RESEARCH/PD ANNUAL REPORT - PROGRESS REPORT

2015 annual report - progress
Daniel Grunbaum
A low-cost sensor network for early detection of Alexandrium and Heterosigma Harmful Algal Blooms in the Puget Sound region
R/SFA-3
Submitted On: 05/10/2016 11:37:29 AM

METRICS & MEASURES

Metric/Measure	Value	Note
Acres of coastal habitat	0	
Fishermen and seafood industry personnel	0	
Communities - economic and environmental development	0	
Stakeholders - sustainable approaches	0	
Informal education programs	0	
Stakeholders who receive information	220	presentations and workshops (140); students reached directly (80)
Volunteer hours	150	7 UW undergraduate and graduate students, one UW faculty and two Hamilton Middle School students trained in ocean technology and participated environmental sensor construction and deployment as volunteers at high, middle and elementary schools the Seattle area and the Olympic Peninsula.
P-12 students reached	2080	Classes on microcontrollers, computing and environmental sensor technology in the context of oceanography, marine biology (including HABs) and biophysics. We worked directly with approximately 20 high school students from Chief Kitsap Academy, and 30 high school and 30 elementary students from Clallam Bay. Each of the teachers in our Olympic Education District teaches multiple STEM classes (typically 2-3 classes, 25-35 students in each) in which they engaged to construct and use sensors derived from our outreach. We estimate a minimum of 2000 students benefited from this outreach.
P-12 educators	52	Classes on microcontrollers, computing and environmental sensor technology in the context of oceanography, marine biology (including HABs) and biophysics. We conducted five workshops of teaching construction and use of environmental sensors to middle and high school teachers. This included one 3-day and two 1-day workshops with 45 teachers from across the Olympic Education District. Each of these teachers has undertaken to mentor three additional teachers from their

		school. In addition we worked intensively (1-day and 2-day workshops) with 5 teachers from Clallam Bay high and elementary schools. We also worked extensively with 2 teachers from the Chief Kitsap Academy (5 1-day workshops). These teachers learned both how to construct low-cost environmental sensors and strategies for constructing, deploying and using the data in classroom settings.

REQUESTED INFORMATION

Publications

No **Publications** information reported

Students Supported

Sasha Seroy (New Student)
sseroy@uw.edu
University of Washington, Oceanography

Field of Study: Oceanography
Advisor: Grunbaum
Degree Type: MS
Degree Year: 2017

Student Project Title: Ocean change impacts on trophic interactions within marine communities

Involvement With Sea Grant This Period (capstone, fellow, intern, etc.): graduate student researcher

Post-Graduation Plans (employer, grad school, etc.): faculty or professional scientist

Was this thesis/dissertation supported by Sea Grant?: No

Thesis / Dissertation:

New or Continuing?: New

Degree awarded this reporting period?: No

Financially supported?: Yes

Katherine Beaumont (New Student)
kob29@uw.edu
University of Washington, Oceanography

Field of Study: Oceanography
Advisor: Keister/Grunbaum
Degree Type: MS
Degree Year: 2018

Student Project Title: Plankton swimming behavioral responses to ocean acidification and hypoxia

Involvement With Sea Grant This Period (capstone, fellow, intern, etc.): graduate student researcher

Post-Graduation Plans (employer, grad school, etc.): faculty or professional scientist

Was this thesis/dissertation supported by Sea Grant?: No

Thesis / Dissertation:

New or Continuing?: New

Degree awarded this reporting period?: No

Financially supported?: Yes

Owen Coyle (Continuing Student)
ocoyle@uw.edu
University of Washington, Oceanography

Field of Study: Oceanography
Advisor: Grunbaum
Degree Type: MS
Degree Year: 2016

Student Project Title: A real-time remote sensor for the enumeration of the harmful alga Heterosigma akashiwo

Involvement With Sea Grant This Period (capstone, fellow, intern, etc.): graduate student researcher and educator

Post-Graduation Plans (employer, grad school, etc.): University faculty or STEM teacher

Was this thesis/dissertation supported by Sea Grant?: Yes

Thesis / Dissertation: A real-time remote sensor for the enumeration of the harmful alga Heterosigma akashiwo

New or Continuing?: continuing

Degree awarded this reporting period?: Yes

Financially supported?: Yes

Narratives

Grunbaum 2016 Update Narrative
Uploaded File: WSG2016_narrative.pdf

Partners This Period

Chief Kitsap Academy
Types: Academic Institution
Scale: Tribal
Notes:

