RESEARCH/PD ANNUAL REPORT - PROGRESS REPORT

2015 annual report - progress
Elizabeth Nesbitt
Fine Scale Monitoring of Puget Sound Ecosystems using Benthic Foraminifera
R/HCE-5
Submitted On: 04/25/2016 07:23:26 PM

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	20	This includes students and community members volunteered for the program, doing active presentations in the lobby of the Burke Museum and talking to members of the public about the project.
Stakeholders who receive information	2000	This includes museum-goers, student groups, and attendees at the annual Undergraduate Research Symposium were student researchers present their findings on research they have done with the project.300
Volunteer hours	300	Includes both behind the scenes volunteers and those who work in the Burke lobby.
P-12 students reached	1000	
P-12 educators	0	

REQUESTED INFORMATION

Publications

Rapid deterioration of sediment surface habitats in Bellingham Bay, Washington State, as indicated by benthic foraminifera
Publication Type: Peer-reviewed: Journals (incl. articles), Books, Proceedings, and Other Documents
Publication Year: 2015
Publication Authors:
Publisher Info: Marine Pollution Bulletin Published by Elsevier
Notes:
Related URLs:
Keywords: Benthic foraminifera, Puget Sound, Pollution Dissolved oxygen, Increased acidity
Publication URLs:
Abstract: Foraminiferal assemblages in sediment grab samples were utilized to evaluate the

impacts of anthro- pogenic activities on benthic habitats in Bellingham Bay, Washington State, U.S.A. Seventy-three samples taken in 1987, 1997, 2006 and 2010 yielded 35 species of foraminifera from 28 genera. Assemblage com- position and diversity data indicate a marked deterioration between 1987 and 2010, contrary to the pub- lished Chemical Index, but analogou to the situation with macrobiota. Correlation of diversity with chemical pollutants and metals did not identify any significant correlations, however, an unrelated but highly relevant study of bottom water dissolved oxygen concentrations and pH in Bellingham Bay sug- gests eutrophication with accompanying hypoxia and acidification may be part of the cause. Thus, the metrics of contamination alone do not adequately characterize habitat viability, and benthic foraminif- eral assemblages provide insight into the health of coastal ecosystems.
Citation: Marine Pollution Bulletin 97 (2015) 273–284
Citation for Coverpage:
SG can post PDF online?:
Uploaded File: Marine_Pollution_Bulletin_2015_NESBITT.pdf

Foraminiferal evidence of sediment toxicity in anthropogenically influenced embayments of Puget Sound, Washington, U.S.A.
Publication Type: Peer-reviewed: Journals (incl. articles), Books, Proceedings, and Other Documents
Publication Year: 2015
Publication Authors:
Publisher Info: Marine Micropaleontology Published by Elsevier
Notes:
Related URLs:
Keywords: Benthic foraminifera, Pollution, Anthropogenic impact, Toxicity, Puget Sound
Publication URLs:
Abstract: Environmental monitoring in estuarine settings depends on sediment quality guidelines and standards (SQG and SQSs) developed using scientific investigation and analysis The purpose of this study was to utilize benthic fora- minifera as a proxy for assessing the healt of two severely impacted embayments within the complex fjordal system of Puget Sound (Washington, United States of America) and testing the efficacy of the standards used in monitoring the Sound. The embayments, Sinclair and Dyes inlets, have been subjected to contamination by military, industrial, residential and agricultural effluents for over 100 years, resulting in some of the most toxic marine sediments in Puget Sound. Although the results of chemical tests were within acceptable limits of the State monitored SQSs, toxicity and biotic assessments were not. The present study found that benthic foraminif- eral assemblages were notably of low species diversity and strongly dominated by species tolerant of various contaminants and dysoxia. Foraminiferal density and diversity deteriorated between 1974 and 2008, with Sinclair Inlet showing a near collapse of foraminiferal assemblages by 2008. A similar trend was seen in the benthic macroinvertebrates studied by the Washington State Department of Ecology. In addition, large numbers of calcareous foraminiferal tests showed signs of dissolution, particularly in Sinclair Inlet; these numbers increased in later sampling years, as did the number of samples that were barren of foraminifera. This suggests a need for re-examination of the metrics used to set environmental standards and the need for better understanding of the compounding effects of contaminants on the biota.
Citation: Marine Micropaleontology 121 (2015) 97–106
Citation for Coverpage:
SG can post PDF online?: No
Uploaded File: Marine_Micropaleontology_2015_Martin.pdf

