buds did not develop into viable clones. OA-induced budding and the associated reduction in larval size suggest new hypotheses regarding physiological and ecological tradeoffs between short-term benefits (e.g. metabolic savings and predation escape) and long-term costs (e.g. tissue loss and delayed development) in the face of climate change.

Citation Chan, K.Y.K, D. Grünbaum, M. Arnberg, M. Thorndyke, S. T. Dupont. 2013. Ocean acidification induces budding in larval sea urchins. Marine Biology. 160(8) 2129-35.

Journal Title Marine Biology

Title Silicic acid supplied to coastal diatom communities influences cellular silicification and the potential export of carbon.

Type Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year 2013 Uploaded File none URL none

Abstract Microcosm experiments were conducted along the Washington and Oregon coasts in May 2009, May 2010, and July 2010 to determine whether variation in the supply of silicic acid from the Columbia River could influence the silicification and sinking potential of coastal diatom blooms. The chlorophyll a concentration increased similarly in communities incubated with added nitrate or both nitrate and silicic acid, indicating that growth was limited by nitrate availability. Communities that grew in the treatment with added silicic acid and nitrate were more silicified than communities in the treatment with only nitrate added. No difference in community composition was detected between these treatments in three out of four experiments. Isolates of Minutocellus, Cylindrotheca, Thalassiosira, and Odontella were obtained from the microcosm experiment conducted in May 2010 and were maintained in the laboratory in 20 mmol L21 silicic acid. All four diatom isolates contained , 2.5 times more silica per cell when silicic acid concentration in the media was increased to 80 mmol L21. The intensity of a fluorescent cellular stain of newly precipitated silica (2-(4-pyridyl)-5{[4-dimethylaminoethyl-aminocarba- moyl)-methoxy]phenyl}oxazole) strongly correlated with silica content among species, but was a less sensitive indicator of changing silicification within a single species. Changes in silicification were not correlated with changes in the transcript abundance of silicic acid transporters. Sinking rates increased roughly 2-fold for cells that contained , 2.5 times more silica. Variation in silicic acid supply alters the silicification of nitrate-fueled coastal diatom blooms and the potential sink of

carbon from coastal zones.

Citation Durkin, C. A., S. J. Bender, K. Y. K. Chan, K. Gaessner, D. Grünbaum and E. V. Armbrust. 2013. Silicic acid supplied to coastal diatom communities influences cellular silicification and the potential export of carbon. Limnol. Oceangr. 58(5) 17-7-1726.

Copyright Restrictions + Other Notes

Journal Title Limnol. Oceangr.

Title Behavioral and physiological changes during benthic-pelagic transition in the harmful alga, Heterosigma akashiwo Potential for rapid bloom formation.

Type Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year 2013 Uploaded File none URL none

Abstract Many species of harmful algae transition between a motile, vegetative stage in the water column and a non-motile, resting stage in the sediments. Physiological and behavioral traits expressed during benthic-pelagic transition potentially regulate the timing, location and persistence of blooms. The roles of key physiological and behavioral traits involved in resting cell emergence and bloom formation were examined in two geographically distinct strains of the harmful alga, Heterosigma akashiwo. Physiological measures of cell viability, division and population growth, and cell fatty acid content were made using flow cytometry and gas chromatography – mass spectrometry techniques as cells transitioned between the benthic resting stage and the vegetative pelagic stage. Video-based tracking was used to quantify cell-level swimming behaviors. Data show increased temperature and light triggered rapid emergence from the resting stage and initiated cell swimming. Algal strains varied in important physiological and behavioral traits, including survivorship during life-stage transitions, population growth rates and swimming velocities. Collectively, these traits function as “population growth strategies” that can influence bloom formation. Many resting cells regained the up-swimming capacity necessary to cross an environmentally relevant halocline and the ability to aggregate in near-surface waters within hours after vegetative growth supporting conditions were restored. Using a heuristic model, we illustrate how strain-specific population growth strategies can govern the timescales over which H. akashiwo blooms form. Our findings highlight the need for identification and quantification of strain-specific physiological and behavioral traits to improve mechanistic understanding of bloom formation and successful bloom prediction.

