

Update Report

Nesbitt, Elizabeth

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

Project: R/COCC-3 - *Using Microbiota for the Evaluation and Monitoring of Puget Sound Ecosystems*

:: STUDENTS SUPPORTED

Coberly, Jerilyn, jerilync@uw.edu, University of Washington, Earth and Space Science, status:new, *no field of study*, advisor:Elizabeth Nesbitt, degree type:BS, degree date:2014-06-01, degree completed this period:No
Student Project Title:

Foraminifera of Dyes Inlet and Sinclair Inlet, Puget Sound

Involvement with Sea Grant This Period:

Student researcher

Post-Graduation Plans:

Graduate school - paleontology or environmental safety

Danner, Adrienne, adann83@uw.edu, University of Washington, Earth and Space Sciences, status:new, *no field of study*, advisor:Elizabeth Nesbitt, degree type:BS, degree date:2013-12-01, degree completed this period:No
Student Project Title:

Temporal assessment of foraminiferal assemblages in Semiahmoo Bay, Puget Sound

Involvement with Sea Grant This Period:

Student researcher, honors project

Post-Graduation Plans:

Graduate school - Puget Sound Foraminifera Project

Hansen, Chase, chase44h@uw.edu, University of Washington, Earth and Space Sciences, status:new, *no field of study*, advisor:Elizabeth Nesbitt, degree type:BS, degree date:2014-06-01, degree completed this period:No
Student Project Title:

An Atlas of Puget Sound Foraminifera

Involvement with Sea Grant This Period:

Student Researcher

Post-Graduation Plans:

Graduate school

Jamieson, Darcy, darcyj13@uw.edu, University of Washington, Earth and Space Sciences, status:cont, *no field of study*, advisor:Elizabeth Nesbitt, degree type:BS, degree date:2012-06-01, degree completed this period:Yes
Student Project Title:

Foraminiferal Diversity in Port Madison, Washington

Involvement with Sea Grant This Period:

Student researcher, honors project

Post-Graduation Plans:

Graduate school

Tomlinson, Robert, robtom001@u.washington.edu, University of Washington, Earth and Space Sciences, status:cont, *no field of study*, advisor:Elizabeth Nesbitt, degree type:BS, degree date:2012-06-01, degree completed this period:Yes

Student Project Title:

Foraminifera of Bellingham Bay

Involvement with Sea Grant This Period:

Student researcher

Post-Graduation Plans:

Work in geotechnical field

Zhang, Bijia, bijaz@uw.edu, University of Washington, Earth and Space Sciences, status:new, *no field of study*, advisor:Elizabeth Nesbitt, degree type:BS, degree date:2014-06-01, degree completed this period:No

Student Project Title:

Foraminiferal Assemblages of Sinclair Inlet and Dyes Inlet, Puget Sound

Involvement with Sea Grant This Period:

Student researcher

Post-Graduation Plans:

graduate school

:: CONFERENCES / PRESENTATIONS

Burke Museum Behind-the-Scenes Night, public/profession presentation, 496 attendees, 2013-02-20

University of Washington Undergraduate Research Symposium Poster Presentation: Foraminiferal Diversity in Port Madison, Washington, public/profession presentation, 1000 attendees, 2012-05-18

Geological Society of America Annual Meeting, Charlotte, N.C. Poster Presentation: DISTRIBUTION OF BENTHIC FORAMINIFERA IN THE SOUTHERN SALISH SEA, WASHINGTON STATE AND BRITISH COLUMBIA

, public/profession presentation, 150 attendees, 2012-11-07

Geological Society of America Annual Meeting, Charlotte, N.C. Talk: ENVIRONMENTAL FACTORS INFLUENCING FORAMINIFERAL DISTRIBUTION IN BELLINGHAM BAY, NORTHERN PUGET SOUND, public/profession presentation, 70 attendees, 2012-11-07

