

## Update Report

### Grunbaum, Daniel

Period: 2/1/2012 - 1/31/2013

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

### :: STUDENTS SUPPORTED

**Chan, Karen**, unknown, University of Washington, Oceanography, status:cont, field of study:Oceanography, advisor:D. Grunbaum, degree type:PhD, degree date:2012-06-01, degree completed this period:Yes

Student Project Title:

Consequences of ocean change for ecological function: Observational and modeling case studies of larval echinoderms

Involvement with Sea Grant This Period:

partial funding from WSG (approximately 1.5 quarters); microscopy and biomechanical modeling of algal cell morphology and movement

Post-Graduation Plans:

currently post-Doc at WHOI seeking a faculty position

**Coyle, Owen**, ocoyle@uw.edu, University of Washington, Oceanography, status:new, 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

**Haak, Gabrielle**, haakg1@tcnj.edu, College of New Jersey, Biology, status:new, field of study:Biology, *no advisor*, degree type:BS, degree date:2014-05-01, degree completed this period:No

Student Project Title:

Environmental impacts on larval morphology and movement

Involvement with Sea Grant This Period:

Blinks Fellow at FHL in Summer 2012; received intensive mentoring on research and perspectives on grad school

Post-Graduation Plans:

grad school

**Rincon, John**, johnny.rincon@gmail.com, Washington University, Biology/Physics, status:new, field of study:Biology, *no advisor*, degree type:BS, degree date:2014-05-01, degree completed this period:No

Student Project Title:

Imager-based surveys of in situ plankton distributions

Involvement with Sea Grant This Period:

Blinks Fellow at FHL in Summer 2012; received intensive mentoring on research and perspectives on grad school

Post-Graduation Plans:

Graduate school or NGO

**Tobin, Elizabeth**, Liz Tobin , University of Washington, Ocean Sciences, 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:

Quantification of transitional swimming behaviors in harmful algae and their implications for pelagic and benthic distributions

Involvement with Sea Grant This Period:

key graduate student collaborator in field work, instrument development, ground truthing, data analysis and stakeholder communication; partially support by WSG funds, together with funding from projects leveraged off this project

Post-Graduation Plans:

Faculty or government research position

**Villalobos, Cristina**, cvillalobos@csumb.edu, CSU Monterey Bay, Marine Science, status:new, field of study:marine biology, *no advisor*, degree type:BS, degree date:2013-05-01, degree completed this period:No

Student Project Title:

Ocean acidification impacts on marine organisms

Involvement with Sea Grant This Period:

Blinks Fellow at FHL in Summer 2012; received intensive mentoring on research and perspectives on grad school

Post-Graduation Plans:

graduate school

## :: CONFERENCES / PRESENTATIONS

Oral conference presentation: Tobin, E., Grunbaum, D and Cattolico, R. A. Benthic-pelagic transitions in the harmful alga, *Heterosigma akashiwo*: Assessing the

influence of swimming behaviors and growth on bloom formation. 15th International Conference on Harmful Algae, Changwon, Korea, public/profession presentation, 75 attendees, 2012-10-30

Invited oral conference presentation: Chan, K.Y.K, Grünbaum, D. 2013. Assessing effects of starvation-induced morphological variations on swimming of larval sand dollars with a novel biomechanical model and video motion analysis at Society for Integrative and Comparative Biology Annual Meeting, San Francisco, CA., public/profession presentation, 75 attendees, 2012-01-06

Invited conference presentation: Grunbaum, D. Secondary characteristics of spatially and temporally heterogeneous populations, public/profession presentation, 75 attendees, 2012-04-19

Seminar: Grunbaum, D. Function follows form: Consequences of shape changes for larval swimming biomechanics., public/profession presentation, 100 attendees, 2012-05-04

## :: ADDITIONAL METRICS

**K-12 Students Reached:**

**Acres of degraded ecosystems restored as a**

	<b>result of Sea Grant activities:</b>
<b>Curricula Developed:</b>	<b>Resource Managers who use Ecosystem-Based Approaches to Management:</b>
<b>Volunteer Hours:</b>	<b>HACCP - Number of people with new certifications:</b>
<b>Cumulative Clean Marina Program - certifications:</b>	

**:: PATENTS AND ECONOMIC BENEFITS**

*No Benefits Reported This Period*

**:: TOOLS, TECH, AND INFORMATION SERVICES**

Description	Developed	Used	Names of Managers	Number of Managers
Imaging Plankton Emergence Trap for real-time remote monitoring of Heterosigma cells and other plankton emerging from marine sediments. R/OCEH-6	<b>Actual</b> (2/1/2012 - 1/31/2013) :	1		0
High-resolution, efficient, portable, low-cost networked microprocessor-based remote sensing platform capable of real-time monitoring of the HAB-forming alga Heterosigma, other plankton. R/OCEH-6	<b>Anticipated</b> (2/1/2013 - 1/31/2014) :	1		0
Low-cost, high-resolution microprocessor-based imager for quantifying finescale plankton distributions, collecting environmental data and quantifying plankton net avoidance. R/OCEH-6	<b>Actual</b> (2/1/2012 - 1/31/2013) :	1		0
	<b>Anticipated</b> (2/1/2013 - 1/31/2014) :	1		0