Citation Tobin, E.. D, D. Grünbaum, J. Patterson and R. A. Cattolico. Behavioral and physiological changes during benthic-pelagic transition in the harmful alga, Heterosigma akashiwo Potential for rapid bloom formation. PLoS One 8(10) Article Number UNSP e76663

Copyright Restrictions + Other Notes

Journal Title P.L.o.S. One

Title Addressing Grand Challenges in Organismal Biology

Type Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year 2014 Uploaded File none URL none

Abstract Animals are complex systems operating at multiple spatial and temporal scales, facing challenges of how to "walk the tightrope between stability and change." Discovering the system-level attributes of organisms that make them resilient or robust, or conversely, sensitive or fragile, presents a grand challenge for biology. Knowledge of these attributes and the mechanisms underlying them is critically needed to predict how organisms will respond to short- and long-term changes in internal and external environments, including those driven by climate change. Organismal biologists require novel approaches that extend beyond traditional disciplinary boundaries, especially partnering with mathematicians and engineers. Pursuing this research enterprise will not only give us deeper understanding of how organisms will face future challenges, but it will also reveal nature-inspired solutions to stability and agility in complex engineered systems, both of which will benefit science and society.

Citation Padilla, D. K., T. L. Daniel, P. Dickinson, D. Grünbaum, C. Hayashi, D. T. Manahan, J. H. Marden, B. J. Swalla and B. Tsukimura. (in review) Addressing Grand Challenges in Organismal Biology. Integr. Comp. Biol.

Journal Title Integrative and Comparative Biology

Title An integrated modeling approach to assessing linkages between environment, organism and phenotypic plasticity

Type Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year 2014 Uploaded File none URL none

Abstract Many of the most interesting questions in organismal biology, especially those involving the functional significance of organismal characteristics, intrinsically transcend levels of biological organization. These organismal functions typically involve multiple interacting biological mechanisms. We suggest that current approaches to organismal biology are ill suited to investigations of organism functions that take advantage of new disciplinary knowledge by spanning diverse spatio-temporal scales, mechanisms and disciplines. Therefore, disciplinary advances have led to both the opportunity and the necessity to reintegrate disciplinary knowledge into a new understanding of the whole organism. We present a conceptual framework for a modeling approach that addresses organism function in an integrative way, incorporating elements from environments, populations, individuals, and intra-organism dynamics such as physiology and behavior. To give substance to our conceptual framework, we develop a focal case study involving phenotypic plasticity in the tooth morphology of snails in the genus Lacuna. We use this case study to illustrate ways in which questions about the evolution and ecology of organism function intrinsically span all these organizational levels. In this case and many others, quantitative approaches that

integrate across mechanisms and scales can suggest new hypotheses about organismal function, and provide new tools to test those hypotheses. Integrative quantitative models also provide roadmaps for the large-scale collaborations among diverse disciplinary specialists needed to gain deeper insights into organism function

Citation Grünbaum, D. and D. K. Padilla (accepted with revisions) An integrated modeling approach to assessing linkages between environment, organism and phenotypic plasticity. Integr. Comp. Biol.

Copyright Restrictions + Other Notes Accepted with Revisions

Journal Title Integrative and Comparative Biology

OTHER DOCUMENTS

No Documents Reported This Period

LEVERAGED FUNDS

Type influenced Period 2013-08-01 2013-11-30Amount $66201

Purpose Grant for Visiting Professorship, Centre for Ocean Life, Danish Technical University, Charlottenlund, Denmark

Source Velux Foundation

UPDATE NARRATIVE

Uploaded File Grunbaum_1240_update_n....8.pdf

This year's research focused on three objectives:

(1) We reconfigured and redeployed the Imaging Benthic Emergence trap (IBET) to make it easier to deploy, more capable, and more robust to field conditions. In particular, the new version has roughly twice the data-gathering capacity, and also is more effective in distinguishing cells already in the near-sediment water column from those emerging during the emergence trap deployment. The new IBET pioneers technological improvements that also enable us to miniturize the next-generation *Heterosigma* remote sensor.

(2) We published laboratory observations of *Heterosigma* cell emergence from resting stages. Surprisingly, cells in these experiments were able to transition into the water column and undergo cell replication within a few hours of exposure to light and warmth, the cues necessary to induce transition. The experiments, conducted by graduate student Liz Tobin, also showed that two strains of *Heterosigma* differed strongly in both swimming and transition efficiency, with one strain apparently having an advantage in swimming capability while the other had superior transition ability. This apparent trade-off inspired a new trait-based model of HAB initiation from resting stages. The model identifies conditions under which different strains – including the two strains observed in Tobin's experiments – can proliferate and which strain would likely dominate an incipient bloom.

(3) We deployed a prototype underway protist imager on the R/V Thompson during the Regional Scale Node engineering cruises in summer 2013. Both P.I. Grunbaum and graduate student Owen Coyle participated in those cruises. Among other milestones, we were able to conduct autonomous sampling over sustained periods of protists and small zooplankton in running seawater from the ships underway flow-through system (the same water as is used by the SeaFlow). This instrument, which shares the low cost and networkability of our other remote sensors, has potential to collect large-scale data of near-surface microplankton from ships of opportunity in many undersampled marine environments.