Geological Society of America Annual Meeting, Charlotte, N.C.

chaired session T119. The Role of Microfossils in Environmental Monitoring, public/profession presentation, 250 attendees, 2012-11-07

Burke Museum Behind-the-Scenes Night, public/profession presentation, 410 attendees, 2012-02-19

University of Washington Undergraduate Research Symposium Poster Presentation: Documenting Environment Shifts in Puget Sound Using Benthic Foraminifera, public/profession presentation, 1000 attendees, 2012-05-18

:: ADDITIONAL METRICS

K-12 Students Reached:0

Acres of degraded ecosystems restored as a result of Sea Grant activities:0

Curricula Developed:0

Resource Managers who use Ecosystem-Based Approaches to Management:0

Volunteer Hours:1575

HACCP - Number of people with new certifications:0

Micropaleontologist Jess Spear volunteers 3-4 days per week to work on the project, with emphasis on Hood Canal samples. Various student volunteers who washed samples. David Martin who did statistical analyses 22 students at North Seattle Community College analyzed DOE samples for their applied science projects under the instruction of Dr. Tracy Furutani. Their data was supplied to this project. Numerous student and adult volunteers in the Geology Division washed samples, kept records and labeled processed samples.

Cumulative Clean Marina Program -0 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 (2/1/2012 - 1/31/2013) :

Anticipated (2/1/2013 - 1/31/2014) :

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) :

Coastal Ecosystems

Actual (2/1/2012 - 1/31/2013) :

Anticipated (2/1/2013 - 1/31/2014) :

:: PARTNERS

Partner Name: Burke Museum Geology Division, type: academic, scale: local

Partner Name: North Seattle Community College

Partner Name: Washington Department of Ecology

:: IMPACTS AND ACCOMPLISHMENTS

Title: Washington Sea Grant-supported project is the first to use foraminifera as an indicator of Puget Sound ecosystem health

Type: accomplishment

Description:

Relevance: Foraminifera are microscopic shelled organisms that inhabit marine sediment. Because of their responses to environmental stressors like pollution and habitat degradation, foraminifera can serve as indicators of ecosystem health. Puget Sound is the only major industrialized estuary in North America where no comprehensive foraminifera study has been conducted.

Response: Washington Sea Grant-funded researchers are analyzing foraminifera populations in Puget Sound with the goals of better understanding the Sound's ecosystems and developing a low-cost, reproducible tool for evaluating and monitoring its health. The team has processed about 1,200 samples dating from 1997 to the present from various sites around Puget Sound.

Results: The project has established the base species composition and regional distribution of Puget Sound foraminifera, published in the Journal of Foraminiferal Research. A statistical analysis shows that four species of calcareous foraminifera (having shells made of calcium carbonate) are dominant. (Others, called agglutinated foraminifera, have shells of cemented sediment.) Initial analyses show no clear relationship between the distribution of foraminifera and such environmental factors as depth, substrate type, salinity, temperature or total organic carbon. But the diversity of foraminifera in one embayment, Bellingham Bay, has diminished over the years, and very few calcareous foraminifera remain there. Researchers are now reviewing state water pollution data to determine what environmental stressors the foraminifera may be responding to – an early use of this key biological benchmark in Washington waters.

Recap:

Washington Sea Grant-supported research maps the distribution of microscopic foraminifera in Puget Sound for the first time, establishing a new, cost-effective tool to monitor the Sound's ecological health.

Comments:

Primary Focus Area: OCEH (HCE)

Associated Goal: Improve understanding and management of emerging and cumulative threats to ocean and coastal health (HCE, Science).