**:: HAZARD RESILIENCE IN COASTAL COMMUNITIES**

*No Communities Reported This Period*

**:: ADDITIONAL MEASURES**

<u>Safe and sustainable seafood</u>	
Number of stakeholders modifying practices	Number of fishers using new techniques

**Actual** (2/1/2012 - 1/31/2013) :  
**Anticipated** (2/1/2013 - 1/31/2014) :

Sustainable Coastal Development  
**Actual** (2/1/2012 - 1/31/2013) :  
**Anticipated** (2/1/2013 - 1/31/2014) :

**Actual** (2/1/2012 - 1/31/2013) :  
**Anticipated** (2/1/2013 - 1/31/2014) :

Coastal Ecosystems  
**Actual** (2/1/2012 - 1/31/2013) :  
**Anticipated** (2/1/2013 - 1/31/2014) :

## :: PARTNERS

Partner Name: American Gold Seafoods  
Partner Name: Cheryl Greengrove, type: academic, scale: local  
Partner Name: Karlista Rickerson, Sound Toxin Volunteer, type: NGO, scale: local  
Partner Name: Link Foundation  
Partner Name: Quartermaster Harbor Yacht Club, type: industry, scale: local  
Partner Name: University of Washington  
Partner Name: Wallingford Imaging Systems, type: industry, scale: local

## :: IMPACTS AND ACCOMPLISHMENTS

Title: **Washington Sea Grant-sponsored research develops autonomous sensors for monitoring harmful algae in Puget Sound**

Type: accomplishment

Description:

Relevance: Aquaculture operations in Puget Sound are impacted by two harmful bloom-forming algae: *Heterosigma akashiwo*, which affects farmed salmon and other valuable species; and *Alexandrium catenella*, which produces saxitoxins that accumulate in bivalves and other filter feeders, causing paralytic shellfish poisoning in humans and other animals that eat them. Currently, finfish aquaculture operations monitor for *Heterosigma* and shellfish are routinely tested for toxins, but cost and lack of personnel limit monitoring and testing. Continuous, automated monitoring for harmful algae could guide targeted testing and reduce costs.

Response: Washington Sea Grant-supported research has developed and deployed high-resolution, low-cost micro-imaging technology that uses embedded computers with high-definition cameras to detect, quantify and characterize harmful algal cells. The imagers work autonomously, either storing data onboard or integrating into a sensor network that streams real-time data to an online server.

Results: In 2011 a prototype imager deployed at a Puget Sound fish farm detected *Heterosigma* cells in the water column and remotely streamed real-time cell counts over the Internet. The image data matched traditional microscope counts at all algal concentrations from blooms to very low levels. In 2012 researchers upgraded the profiler technology and built a second prototype that targeted *Alexandrium* cells when they emerged from the sediment. In field tests, the imager distinguished chains of *Alexandrium* cells and measured their abundance and swimming velocities. Costing less than \$500 and requiring only minimal power, the imager demonstrated novel capabilities for monitoring and predicting harmful blooms.

Recap:

Washington Sea Grant-supported research develops and deploys high-resolution, low-cost micro-imaging technology to detect, quantify and characterize swimming algae, enabling remote, real-time detection of harmful *Alexandrium* and *Heterosigma* blooms.

Comments:

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:

American Gold Seafoods

Link Foundation

Quartermaster Harbor Yacht Club

University of Washington, School of Oceanography, College of the Environment (UW)

University of Washington, Tacoma, College of Arts and Sciences (UW)

Wallingford Imaging Systems

## :: PUBLICATIONS

Title: **An interdisciplinary guided inquiry on estuarine transport using a computer model in high school classrooms**

Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2012

Uploaded File: [abt.2012.74.1.7.pdf](#), 985 kb

URL: *none*

Abstract:

The National Science Education Standards have highlighted the importance of active learning and reflection for contemporary scientific methods in K–12 classrooms, including the use of models. Computer modeling and visualization are tools that researchers employ in their scientific inquiry process, and often computer models are used in collaborative projects across disciplines. The goal of this project was to develop and field-test a module that used a computer model to teach marine sciences content in an applied, inquiry-based, and collaborative manner. Students used an estuarine transport model to explore the question of how circulation patterns affect planktonic organisms, demonstrating the interdisciplinary interaction of physics and biology. Our experience suggests that computer models, when used for inquiry, can help foster students' understanding of the nature of science and critical-thinking skills.