American Gold Seafoods
Types: Industry/Business
Scale: LOCAL
Notes:

Taylor Shellfish Farms
Types: Industry/Business
Scale: LOCAL
Notes:

Society for Integrative and Comparative Biology
Types: Academic Institution
Scale: FEDERAL or NATIONAL
Notes:

Wallingford Imaging Systems
Types: Industry/Business
Scale: LOCAL
Notes:

Center for Wooden Boats
Types: NGO
Scale: LOCAL
Notes:

Suquamish Tribe
Types: Government
Scale: Tribal
Notes:

SoundToxin
Types: Sea Grant Program
Scale: REGIONAL
Notes:

TLCZ Shellfish
Types: Industry/Business
Scale: LOCAL
Notes: John Hansen

Clallam Bay High and Elementary School
Types: Academic Institution
Scale: LOCAL
Notes:

STANDARD QUESTIONS

Impacts and Accomplishments

(1)

Type	impact
Title	Washington Sea Grant researchers enlist students, teachers and 3-D printers in building a low-cost system to detect toxic marine algae and learn about marine environments
	A new generation of low-cost technologies—3-D printers, micro-controllers, cellphone imagers—offers the potential to produce transformative

Relevance	sensors for real-time, networked monitoring of toxic algae and other marine phenomena. The technologies advance harmful bloom prediction; they also create a natural synergy between scientific requirements, students' interests and societal needs for a more technologically-informed workforce.
Response	Washington Sea Grant-supported researchers provided teachers and students with hands-on tools, curricula and assistance to take advantage of this synergy. The team developed ocean technology and engineering instructional materials for STEM education initiatives—including the Olympic STEM Partnership Program—ran workshops, and developed a webinar for teachers on how to construct temperature sensors with students. They developed data-logging sensors coded with user-friendly software that is easy for students to program and operate. Working with Clallam Bay teachers and students, the team taught oceanography topics spanning ocean technology and ecology such as harmful algal blooms, biophysics of organism sensing and locomotion, and data analysis.
Results	Team members directly engaged 45 middle and high school teachers, indirectly involved 90 others and reached 2,080 students. Students from the Suquamish Tribe's Chief Kitsap Academy were able to construct and deploy marine sensors and analyze and interpret their data. Graduate students worked with a class at Seattle’s Jane Adams Middle School to build and deploy sensors in the school’s wetland.
Recap	Washington Sea Grant researchers empowered students to build and use instruments for monitoring local environments, offering an effective, low-cost approach for advancing STEM education.
Comments	
Primary Focus Area	Ocean Literacy and Workforce Development
Secondary Focus Areas	
Goals	The future workforce is skilled in disciplines critical to coastal and ocean economies and ecosystem health.
Partners	Chief Kitsap Academy Clallam Bay School Jane Adams Middle School Hamilton Middle School Olympic STEM Partnership Program SoundToxins Suquamish Tribe Wallingford Imaging Systems Washington State Office of the Superintendent of Public Instruction
	* Type impact * Title Washington Sea Grant research develops low-cost instrument for quantitative remote sensing of harmful algae * Relevance The fish-killing rhaphidophyte Heterosigma is a primary causes of harmful algal blooms (HABs) in Puget Sound. While

PI Draft	monitoring programs are maintained throughout western Washington, efforts to mitigate damage to fisheries and aquaculture operations are hamstrung by current inability to predict or model HAB events. Low-cost approaches to quantifying cell populations before and during blooms 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 developed a quantitatively accurate and verified remote, low-power micro-imaging HAB sensors based on previous Washington Sea Grant funding to enable inexpensive, widely distributed real-time automated sensors. The instrument automatically uploads summary data including the number and swimming characteristics of Heterosigma cells present in the water column. Additionally, the instrument can be programmed to assess the whole mesoplankton community, rather than solely Heterosigma cells. * Results Quantitatively accurate automated monitoring has made it possible to track the widely varying abundance and behavior of different Heterosigma strains. The new technologies significantly improved onboard image capture and onsite image analysis. By enahncing accuracy of abundance and behavior assays while maintaining low per-unit costs, the new instruments enable real-time in-water monitoring and data integration with predictive geophysical models by 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 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 Sustainable Fisheries and Aquaculture Secondary Focus Areas Healthy Coastal Ecosystems,Ocean Literacy and Workforce Development Goals Ocean and coastal resources are managed using ecosystem-based approaches.,Aquaculture operations and shellfish harests are safe, environmentally sustainable and support economically prosperous businesses.,The future workforce is skilled in discilines critical to coastal and ocean economies and ecosystem health. Partners American Gold Seafoods Chief Kitsap Academy Clallam Bay School Ocean Inquiry Project Society for Integrative and Comparative Biology SoundToxin Suquamish Tribe Taylor Shellfish Farms University of Washington Wallingford Imaging Systems ---------- * Title Washington Sea Grant research develops intuitive, easy-to-build environmental sensors for STEM education *