Related Partners:

North Seattle Community College

University of Washington, Burke Museum of Natural History and Culture (UW)

Washington State Department of Ecology

:: PUBLICATIONS

Title: Distribution of benthic foraminifera in the southern Salish Sea, Washington state and British Columbia

Type: Workshops, Proceedings, Symposia Including Highlights/Summaries of (please note: document number reflects the year the proceedin Publication Year: 2012

Uploaded File: *none*

URL: *none*

Abstract:

This investigation is the first comprehensive study of benthic foraminifera in the Salish Sea, a small sea bordered to the east by British Columbia and Washington state and to the west by Vancouver Island and the Olympic Peninsula. The study was conducted in the southern Salish Sea, which includes Puget Sound and the area north to the Canadian border. Samples were collected by the Washington Department of Ecology as part of the Puget Sound Assessment and Monitoring Program, and span the time period from 1997 to the present. Ten sites, termed Temporal sites, were sampled annually and cover all parts of Puget Sound and north to Drayton Harbor near the Canadian border. Other sites were sampled on a rotating basis concentrating on one area (north, central, south) each year. For this study, 64 samples were investigated, including multiple years of temporal samples from Bellingham Bay (north Sound), Possession Sound (central Sound), and Commencement Bay (south Sound). Forty-nine species of benthic foraminifers were present, however, the assemblage was dominated by four species, *Elphidium hannai*, *E. excavatum*, *Buccella frigidum*, and *Eggerella advena*. Species richness was variable, ranging from one to 12 species per sample; foraminiferal density was likewise variable, ranging from one to over 6000 individuals per gram of dry sediment. Samples with the highest density occurred in the northern bays and in Possession Sound. No geographic or temporal trends were noted in species richness. Agglutinated species were most abundant in the northern part of the study area, virtually absent in the central part, and present in small numbers in southern Puget Sound. Multi-dimensional scaling and canonical correspondence analysis were carried out using the environmental parameters depth, sediment type, salinity and temperature. These indicate sediment type and depth are the most important factors controlling foraminiferal distribution. This does not, however, explain the strong dominance of agglutinate foraminifera and high densities in the north, and this requires further investigation.

Citation:

Martin, R.A., E.A. Nesbitt, and D.E. Martin. 2012. Distribution of benthic foraminifera in the southern Salish Sea, Washington state and British Columbia. *Geological Society of America Abstracts with Programs* 44:582.

Copyright Restrictions + Other Notes:

Journal Title: *none*

Title: **Documenting Environment Shifts in Puget Sound Using Benthic Foraminifera**

Type: Workshops, Proceedings, Symposia Including Highlights/Summaries of (please note: document number reflects the year the proceedin Publication Year: 2012

Uploaded File: *none*

URL: *none*

Abstract:

This project focuses on using microbiota to determine environmental changes in Puget Sound, specifically benthic foraminifera. Benthic foraminifera are single celled organisms that produce a shell and live at the bottom of the ocean. Because foraminifera have characteristic ecologic requirements, they can be used to document environmental changes over time. In addition, foraminifera's short reproductive cycle (weeks to months) and species specific reactions to environmental changes enable high resolution studies of ecosystem health and reaction to mitigation efforts. By examining the density, diversity and assemblage composition of foraminifera in samples of sediment several determinations can be made about environment in the local region at the time the sediment was deposited. This study focuses on stations in Bellingham Bay, WA using 11 sediment samples taken between 1997 and 2011 by the Washington state Department of Ecology. From 2002 to 2006 a clear drop in foraminiferal density is observed in Bellingham Bay. This indicates a serious change in environment for the area during this period; changes that may include an increase or decrease in pollution, an increase in pH, or changing climatic conditions. In the Bellingham Bay area a very low species diversity is also observed. This lack of diversity can also indicate various climatic or other environmental conditions. For example, the most dominant

species in these samples, *Eggerella advena*, is known to colonize areas of sewage pollution in other bays. By comparing the Bellingham Bay stations to others in Puget Sound, it will be possible to document environmental shifts over the last 15 years.

Citation:

Tomlinson, R., E. Nesbitt, and R. Martin.. 2012. Documenting environment shifts in Puget Sound using benthic foraminifera. University of Washington Undergraduate Research Symposium, May 18, 2012.