Citation:

Chan, K.Y.K., S. Yang, M.E. Maliska, D. Grunbaum. 2012. An interdisciplinary guided inquiry on estuarine transport using a computer model in high school classrooms. *American Biology Teacher*, 74:26-33.

Copyright Restrictions + Other Notes:

Reported in AR2012

Journal Title: *American Biology Teacher*

Title: **Biomechanics of larval morphology affect swimming: insights from the sand dollars (*Dendraster excentricus*)**

Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2012

Uploaded File: *none*

URL: *none*

Abstract:

Most planktonic larvae of marine invertebrates are denser than sea water, and rely on swimming to locate food, navigate advective currents, and avoid predators. Therefore, swimming behaviors play important roles in larval survival and dispersal. Larval bodies are often complex and highly variable across developmental stages and

environmental conditions. These complex morphologies reflect compromises among multiple evolutionary pressures, including maintaining the ability to swim. Here, I highlight metrics of swimming performance, their relationships with morphology, and the roles of behavior in modulating larval swimming within biomechanical limits. Sand dollars have a representative larval morphology using long ciliated projections for swimming and feeding. Observed larval sand dollars fell within a narrow range of key morphological parameters that maximized their abilities to maintain directed upward movement over the most diverse flow fields, outperforming hypothetical alternatives in a numerical model. Ontogenetic changes in larval morphology also led to different vertical movements in simulated flow fields, implying stage-dependent vertical distributions and lateral transport. These model outcomes suggest a tight coupling between larval morphology and swimming. Environmental stressors, such as changes in temperature and pH, can therefore affect larval swimming through short-term behavioral adjustments and long-term changes in morphology. Larval sand dollars reared under elevated pCO<sub>2</sub> conditions had significantly different morphology, but not swimming speeds or trajectories. Geometric morphometric analysis showed a pH-dependent, size-mediated change in shape, suggesting a coordinated morphological adjustment to maintain swimming performance under acidified conditions. Quantification of the biomechanics and behavioral aspects of swimming improves predictions of larval survival and dispersal under present-day and future environmental conditions.

Citation:

Chan, K.Y.K. 2012. Biomechanics of larval morphology affect swimming: insights from the sand dollars (*Dendraster excentricus*). *Integrative and Comparative Biology*, 54:458-469.

Copyright Restrictions + Other Notes:

Reported in AR2012

Journal Title: *Integrative and Comparative 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  $\mu\text{mol L}^{-1}$  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  $\mu\text{mol L}^{-1}$ . The intensity of a fluorescent cellular stain of newly precipitated silica (2-(4-pyridyl)-5-[4-dimethylaminoethyl-aminocarbonyl]-methoxy]phenyl)oxazole, PDMPO) 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:

Grunbaum, D. 2013. Silicic acid supplied to coastal diatom communities influences cellular silicification and the potential export of carbon. *Limnology and Oceanography* (In press).

Copyright Restrictions + Other Notes:

To be reported in AR2013

Journal Title: *Limnol. Oceanogr.*

Title: **Chan, K.Y.K, D. Grünbaum, M. Arnberg, M. Thorndyke, S. T. Dupont. (In press). 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 CO<sub>2</sub>, 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<sub>2</sub> level (>700 μatm). Budding was observed in >50% of the population and was synchronized over short periods of time (~ 24 hours), 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* (in press).

Copyright Restrictions + Other Notes:

To be reported in AR2013

Journal Title: *Marine Biology*

Title: **Newspaper: Elizabeth Tobin "In science, words matter"**

Type: Publication Year: 2012

Uploaded File: *none*

URL: *none*

Abstract:

N.A.

Citation:

E. Tobin. In Science, words matter. *Los Angeles Times*, April 2, 2012.

Copyright Restrictions + Other Notes:

To be reported in AR2013

Journal Title: *Los Angeles Times*

**:: OTHER DOCUMENTS**

*No Documents Reported This Period*

**:: LEVERAGED FUNDS**

Type: influenced Period: 2012-08-15::2012-12-31 Amount: \$4375

Purpose:

Student Support - ARCS Fellowship to Owen Coyle

Source: ARCS Foundation



**WASHINGTON SEA GRANT PROGRESS REPORT**  
for the period 2/1/2012 – 1/31/2013

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

Principal Investigator and Affiliation:  
**Daniel Grunbaum** University of Washington, School of Oceanography

### **1. ACCOMPLISHMENTS AND OUTCOMES**

A key impediment to applied and basic ecological understanding of marine communities is the difficulty and expense of acquiring timely, detailed, broad-scale data about plankton distribution and condition. This project utilizes microvideography and computerized motion-tracking to quantify cell abundance and state of harmful algal species with major negative economic and ecological impacts in Washington and temperate waters worldwide. Our proposal was to use existing video methodologies. However, major advances have since occurred in low-power single board computing and imaging. Hence, we wholly redesigned our imaging technologies, using embedded microprocessors with onboard high-definition cameras. The new imager package has approximately 16 times the pixel resolution, one-sixth the cost, and one-tenth the weight as our original design. It digitizes images losslessly, circumventing problems imaging small particles with common compression standards, and is programable to work autonomously, stream live video, and/or record environmental data and control external devices.