Students Supported

Jacqueline Divita (Continuing Student)
jacdivita@gmail.com
University of Washington, Earth and Space Sciences

Field of Study: Earth and Space Sciences
Advisor: Nesbitt
Degree Type: BS

Degree Year: 4

Student Project Title: Foraminifera: Indicators of Pollution in Commencement Bay, Puget Sound, Washington

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

Post-Graduation Plans (employer, grad school, etc.): Employer, possible graduate school

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

Thesis / Dissertation:

New or Continuing?: continuing

Degree awarded this reporting period?: Yes

Financially supported?: Yes

Elizabeth Grant (Continuing Student)
grant9@uw.edu
University of Washington, Earth and Space Sciences

Field of Study: Earth & Space Sciences/Biology
Advisor: Nesbitt
Degree Type: BS
Degree Year: 2016

Student Project Title: Superfund site Eagle Harbor shows low Foraminifera species diversity

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

Post-Graduation Plans (employer, grad school, etc.): Graduate School in Boston

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

Thesis / Dissertation:

New or Continuing?: continuing

Degree awarded this reporting period?: Yes

Financially supported?: Yes

Keelin Lacey (Continuing Student)
klacey@uw.edu
University of Washington, Earth and Space Sciences

Field of Study: Earth and Space Science
Advisor: Nesbitt
Degree Type: BS
Degree Year: 2015

Student Project Title: Assessing water quality in San Juan Islands, Washington, using benthic foraminifera

Involvement With Sea Grant This Period (capstone, fellow, intern, etc.): Student

researcher

Post-Graduation Plans (employer, grad school, etc.): job with geological consulting company

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

Thesis / Dissertation:

New or Continuing?: continuing

Degree awarded this reporting period?: Yes

Financially supported?: Yes

Narratives

Fine Scale Monitoring of Puget Sound Ecosystems using Benthic Foraminifera R/HCE-5
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Partners This Period

Washington Department of Ecology
Types: Government
Scale: STATE
Notes: Provides sediment samples and analytical data

University of Washington, Burke Museum of Natural History and Culture (UW)
Types: Academic Institution
Scale: STATE
Notes: Provides office and laboratory space and equipment

Prof. Daniel Fredericks
Types: Academic Institution
Scale: STATE
Notes: Austin Peay University, Clarksville, Tennessee

Austin Peay University
Types: Academic Institution
Scale: STATE
Notes: Prof. Daniel Fredericks; Austin Peay University, Clarksville, Tennessee

STANDARD QUESTIONS

Impacts and Accomplishments

(1)

Type	accomplishment
Title	Washington Sea Grant research studies microscopic foraminifera to assess environmental health of Puget Sound sea-bottom ecosystems
	Assessing environmental health and monitoring mitigation efforts are pressing concerns throughout Puget Sound. Efforts to do so have focused on