	Relevance Environmental sensors based on microcontrollers provide a natural synergy between scientific requirements, students' interests and the societal needs for a more technologically-informed workforce. However, the software that runs most microprocessors is complex and difficult for many students, stakeholders and other citizens to understand, use and troubleshoot. * Response New low-cost, high performance microprocessors running on the python programming language provide a greatly improved learning and sampling design platform for environmental monitoring. Unlike standard microprocessor control systems, Python is designed to be interactive and intuitive for new users, and the version engineered for microcontrollers ("Micropython") is stable and well documented. * Results New environmental sensors based on microcontrollers running Python have been developed and tested in K-20 classroom settings as platforms for enhancing technological and quantitative skills. By enabling scientifically informative, inexpensive crowd-sourced environmental sensors to be developed by students and other citizen scientists, this research dramatically increases the potential for high resolution regional monitoring of ocean change. * Recap Washington Sea Grant-support work synergizes user-friendly microprocessor technology with environmental sensing needs to empower individuals and communities to monitor environmental change. Comments Primary Focus Area Healthy Coastal Ecosystems Secondary Focus Areas Resilient Communities and Economies,Ocean Literacy and Workforce Development Goals Coastal communities and economies are vibrant and resilient.,Coastal communities engage in comprehensive planning and sustainable development.,Communities prepare, respond and adapt to coastal hazards and climate change.,The public is ocean literate.,The future workforce is skilled in discilines critical to coastal and ocean economies and ecosystem health. Partners Olympic STEM Partnership Program, Chief Kitsap Academy, Clallam Bay School Ocean Inquiry Project, Jane Adams Middlle School, Hamilton Middle School, SoundToxin, Suquamish Tribe, University of Washington Wallingford Imaging Systems

Tools, Technologies, Information Services / Sea Grant Products

(1)

Description	Low-cost python-based microcontroller data-logging environmental sensors for construction and field deployment by students/stakeholders
Developed (in the reporting period)?	Yes

Used (in the reporting period)?	Yes
Used for EBM?	No
ELWD product?	Yes
Number of managers	0
Description/Names of managers	

(2)

Description	Analytical procedure for quantifying Heterosigma cell population densities from rise times and plateaus in remote sensing video instrument data
Developed (in the reporting period)?	Yes
Used (in the reporting period)?	No
Used for EBM?	No
ELWD product?	Yes
Number of managers	0
Description/Names of managers	

(3)

Description	Low-cost microcontroller-based telemering halocline transmissometer for remote detection and monitoring of Heterosigma HABs.
Developed (in the reporting period)?	Yes
Used (in the reporting period)?	No
Used for EBM?	No
ELWD product?	Yes
Number of managers	0
Description/Names of managers	

Economic Impacts

No **Economic Impacts** information reported

Community Hazard Resilience

No **Community Hazard Resilience** information reported

Meetings, Workshops, Presentations

(1)

Type of Event	Public or professional presentation
Description	Two-day workshop teaching participants of the Olympic STEM Partnership Program to construct and use networked temperature sensors with their classes. Each participant successfully built and took home their own sensor, with extensive curricular materials to facilitate sensor-building in their own classes.
Event Date	06-24-2015
Number of Attendees	50

(2)

Type of Event	Public or professional presentation
Description	One-day workshop developing classroom strategies for construction and use of networked temperature sensors with their classes.
Event Date	08-11-2015
Number of Attendees	50

(3)

Type of Event	Public or professional presentation
Description	Webinar to refine teachers' classroom strategies and troubleshooting skills in construction and use of networked temperature sensors with their classes.
Event Date	01-28-2016
Number of Attendees	40

Leveraged Funds

(1)