As proposed, we deployed our prototype remote sensor for a HAB-forming alga, *Heterosigma*, for an extended period (> 2 months) operating autonomously in an industrial field setting. Essential support for this deployment was provided by our stakeholder partner, the American Gold Seafood (AGS) facility on Bainbridge Island, WA. The instrument's deployment substantially exceeded the proposed 1 week goal for unattended autonomous operation. Data analysis is still in progress, but we have established close correspondence between remotely sensed real-time optical counts from our autonomous instrument and on-site cell counts by AGS staff, particularly during the one significant *Heterosigma* event during the deployment period.

A key goal for our instrument has been to detect cells at low pre-bloom densities (20 cells/ml is an operational threshold for aquaculturists). The imager creates an internal halocline, which concentrates *Heterosigma* cells and excludes many other plankton species. We used laboratory cultures to show that, at 20 cells/ml and without a halocline (i.e., with no concentration of cells above the nominal density) the imager tracks approximately 200 cells within each video frame. This suggests the imager can, with long imaging sequences, detect cell populations of <0.2-2 cells/ml. Assessing and optimizing the instrument's sensitivity under field conditions is still an area of active research, but data from the summer of 2011 demonstrate detection at cell densities well below thresholds for deleterious impacts on farmed fish.

With a low-cost PVC housing and associated pumps, a remote *Heterosigma* sensor for

networked or autonomous operation costs approximately \$500, meeting our goal of low-cost sensors practical to implement in a regional prediction network. Our imaging technology applies broadly in plankton ecology. We are currently collaborating with the Suquamish Fisheries Department to adapt our imaging technology to monitor crab larval populations, based on a previous design for at-sea optical observations; with the Northwest Fisheries Science Center's Ocean Acidification laboratory to design flow-through sensors for quantifying abundance and morphology of cultured fish and invertebrate populations; and with the Greengrove Laboratory at UWT in quantifying emergence of Harmful Algal Bloom-forming cells (*Alexandrium*) from resting stages in sediments.

In this reporting period, we made three substantial advances in development of remote HAB imaging sensors in line with the objectives of our proposal. First, we upgraded our imaging technology to a more powerful microcomputer platform, and adapted our capture and processing software to the new platform. Second, we leveraged funds from a Link Foundation Fellowship to graduate student Liz Tobin to design, construct and deploy new type of imager, an Imaging Benthic Emergence Trap (IBET). This instrument combines a traditional benthic emergence trap, in which harmful algal cells and other plankton emerging from resting stages in the sediments are confined within a plankton net for later study, with an imaging microcomputer. This instrument has potential to provide early warning of incipient HABs, by revealing the locations and times at which precursor cells enter the water column. Third, we broadened the scope of our image-based remote sensing to include another key HAB-forming alga in Washington State waters, *Alexandrium catenella*. We demonstrated in field trials at Quartermaster Harbor, Washington, that this instrument can distinguish chains of *Alexandrium in situ*, quantify the size/frequency distribution of chains, and characterize their size-specific swimming velocities.

Graduate student Liz Tobin, P.I. Grunbaum and collaborator Rose Ann Cattolico also completed a laboratory study quantifying emergence rates of *Heterosigma* from benthic resting stages into pelagic vegetative stages. Key results of this study are surprisingly rapid emergence of cells, beginning less than 24 hours after exposure to growth-supporting light and temperature cues, and an unexpectedly high incidence of cell replication immediately after emergence. This replication was first detected by video-based cell counts, and subsequently confirmed using flow cytometry to track increases in cells' DNA complements during synchronized cell division. Tobin showed that two geographically and genetically distinct strains differ in swimming, efficiency of transitions into and out of resting stages, and metabolic characteristics such as lipid content that are often associated with swimming and other resource-intensive cell activities.

Finally, graduate student Karen Chan and three Under-Represented Minority undergraduates from Friday Harbor Labs' Blinks Research Experience for Undergraduates program leveraged models and imaging techniques derived from this research (and earlier, associated Sea Grant funded work) to investigate field distributions of larval crabs, behavioral responses of echinoderm larvae to starvation stress, and the impacts of Ocean Acidification on larval echinoderm behavior, feeding rate, morphology and cloning.