Relevance	chemical indices and macroinvertebrate data, but have not accounted for the microbiota that are essential components of the ecosystem. By contrast in other estuaries, tiny benthic shelled protists, called foraminifera, have served as an inexpensive tool for measuring the health of benthic ecosystems and the success of remediation. Because foraminifera are microscopic and ubiquitous in marine sediments, investigations can be conducted at a fine scale.
Response	This project continued the work of previously funded Washington Sea Grant research pioneering the use of foraminifera as indicators for Puget Sound health. Researchers further developed a foraminiferal tool for ecosystem monitoring and applied the tool to individual embayments, from the San Juan Islands to the Eagle Harbor Superfund site and industrialized Commencement Bay. The tool employed multiple indicators, including the composition, density and diversity of the assemblages.
Results	In heavily impacted embayments, foraminiferal assemblages showed low density and diversity, dominance by pollution-tolerant species, and large numbers of partially dissolved individuals. With efficacy established and findings published, this tool is now being applied to many parts of the Sound. Project members have demonstrated its operation to grade-school and college students and other local groups, advancing public knowledge of Puget Sound's condition.
Recap	Washington Sea Grant-supported researchers developed and tested a low-cost tool for monitoring the health of Puget Sound's benthic ecosystems, a tool which is now being more broadly applied.
Comments	
Primary Focus Area	Healthy Coastal Ecosystems
Secondary Focus Areas	Resilient Communities and Economies,Ocean Literacy and Workforce Development
Goals	Ocean and coastal resources are managed using ecosystem-based approaches.|Coastal water resources sustain human and ecosystem health.|The future workforce is skilled in disciplines critical to coastal and ocean economies and ecosystem health.
Partners	Austin Peay University University of Washington, Burke Museum of Natural History and Culture (UW) Washington State Department of Ecology
	* Type impact * Title Fine Scale Monitoring of Puget Sound Ecosystems using Benthic Foraminifera * Relevance Assessing environmental health and monitoring effects of mitigation efforts is a concern throughout Puget Sound. Methods to accomplish this

PI Draft	have so far focused on the use of chemical indices and data from macroinvertebrates, but have not accounted for the microbiota, which are essential components of the ecosystem. In other estuaries, microscopic benthic shelled protists, called foraminifera, are used as an inexpensive tool to measure the health of benthic ecosystems and the impacts of remediation. * Response A previous WSG project pioneered the use of foraminiferal indicators in Puget Sound. This project continued the work of developing a foraminiferal tool for ecosystem monitoring and applied this tool to individual embayments in the Sound. Because foraminifera are microscopic and ubiquitous in marine sediments, investigations can be conducted at fine scale. * Results Our monitoring tool developed utilizes multiple indicators. In embayments that have been heavily impacted by stresses, foraminiferal assemblages show low density and diversity, dominance by pollution-tolerant species and the presence of partially dissolved individuals. The results from using this tool have been applied to numerous parts of the Sound and the findings published. Outreach efforts by members of this project have reached public school and college students and members of the public through presentations and demonstrations designed to promote awareness of environmental issues. * Recap This Washington Sea Grant project developed a tool for monitoring the health of Puget Sound benthic ecosystems while at the same time promoting public awareness of environmental issues. Comments Primary Focus Area Healthy Coastal Ecosystems Secondary Focus Areas Ocean Literacy and Workforce Development Goals Ocean and coastal resources are managed using ecosystem-based approaches.,The public is ocean literate.,The future workforce is skilled in discilines critical to coastal and ocean economies and ecosystem health. Partners Washington Department of Ecology Burke Museum, University of Washington

Tools, Technologies, Information Services / Sea Grant Products

(1)

Description	Project Website - Puget Sound Foram Research Project (http://www.burkemuseum.org/blog/curated/puget-sound-foram-research-project)
Developed (in the reporting period)?	Yes
Used (in the reporting period)?	Yes
Used for EBM?	

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	Undergraduate Research Symposium University of Washington Title of Presentation: Foraminifera: Indicators of Pollution in Commencement Bay, Puget Sound, Washington Presenter: Jacqueline Divita
Event Date	05-15-2015
Number of Attendees	1000

(2)

Type of Event	Public or professional presentation
Description	Undergraduate Research Symposium University of Washington Title: Assessing water quality in San Juan Islands, Washington, using benthic foraminifera. Presenter: Keelin Lacey
Event Date	5/15/2015
Number of Attendees	0

(3)

Type of Event	Public or professional presentation
Description	Geolgical Society of America Annual Meeting, Baltimore, MD Title: ENVIRONMENTAL IMPLICATIONS OF CHANGES IN BENTHIC FORAMINIFERAL ASSEMBLAGES IN SOUTHERN PUGET SOUND, WASHINGTON STATE, USA Presenters: Daniel L. Frederick, Britney E. Dreher, Ruth A. Martin, Elizabeth A. Nesbitt
Event Date	11/4/2015
Number of Attendees	200