Purpose	Olympic STEM Partnership Program - Improvement of mathematics and science instruction through partnerships between school districts, institutions of higher learning, ESDs and educational organizations.
Source	Mathematics and Science Partnership Program (MSP), Office of the Superintendent of Public Instruction, Washington State
Amount	133333
Start Date	06-01-2015

End Date	01-31-2016

(2)

Purpose	A low-cost sensor network for early detection of Alexandrium and Heterosigma Harmful Algal Blooms in the Puget Sound Region - graduate student fellowship
Source	Friday Harbor Labs
Amount	6000
Start Date	07-01-2015
End Date	08-31-2016

1) HAB remote sensor development
This year we conducted extensive laboratory studies of the Heterosigma HAB remote sensing instrument to calibrate cell counts in video sequences as quantitative indicators of cell population water. This instrument is designed to be small, light weight, low cost, and easily manufactured and deployed using off-the-shelf and 3D printed components. Its operation takes advantage of *Heterosigma* cells' upswimming behavior and ability to cross strong haloclines that act as barriers to most other plankton and passive particles, which are well characterized from earlier Washington Sea Grant-funded research. Hence inferring cell densities from video requires a detailed understanding of *Heterosigma* swimming behavior, especially diel variations and responses to light and dark. Graduate student Owen Coyle has completed a detailed statistical analysis of rise times and plateaus in video counts, enabling us to estimate cell population densities with relatively high precision. This manuscript, which he is about to submit to Limnology and Oceanography Methods, is the basis of his Masters degree which was awarded in December 2015. Our intent is to deploy our Heterosigma HAB sensors in the field during Summer 2016.

2) Crowd-sourced instrumentation for networked marine environmental sensors
In previous research on this grant, we worked with our industry partners Wallingford Imaging Systems to leverage our remote sensor technology by constructing and deploying a first generation of very low cost networked sensors for the marine environment. This included trial deployment of sensor prototypes at an oyster farm near Shelton, WA, at the Center for Wooden Boats (an NGO supporting public education/outreach), and at the Clallam Bay High and Elementary School. We have now upgraded those sensors, so that they can perform video imaging to characterize fish and plankton in the marine environment. We also developed a second generation of networked temperature sensors, which is significantly reduced in size and cost, and substantially improved in battery life and ease of construction, relative to the first. The new sensors use micropython -based microcontrollers to record sensor readings and upload real-time data, making them both more stable and easier to use by stakeholders and students. We developed low-cost methods for constructing environmentally robust strings of digital temperature sensors, to obtain continuous temperature profiles across the top 5-20 meters of the near-shore water column – the most relevant depth range for oyster growers and other stakeholders, and critical information for geophysical modelers. In addition to temperature, we developed a very low-cost *Heterosigma* HAB detector based on transmissometry rather than cell-level imaging, which induces bioconvection to concentrate cells internally to maximize sensitivity. This new sensor is the basis of a Record of Invention filed through the University of Washington. We intend to test-deploy the new generation of sensors during Summer 2016.

3) STEM/Ocean Technology Education
We provided ocean technology and curricular materials developed using Washington Sea Grant funding to a number of STEM education initiatives. Engineering is the STEM area in which teachers are typically least prepared to educate students. We engaged with students at the Chief Kitsap Academy of the Suquamish Tribe, teaching them to construct sensors, deploying them in the marine environment in front of their school, and working with them to analyze and interpret their data. We also worked with teachers and students at the Clallam Bay High and Elementary School, teaching them a range of oceanography topics spanning ocean technology, ocean ecology including Harmful Algal Blooms, biophyics of organism sensing and locomotion, and data analysis. Clallam Bay currently has a one of our student-built temperature sensor arrays streaming data. An interdisciplinary team of UW graduate students is working with a Jane Adams Middle School class to build and deploy sensors in their wetland. Our WSG-funded ocean technology is also a central focus of the Olympic STEM Partnership Program, a STEM education initiative directly involving 45 middle and high school teachers and indirectly involving 90 others. Working with this program, we have run three workshops and a webinar

in which we taught teachers to construct their own temperature sensors. WSG funded ocean technology was the foundation of a new undergraduate Ocean Technology course in the School of Oceanography, which as of the 2016-17 academic year will be required for all majors. We are currently seeking additional funding to enable this course to be taught in other institutions, with an initial focus on Grays Harbor College.