Copyright Restrictions + Other Notes:

Journal Title: *none*

Title: **Foraminiferal Diversity in Port Madison, Washington**

Type: Workshops, Proceedings, Symposia Including Highlights/Summaries of (please note: document number reflects the year the procedin Publication Year: 2012

Uploaded File: *none*

URL: *none*

Abstract:

Puget Sound is home to countless aquatic species, all of whom are dependent on healthy water conditions. At the bottom of the trophic web are foraminifera—single celled organisms that directly reflect the environment they live in, because each species has a very narrow range of acceptable habitats. Foraminifera can be used to assess local conditions on a very fine scale, and to assess the large-scale health of the body of water. This type of study has been done on numerous bodies of water throughout the world and is well proven, but has never been applied to Puget Sound. As a small part of this overarching project, I focus on identifying and analyzing foraminifera from Port Madison, a part of Puget Sound relatively sheltered from anthropogenic impact. Port Madison thus acts as a control with which to compare samples from other locations in Puget Sound. Preliminary results indicate that Port Madison has a very high diversity of foraminifera with at least 12 different species immediately apparent, but a relatively low abundance of about 28 foraminifera per gram of sediment. In comparison with other locations throughout Puget Sound, this shows that anthropogenic conditions decrease the diversity of foraminifera, and areas like Port Madison where little anthropogenic activity is present yield higher diversity. Data from sheltered areas help build a knowledge base for a healthy Puget Sound, which in turn gives us an idea of what to work toward in future attempts to promote a healthier Puget Sound.

Citation:

Jamieson, D., E. Nesbitt, R. Martin. 2012. Foraminiferal diversity in Port Madison, Washington. University of Washington Undergraduate Research Symposium, May 18, 2012

Copyright Restrictions + Other Notes:

Journal Title: *none*

Title: **Environmental factors influencing foraminiferal distribution in Bellingham Bay, Northern Puget Sound**

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

Uploaded File: *none*

URL: *none*

Abstract:

The purpose of this study was to monitor foraminiferal assemblages in Bellingham Bay, northern Puget Sound, Washington, over time and correlate any changes with known environmental factors. Bellingham Bay is located northeast of the Straits of Juan de Fuca and is separated from the Straits of Georgia by the Lummi Peninsula,

Portage and Lummi islands, and is bordered to the east by the city of Bellingham. Freshwater input comes primarily from the Nooksack River that originates on the volcanic peak of Mt. Baker. Sediment size is dominantly silt and clay.

Benthic infaunal indices in Bellingham Bay are low, though they increase southward, and degraded sediment conditions have been recorded. Ten foraminiferal samples from a single (temporal) site, collected by the Washington Department of Ecology between 1997 and 2012, were utilized. In addition, several samples from other parts of Bellingham Bay were examined for comparison. Results from the single temporal site show extremely high foraminiferal density (as high as 6120 individuals/gram dry sediment) in many sites. Conversely, some of the additional samples produced no foraminifera at all, and consisted of only comminuted plant debris. Species richness varied between 1 and 12, with the highest in the inner harbor sample and lowest in the temporal sample collected in 2006. The temporal samples showed a striking trend of decreasing foraminiferal density over the time studied. *Elphidium advena*, a highly tolerant species known to be an opportunistic colonizer of polluted areas particularly those impacted by sewage, was the dominant species in the temporal samples; this site lies offshore the sewage treatment plant for the City of Bellingham. The proportion of *E. advena* in these samples decreased over time, possibly due to implementation of a comprehensive storm-water management plan beginning in 1997. The plan was updated in 2007. In 2004, the proportion of *E. advena* rose suddenly and then fell again in subsequent years. The fluctuations could be attributed to major storms and flooding that occurred at the end of 2003 and which overwhelmed the storm-water system and may have released sewage into the Bay.