Leveraged Funds

No **Leveraged Funds** information reported

Fine Scale Monitoring of Puget Sound Ecosystems using Benthic Foraminifera R/HCE-5

Introduction

The purpose of this project is to build on work done by the Puget Sound Foram Research Project at the Burke Museum, University of Washington to complete development of a low-cost, reproducible proxy for fine-scale assessment and monitoring the health of Puget Sound ecosystems and to test the application of this tool on some of the most at-risk areas of Puget Sound. In this project we use sediment samples, cores and data obtained from the Washington Department of Ecology to develop a reproducible tool utilizing benthic foraminifera (microscopic, shelled protists) for evaluating and monitoring the health of Puget Sound, as well as adding substantially to the body of information on the Sound and its ecosystems. To accomplish this, we hired a full-time post-doctoral fellow experienced in this field as project manager and undergraduates at the University of Washington to conduct the research and outreach activities.

What we have accomplished

From February 1, 2015 to January 31, 2016, WSG funds continued to support three undergraduate were hired as student researchers to continue the work of the Puget Sound Foram Research Project. In April and June, 2015, Washington Department of Ecology (WDOE) collected 43 more samples, bringing the total we have to ~850.

Two peer-reviewed papers reporting on work done by the project were published this year:

- *Foraminiferal evidence of toxicity in Sinclair and Dyes Inlets, Bremerton, WA, U.S.A.*, which was published in the journal Marine Micropaleontology. Citation Marine Micropaleontology 121 (2015) 97–106
- *Rapid deterioration of sediment surface habitats in Bellingham Bay, Washington state, as indicated by benthic foraminifera,* was published in Marine Pollution Bulletin. Citation Marine Pollution Bulletin 97 (2015) 273–284

This year's students, Elizabeth Grant, Keelin Lacey and Jacqueline Divita concentrated on three different areas: the Eagle Harbor superfund site, the San Juan Islands, and Commencement Bay (Fig. 1). In Eagle Harbor samples, foraminiferal assemblages were found to have low diversity and a large number of individuals showing signs of partial dissolution. Samples from the San Juan islands displayed variable diversity which was highest in samples from outside heavily trafficked embayments. Roche Harbor and Westcott Bay had a large number of partially dissolved individuals. In Commencement Bay, although there were low diversity and a large number of dissolved specimens, the diversity appears to be improving. The PI and project manager are presently preparing a paper for publication on Commencement Bay.

