Update Report

Period: 2/1/2014 - 1/31/2015

Project: R/SFA-3 - *A low-cost sensor network for early detection of Alexandrium and Heterosigma Harmful Algal Blooms in the Puget Sound region*

STUDENTS SUPPORTED

Coyle, Owen, ocoyle@uw.edu, University of Washington, Oceanography, status: cont, field of study: oceanography, advisor: Grunbaum, degree type: MS, degree date: 2015-06-01, degree completed this period: No
Student Project Title: *none*
Involvement with Sea Grant This Period: *none*
Post-Graduation Plans:
faculty position

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: Yes
Student Project Title: *none*
Involvement with Sea Grant This Period: *none*
Post-Graduation Plans:
Independent NSF grant to pursue HAB work in Alaska

CONFERENCES / PRESENTATIONS

Conference poster presentation: Coyle, O. L., Grünbaum D. AFFORDABLE ENVIRONMENTAL SENSORS FOR USE IN HARMFUL ALGAL BLOOM DETECTION AND EDUCATIONAL ENRICHMENT. Oral presentation at the Western Society of Naturalists Annual Meeting, Tacoma, WA, November 14., public/profession presentation, 100 attendees, 2014-11-14

Conference oral presentation: Grünbaum D. Democratizing assessments of changing marine environments: applications of imaging micro-computers to quantify plankton movements in the laboratory and field. Oral presentation at the Water & Biodiversity Forum, Okanagan Institute for Biodiversity, Resilience, and Ecosystem Services (BRAES), University of British Columbia, Okanagan Campus, Kelowna, Britich Columbia, Canada., public/profession presentation, 125 attendees, 2014-09-16

Seminar: Daniel Grünbaum (2014) Linking cognition and spatial memory to individual movements and ecological Interactions. Mathematics and Physics Colloquium, University of British Columbia, Okanagan Campus, Kelona, BC, public/profession presentation, 30 attendees, 2014-09-15

Seminar: Daniel Grünbaum (2014) Linking cell-level tradeoffs in physiology, movement and reproduction to Harmful Algal Bloom dynamics: Observations, models, and directions for future research. IAS/School of Science Joint Lecture, Hong Kong University of Science and Technology, Hong Kong, June 20., public/profession presentation, 75 attendees, 2014-06-20

Conference oral presentation: Grünbaum D., Emlet R. The functional morphology of minimalist morphologies: swimming performance of blastulae, gastrulae, and other spheroidal organism architectures. Oral presentation at the Western Society of Naturalists Annual Meeting,, Tacoma, WA, November 15., public/profession presentation, 50 attendees, 2014-11-15

Seminar: Daniel Grünbaum (2014) Signs of movement: Synergies of biomechanics, behavior and spatial ecology in ocean ecology applications. C.S.I.R.O. Hobart, Tasmania, Australia., public/profession presentation, 75 attendees, 2014-04-02

ADDITIONAL METRICS

P-12 Students Reached: Oceanography, marine biology and bio-physics lectures and laboratories with high (55), middle (35) and elementary school students (40) at Clallam Bay School, Clallam Bay, WA; Harmful Algal Blooms, Puget Sound model and instrumentation building with Chief Kitsap Academy students (15)	160	**P-12 Educators Trained:** Sensor-building training session at Clallam Bay School, Clallam Bay, WA (5); HAB training and experiential learning for Salish Seas Expeditions instructors (10); oceanography and sensor building with Chief Kitsap Academy teachers (2)	17
Participants in Informal Education Programs:	0	**Volunteer Hours:**	0
Acres of coastal habitat protected, enhanced or restored:	0	**Resource Managers who use Ecosystem-Based Approaches to Management:**	0
Annual Clean Marina Program - certifications:	0	**HACCP - Number of people with new certifications:**	0

ECONOMIC IMPACTS

No Economic Impacts Reported This Period

SEA GRANT PRODUCTS

Description	Developed?	Used?	ELWD?	Number of Managers	Names of Managers
Networked remote sensor for cells of the HAB-forming alga Heterosigma akashiwo which can be constructed by stakeholders with simple hand tools	Yes	No	Yes	0	

using 3D printable and locally available components				
Kit for construction of remote sensors for temperature and other environmental variables by K-12 students in underserved communities.	Yes	Yes	Yes	0
Inexpensive 3D printable field sampling kit to detect pre-HAB cell populations of the alga Heterosigma akashiwo	Yes	No	No	0
Inexpensive networked sensor for real-time reporting of temperature profiles and other environmental data for oyster growers.	Yes	Yes	No	0

HAZARD RESILIENCE IN COASTAL COMMUNITIES

No Communities Reported This Period

ADDITIONAL MEASURES

Number of stakeholders modifying practices:	Sustainable Coastal Development **# of coastal communities:**