Citation:

Nesbitt, E.A., R.J. Tomlinson, and R.A. Martin. 2012. Environmental factors influencing foraminiferal distribution in Bellingham Bay, Northern Puget Sound. Geological Society of America Abstracts with Programs 44:523.

Copyright Restrictions + Other Notes:
Reported in AR2012

Journal Title: *none*

Title: **DISTRIBUTION OF FORAMINIFERA IN PUGET SOUND, WESTERN WASHINGTON, U.S.A.**

Type: Reprints from Peer-Reviewed Journals, Books, Proceedings and Other Documents Publication Year: 2013
Uploaded File: [Martin et al. 2013 JFR.pdf](#), 3266 kb

URL: *none*

Abstract:

Puget Sound, the southern portion of the Salish Sea, has been intensely studied for its macrofauna, but lacks a comprehensive study of its benthic foraminifera. The Sound is a fjord-like lowland consisting of numerous smaller estuaries. Much of it has been heavily impacted by anthropogenic activities, and two locations have been designated as federal Superfund sites. The purpose of this investigation was to survey the benthic foraminifera present in Puget Sound and relate their distribution to environmental parameters. The 64 grab samples used were provided by the Washington Department of Ecology through their annual Puget Sound Ambient Monitoring Program and span the years 1997 to 2010. The investigation recorded 46 species of benthic foraminifera, with four species dominating the assemblages: *Elphidium advena* (Cushman, 1921), *Elphidiella hannai* (Cushman and Grant, 1927), *Elphidium excavatum* (Terquem, 1875), and *Buccella frigida* (Cushman, 1922). Agglutinated taxa were dominant in the northern Sound and parts of the south Sound, but nearly absent in samples from the central Sound. Density and diversity indices were extremely variable throughout the Sound, even in samples taken from the same site over a number of years. Canonical correspondence analysis indicated that no single environmental parameter analyzed was responsible for the distribution of foraminifera. Cluster analysis yielded four main groups dominated by the four taxa listed above. These clusters were heterogeneous in their distribution, with samples from the same sample site grouped in different clusters in different years. The extreme heterogeneity of

the results indicates the need for a series of smaller-scale investigations focusing on individual embayments in order to better understand the foraminiferal distributions and to develop a foraminiferal monitoring tool unique to Puget Sound.

Citation:

Martin, R.A., E.A. Nesbitt, and D.E. Martin. In press. 2013. Distribution of foraminifera in Puget Sound, Western Washington, U.S.A. *Journal of Foraminiferal Research*.

Copyright Restrictions + Other Notes:

To be reported in AR2013

Journal Title: *Journal of Foraminiferal Research*

:: OTHER DOCUMENTS

No Documents Reported This Period

:: LEVERAGED FUNDS

No Leveraged Funds Reported This Period

Using Microbiota for the monitoring and evaluation of Puget Sound Ecosystems

Nesbitt_5615

Introduction

This project was designed to add to the body of information on Puget Sound and its ecosystems and to develop a low-cost, reproducible monitoring tool for evaluating and monitoring the health of the Sound. We are utilizing benthic foraminifera, microscopic shelled protists that inhabit the sediment, on or under the surface or creep up vegetation (Fig. 1). Despite their simplicity and their position at the bottom of the food chain, foraminifera are used as environmental indicators globally due to their specific habitat preferences and individual tolerances to environmental stressors. Until now, however, Puget Sound was the only major industrialized estuary in the United States without a comprehensive study of its foraminiferal assemblages.

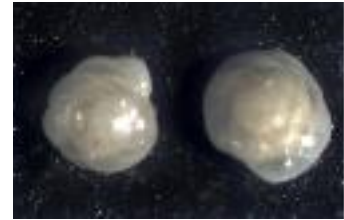


Figure 1 *Buccella frigida*, one of the most common foraminifera species in Puget Sound.