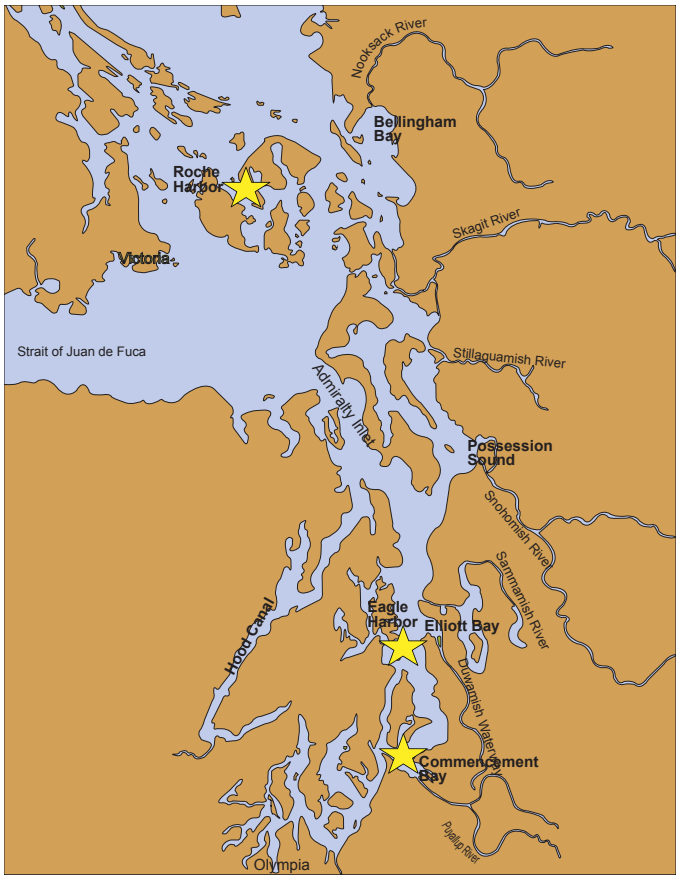

Figure 1. Locations of study areas used by this year's student researchers

Outreach

Student researchers presented their work on this project at the UW Undergraduate Research Symposium on May 15, 2015. Poster presentations were given by Jacqueline Divita on her work on Commencement Bay and by Keelin Lacey on the San Juan Islands. Elizabeth Grant gave a talk reporting on her work on the Eagle Harbor area.

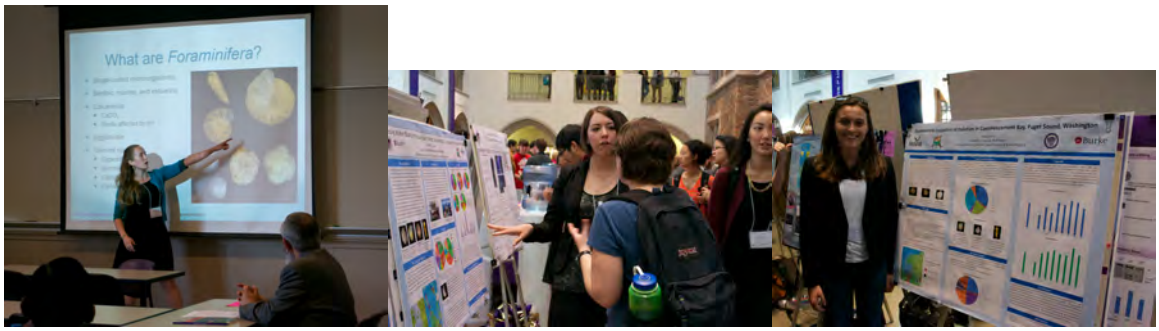

Figure 2. Foram Project students Elizabeth Grant, Keelin Lacey, and Jacqueline Divita present their research findings at the 2015 Undergraduate Research Symposium

Each year the Burke Museum hosts a "Behind the Scenes" evening in which museum members are allowed to explore the usually unseen areas of the museum and talk to researchers. An entire room in the Geology Division was devoted to the Puget Sound Foram Research Project, where we set out microscopes, cameras linked to iPads, photographs, research posters, and equipment. All students participated in the evening, interacting with the public, explaining various aspects of our work and demonstrating equipment and techniques. Approximately 700 members of the public toured the museum that evening.

Continuing a project that started in 2014, the Puget Sound Foram Research Project is an integral component of the Burke Reveal Team (BuRT), which acquaints the public with research being conducted behind the scenes at the Burke and with the issues eing explored in this research. Volunteers trained by the PSFRP post-doctoral fellow, Ruth Martin, continue to demonstrate and explain the work and assist members of the public with microscopes and other equipment. Microscopes used in the exhibit were purchased with WSG funds.

Figure 3. Volunteer works in the museum gallery explaining aspects of the project to visitors.

Challenges

The biggest challenge we have met is time. Many aspects of the project took much longer than we anticipated at the start. For example, many samples are so full of organic matter that they are extremely difficult to process. Others have very few foraminifera compared with the volume of sediment and it is necessary to float these in trichloroethylene before they can be picked. This chemical is difficult to obtain, taking weeks to ship and arrive when ordered.