PARTNERS

Partner Name: American Gold Seafoods

Partner Name: Chief Kitsap Academy

Partner Name: Clallam Bay School, type: Academic Institution, scale: Local
Partner Name: Google, type: Industry and Business, scale: International
Partner Name: Ocean Inquiry Project
Partner Name: Salish Seas Expeditions, type: NGO, scale: Regional
Partner Name: Society for Integrative and Comparative Biology
Partner Name: SoundToxin, type: Sea Grant Programs, scale: State
Partner Name: Suquamish Tribe
Partner Name: Taylor Shellfish Farms
Partner Name: University of Washington
Partner Name: Wallingford Imaging Systems

IMPACTS AND ACCOMPLISHMENTS

Title: **Washington Sea Grant research uses 3D printing to further streamline low-cost automated technology for monitoring harmful algae**
Type: impact
Relevance, Response, Results:
Relevance: The fish-killing rhaphidophyte Heterosigma and the neurotoxin-producing dinoflagellate Alexandrium are primary causes of harmful algal blooms (HABs) in Puget Sound. While monitoring programs are maintained throughout western Washington, efforts to mitigate damage to fisheries and aquaculture operations are hamstrung by current inability to predict or anticipate HAB events. Low-cost approaches to detecting emergent pre-bloom cells would dramatically boost preparedness and could also support a wide range of other research and monitoring needs, such as state-mandated temperature monitoring of oyster beds.
Response: Researchers comprehensively redesigned and streamlined the remote, low-power micro-imaging HAB sensors developed from previous Washington Sea Grant funding to develop inexpensive, widely distributed real-time automated sensors. They replaced professionally machined components with inexpensive 3D-printed and hardware-store parts incorporating improved microprocessing and optical technologies securely sealed against corrosive seawater. And they devised an ultra-low-cost, 3D-printed test-tube insert that concentrates any Heterosigma present to measurable levels.
Results: Automated monitoring has made it possible to track the widely varying behavior of different Heterosigma strains. The new technologies significantly improved onboard image capture and onsite image analysis. By radically reducing per-unit costs, the 3D printing puts automated, real-time in-water monitoring within

reach of students and citizen scientists such as WSG's SoundToxins monitors. The approach has opened new educational opportunities and possibilities for networked citizen science research.
Recap:
Recap: Washington Sea Grant-supported research develops and refines transformative low-cost sensor technology for real-time, networked monitoring of toxic algae and other marine phenomena, opening new possibilities for harmful bloom prediction and engagement of citizen scientists.
Comments:
Primary Focus Area: SFA
Secondary Focus Area: HCE
Associated Goals: Aquaculture operations and shellfish harvests are safe, environmentally sustainable, and support economically prosperous businesses. (SFA)
Ocean and coastal resources are managed using ecosystem-based approaches. (HCE)
Partners:
American Gold Seafoods
Chief Kitsap Academy
Clallam Bay School
Google
Ocean Inquiry Project
Salish Seas Expeditions
Society for Integrative and Comparative Biology
SoundToxin
Suquamish Tribe
Taylor Shellfish Farms
University of Washington
Wallingford Imaging Systems
Related Partners: *none*

PUBLICATIONS

Title: **Addressing Grand Challenges In Organismal Biology: The Need For Synthesis**
Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2014
Uploaded File: Padilla_et_al_BioScien....4.pdf, 664 kb
URL: *none*
Abstract:
Animals are complex systems operating at multiple spatial and temporal scales, facing the challenge of how to change in appropriate ways,
degrees, and times, in response to the diverse internal and external influences to which they are exposed. Discovering the system-level attributes
of organisms that make them resilient or robust—or sensitive or fragile—to change presents a grand challenge for biology. Knowledge of these
attributes and the underlying mechanisms controlling them is crucially 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 when they partner with mathematicians and engineers. Pursuing this research
enterprise will not only give us a deeper understanding of how organisms will face future challenges, but it will also reveal nature-inspired
solutions in complex engineered systems, both of which will benefit science and society.

Citation:

Padilla, D. K., T.L. Daniel, P.S. Dickinson, D. Grunbaum, C. Hayashi, D.T. Manahan, J. H. Marden, B.J. Swalla, B. Tsukimura. 2014. Addressing Grand Challenges In Organismal Biology: The Need For Synthesis. Bioscience. 64(12): 1178-1187.