The goals of our project are to meet, at least in part, goals in all four Critical Program Areas of Washington Sea Grant. We will do this by:

1. conducting basic research that results on the foraminifera of Puget Sound, with the intention of using these results to develop a simple monitoring tool for the health of Puget Sound;
2. making our research results available to interested agencies;
3. recruiting and training University of Washington students to conduct research and design and deliver outreach;
4. developing educational presentations and exhibits for academic and general audiences.

Samples were provided by the Washington Department of Ecology, which maintains an annual sampling program in Puget Sound. Samples available to for this project date from 1997 to the present including those from 10 Temporal stations that are sampled annually. Figure 2 shows locations from which samples were collected in Puget Sound. To date we have ~1200 samples, 628 have been processed, 97 have been analyzed.

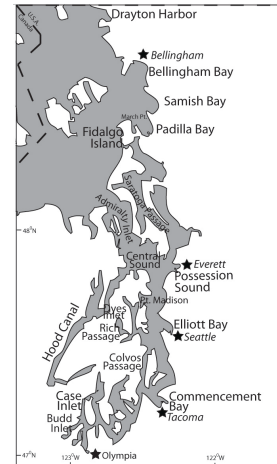


Figure 2. Locations of sampling sites.

What we have accomplished

Since the project began in early 2013, we have recruited and trained six undergraduate students to help with our research and conduct projects of their own (Fig. 3). Two students conducted and reported on their projects in May, 2012; one student concentrated on variations in foraminiferal assemblage composition taken at the same Bellingham Bay site over a 10 year period. The data he collected indicated the foraminifera had reacted to sewage overflows during storms and floods. The other student in 2012 worked with samples taken from the relatively pristine Port Madison area, and compared them with locations in the Central Basin and Elliott Bay.



Figure 3. Students at work in microfossil lab at the Burke Museum.

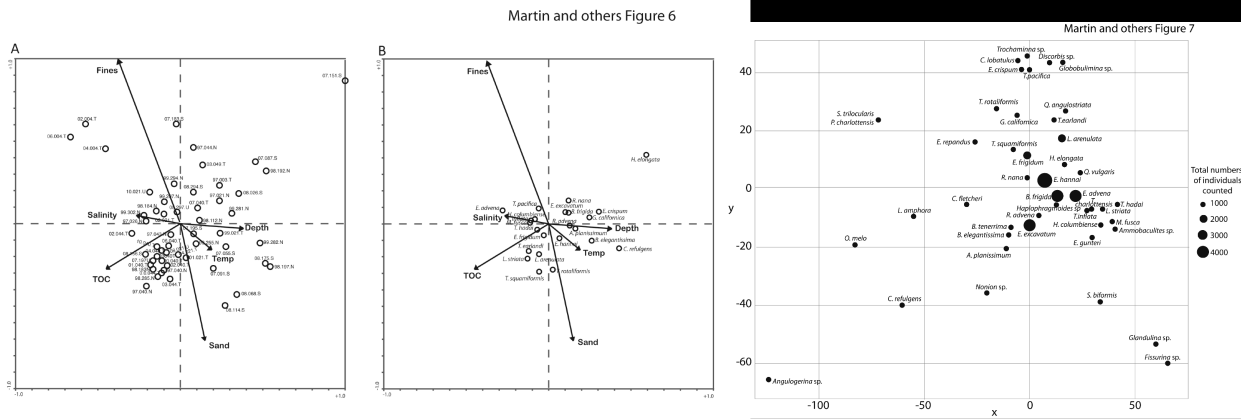


Figure 4 Canonical correspondence analysis and multidimensional scaling allow comparison of foraminiferal assemblages and environmental parameters