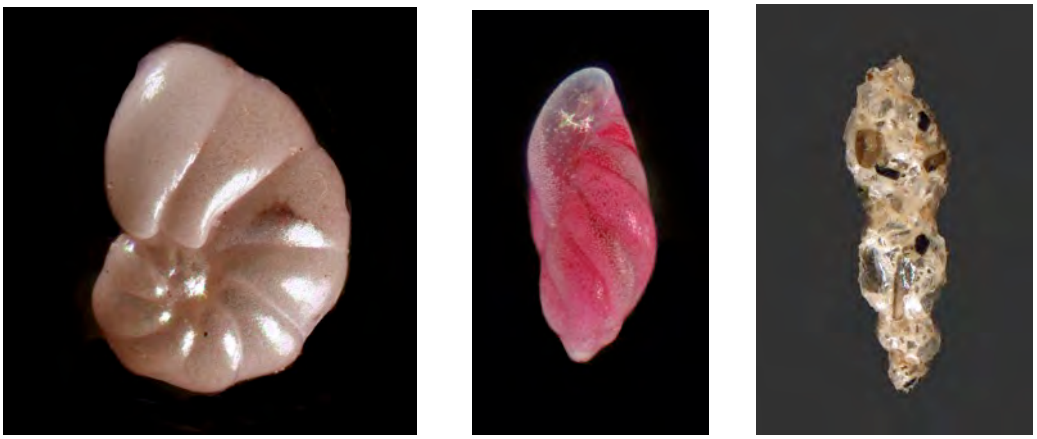

Figure 4. Examples of images of Puget Sound foraminifera

Development of a monitoring tool also proved challenging due to the complexity of Puget Sound itself, and to the composition of foraminiferal species assemblages. Researchers in other estuaries and coastal areas are able to use a pollution index that utilizes the ratio of two foraminifera species not present in Puget Sound in substantial numbers. Our monitoring tool is thus not a simple ratio of one species to another, but incorporates assemblage composition, and density and diversity information for the species that are present. Poor sediment conditions are indicated by

- low foraminiferal density (numbers of individuals present), sometimes as low as 0,
- low diversity (lower even than many other polluted estuaries),
- dominance of stress-tolerant species,
- presence of large numbers of calcareous specimens showing partial dissolution (indicating excess acidity).

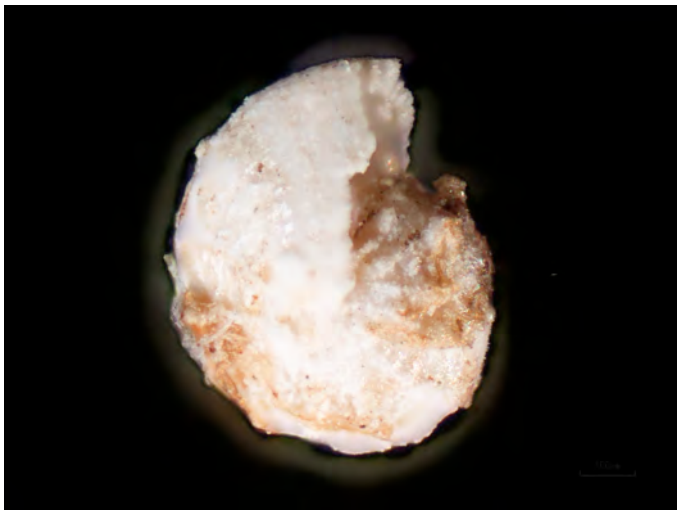

Figure 5. Foraminiferal specimen showing partial dissolution of its shell, indicating excess acidity.

For example, it is clear from work in Bellingham Bay that the presence of large numbers of the agglutinated taxon *Eggerella advena* coupled with a paucity of calcareous species, and a high percentage of partially dissolved calcareous specimens, is indicative of poor bottom conditions including high acidity. Since no single pollutant we have compared with our assemblages stands out as a cause of degraded foraminiferal assemblages, the deterioriation is most probably due to a combination of factors such as chemical pollutants, high acidity and low oxygen. The effects of these stressors may not be simply additive, but compounding, which is why the results are devastating to the foraminifera and causes are difficult to identify. We are presently preparing a paper on this tool to be submitted to *Northwest Science*, and we are applying it to other parts of the Sound.

Since foraminifera are low on the food chain, consumed by snails, sand dollars, tiny fish and anything else fairly small, perturbations at this level must reverberate throughout the ecosystem. It is clear, then, that Puget Sound foraminifera have a story to tell about the environment in which they live, and that story is a useful tool in the assessment of the well-being of the Sound and other estuaries.