Copyright Restrictions + Other Notes:

Journal Title: Bioscience

Title: **Impacts of ocean acidification on survival, growth, and swimming behaviors differ between larval urchins and brittlestars.**

Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2015

Uploaded File: *none*

URL: *none*

Abstract:

Ocean acidification (OA) is widely recognized as an increasing threat to marine ecosystems. Many marine invertebrates have dual-phase life cycles in which planktonic larvae connect and sustain otherwise disconnected benthic adult populations. Many planktonic larvae are particularly sensitive to environmental stresses including OA. Here, we compared the developmental dynamics, survivorship, and swimming behaviors of plutei of two ecologically important echinoderm species that naturally experience variability in ambient pH: the purple urchin Strongylocentrotus purpuratus and the infaunal brittlestar Amphiura filiformis. Sensitivity to decreased pH differed between these two species and between maternal lineages. Larvae of both species experienced increased mortality and reduced growth rate under low pH conditions. However, larval brittlestars appeared more sensitive and experienced over 80% mortality after 7 days exposure to pH 7.7. Larval urchins from one maternal lineage underwent highly-synchronized budding (release of blastula-like particles) at low pH. Observed budding temporarily increased numerical density and reduced individual size, leading to differences in growth and mortality rates between the two half-sibling groups and another population. Swimming speeds of larval brittlestars were reduced in decreased pH. In contrast, acidification had either no effect or positive effect on swimming speeds of larval urchins. The observed differences between species may be a reflection of pre-exposure in their natural habitats: larval brittlestars experience a relatively stable in situ pH environment, while larval urchins are occasionally exposed to low pH in upwelling regions. Urchins may therefore exhibit short-term compensatory responses such as budding and increased swimming speed. Natural selection could potentially act upon the significant variations we observed between maternal lineages, resulting in more

resilient populations confronting chronic exposure to ocean acidification.
Citation:
Chan, K.Y.K, D. Grünbaum, M. Arnberg, S. T. Dupont. 2015. Impacts of ocean acidification on survival, growth, and swimming behaviors differ between larval urchins and brittlestars. ICES Journal of Marine Science. In press.
Copyright Restrictions + Other Notes:
Journal Title: ICES Journal of Marine Science

Title: **Detection and Quantification of Life-stage Transition Behaviors in Harmful Algae and their Implications for Pelagic and Benthic Distributions**
Type: Full theses / Dissertations Publication Year: 2014
Uploaded File: *none*
URL: *none*
Abstract:
Harmful algal blooms (HABs) occur when accumulations of algae or algal toxins have adverse
impacts on aquatic ecosystems, public health and/or coastal resources. Many of the behavioral
and physiological functional traits that regulate HAB dynamics remain poorly understood.
Improved understanding of these traits and innovative technologies to detect HAB cells in situ
are important for assessing future bloom scenarios and establishing appropriate HAB mitigation
and management strategies.

Many HAB-forming species exhibit a dual-stage life history, alternating between pelagic and
benthic life stages. Rates of transition between pelagic and benthic habitats can regulate cell
dispersal and contribute to the timing and severity of HABs. Yet, life stage transitions are among
the least understood aspects of HAB dynamics. The focus of this research was to characterize
iand quantify behaviors of harmful motile marine algae during life-stage transitions and to assess
their influence on pelagic and benthic population distributions.

Two HAB species that commonly occur in the Salish Sea, the fish killing raphidophyte,
Heterosigma akashiwo, and the toxic dinoflagellate, Alexandrium catenella, were the focus of
these studies. A combination of field, laboratory and modeling methods were used to elucidate
the role of life-stage transitions in bloom dynamics. The primary objectives were to (1) examine
benthic emergence characteristics of naturally occurring cysts of A. catenella

(Chapter 2); (2)
quantify strain-specific swimming characteristics during life stage transitions of H. akashiwo; (3)
assess how specific behavioral and physiological traits regulate vertical fluxes and population
distributions of H. akashiwo (Chapters 3 and 4); and (4) develop a low cost, field-deployable
sensor to detect and characterize algal benthic emergence in situ (Chapter 5).

The research outcomes indicated that important algal physiological and behavioral traits,
including cell survivorship during transitions between life stages, internal regulation of benthic
emergence rates, transitional swimming behaviors and post-transition specific growth rates,
govern vertical distributions of some harmful algae and the timescales over which HABs form
and dissipate. These traits were shown to be largely species and strain dependent, resulting in
both species- and region-specific benthic emergence and growth strategies. Results demonstrate
that behavioral and physiological traits expressed during life-stage transitions play critical roles
in regulating distributions of harmful algal populations. Further, in situ detection and monitoring
of benthic emergence and other behavioral traits of harmful algae will improve mechanistic
understanding of HAB formation and enhance our capacity for successful bloom prediction.
Citation:
Quantification of Life-stage Transition Behaviors in Harmful Algae and their Implications for Pelagic and Benthic Distributions
Tobin, Elizabeth D. University of Washington, ProQuest, UMI Dissertations Publishing, 2014. 3641646.
Copyright Restrictions + Other Notes:
Journal Title: *none*

OTHER DOCUMENTS

No Documents Reported This Period

LEVERAGED FUNDS

Type: influenced Period: 2014-02-01: : 2015-01-30Amount: $5000
Purpose:
ARCS Fellowship to Owen Coyle
Source: ARCS Foundation

Type: influenced Period: 2015-01-30: : 2016-03-13Amount: $20000

Purpose:
Funds Salish Seas Expeditions to run courses for under-served students using our curricular materials to build sensors and deploy them at sea
Source: Google Community Grant #TFR15-00657

UPDATE NARRATIVE

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Our research this year focused on three primary areas:

1) HAB remote sensor development
We comprehensively redesigned our Harmful Algal Bloom remote sensor to take advantage of new technologies, with the specific objective of enabling students, aquaculturists and other stakeholders to construct and deploy these sensors without requiring specialized equipment such as a machine shop. An important innovation is that the current design makes extensive use of 3D printed parts. 3D printers are rapidly becoming cheaper and will soon be available via school shops and community maker-spaces to most students and stakeholders. Our new design substitutes 3D printed components for what in the old design were professionally machined parts. This redesign has required significant new investment in engineering and fabrication techniques. However, the current design can be now self-constructed entirely from off-the-shelf components by anyone with access to a local hardware store or on-line vendors, and to a 3D printer. We anticipate developing our sensor in a kit form, to facilitate use as a focal project for technology-oriented classes, and to promote adoption by ocean-side citizens and businesses, aquaculturists and other stakeholders. We also invested engineering and software development time to adopt a new generation of microcomputer, improving on-board image capture and on-site analysis of swimming HAB cells. As we move to scale up deployment of a sensor network, the ability of our instruments to minimize uploading bandwidth by analyzing most or all of the video data they acquire will be increasingly important. We are currently constructing HAB remote sensors to be deployed in Spring and Summer of 2015.

2) Crowd-sourced instrumentation networked marine environment sensors
The remote sensor technology we developed in our HAB instrumentation research has resulted in new opportunities for very low cost networked sensors for marine environment characteristics. We and our industrial partners, Wallingford Imaging Systems (WIS), made substantial investments this year in exploiting these opportunities to serve Washington State stakeholders. For example, a new regulation being implemented by the Washington State Department of Health requires oyster growers to document the water temperature at the specific location and depth of their product, and imposes a temperature threshold above which they are not allowed to harvest. There is currently no mechanism by which growers can satisfy this regulation. We are working closely with WIS to provide low-cost networked sensors that autonomously report real-time profiles across depth of temperature and other environmental variables. These sensors are suitable for continuous deployment under realistic field conditions, and to provide accurate and verifiable data that will enable growers to meet DoH requirements. Promoting oyster cultivation is only one application of these low-cost sensors. We anticipate making these widely available to students and citizen-scientists, who will then have the ability to acquire accurate and verifiable georeferenced environmental data. These crowd-sourced data will provide ground-truthing for geophysical circulation models now being developed; the models will provide complementary fore- and hind-casting of the destination and prior history of water associated with specific sensor observations. We are currently alpha-testing prototypes of these sensors and expect to beta-test instruments at oyster farms around Puget Sound in Spring 2015. We developed HetSticks, a new technology for very low cost assessment of pre-HAB populations of *Heterosigma* cell abundance. Het-Sticks consist of a 3D-printed insert for ordinary laboratory test tubes. Filled with low salinity water and deployed for a few hours or days, HetSticks accumulate *Heterosigma* cells at concentrations that are a high multiple of ambient concentration. We are working with SoundToxin to coordinate field testing and deployment of these sampling tools, and have filed a Record of Invention for HetSticks.

3) STEM/Ocean Technology Education
We have done extensive work this year in design of curricular materials for STEM education in the context of oceanography, marine biology and ocean technology, with an emphasis on under-served

students in Tribal and rural schools. We worked with two schools, Chief Kitsap Academy and Clallam Bay School, to teach high, middle and elementary school students elements of biology, physics, engineering and geosciences. We will be returning to both schools in Spring 2015 to train teachers and build sensors with students. We partnered with Salish Seas Expeditions (SSE) to design a curricular sequence for under-served schools in which students construct their own sensors, design a field observation program, go to sea on an SSE vessel to obtain data with their own sensors, analyze the data and present their conclusions. Google Community Grants has awarded $20,000 to this project. The sequence of student-built sensors deployed in the field to test student-developed hypotheses, followed by critical analysis of students' own data, is a model that we will providing teachers in an up-coming Washington State-funded teacher education program, and we expect will be a central component in the Master of Science in Science Teaching program being developed by the UW College of the Environment. We also contributed substantially to the Ocean Technology undergraduate program being developed by the UW School of Oceanography.