The Principal Investigator and Post-Doctoral Fellow used the data collected by students and themselves to do a regional-scale survey of the distribution of foraminifera in Puget Sound, correlating these distributions with environmental factors such as substrate type, salinity, temperature and total organic carbon (TOC). They documented 46 individual species of foraminifera in the Sound, dominated by four species. Statistical methods were used to correlate assemblages with environmental parameters (substrate, depth, temperature, salinity, and TOC). Canonical correspondence analysis and multidimensional scaling indicate no single parameter was responsible for distribution of the foraminifera (Fig. 4). Cluster analysis yielded four clusters, all of which were based on the same four dominant species in differing

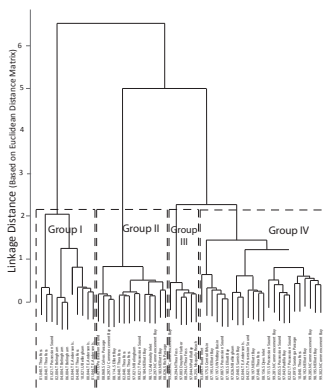


Figure 5 Cluster analysis showing four clusters divided on the basis of proportions of dominant species of foraminifera.

proportions (Fig. 5). The conclusion of this initial study of Puget Sound foraminifera was that the regional and temporal distribution of foraminifera in the Sound shows no clear relationship to the environmental parameters studied Puget

Sound differs from other estuaries that have been investigated in the large number of component small bays and estuaries, each with its own environmental conditions and impacts. In addition, the heterogeneity of distribution is extreme. It is therefore imperative to study each component area of the Sound separately.

The results of this initial, regional study are in press in the *Journal of Foraminiferal Research*. Figures 4 and 5 of this report are part of that submitted paper.

For the 2012-2013 academic year, four more undergraduate students were hired and are working on select regions of the Sound. One is concentrating on a temporal station from Semiahmoo Bay, which should act as a “control” site, as it comparatively small anthropogenic activity. Two other students are studying Sinclair inlet and Dyes Inlet, both of which are adjacent to the city of Bremerton and are thus heavily impacted by the naval shipyards. The fourth student is helping to compile and illustrate an “Atlas of Puget Sound Foraminifera”, which will serve as a reference for future studies in Puget Sound and as comparison for workers in other estuaries worldwide.

The PI and Post-Doctoral Fellow are using the student research as the basis for more in-depth studies of individual embayments. The research on Bellingham Bay in 2012 was the basis for a

rigorous study of that bay which is now in preparation for publication. Using extensive sampling done in 1997, 2006 and 2010, we have pinpointed fluctuations in assemblages and diversity and a zone of possible dys/anoxia in the sediments of the middle of the Bay. Presently we are preparing to perform carbon and oxygen stable isotope analyses on foraminiferal tests from this area to ascertain whether there is any impact on the chemistry of the tests in areas of high TOC.

Outreach

Students who work on the project present their work at the UW Undergraduate Research Symposium in May of each year. The two students in 2012 presented their research, and this year's four students are preparing their abstracts at the present time.



Figure 6 Student researcher demonstrates at 2012 "Behind the Scenes" night

All students participate in the Burke Museum Behind-the-Scene event in February (Fig. 6). At this event, members of the public tour the inner workings of the museum, We have a separate section for the Puget Sound Foraminifera Project where the student researchers interact with visitors, let them look through microscopes, and explain the project and their parts in it. One student developed a children's game that simulates looking for the right habitat for benthic foraminifera species. In April 2013 the museum will have themed weekends during which the research participants will have an exhibit that explains the project and presents posters and activities to engage the public and inform them of their work and the challenges faced by Puget Sound.

In addition to our students at the University of Washington, we have also worked with Dr. Tracy Furutani and 22 of his students from North Seattle Community College. These students were given training by the post-doctoral fellow, then analyzed samples provided by us as their applied science project in Geology. Data they gathered were given to us for use in the project.

Challenges

The biggest challenge we have met is time. Many aspects of the project are taking much longer than we anticipated at the start. For example, many samples are so full of organic matter that they are extremely difficult to pick. Others have very few foraminifera compared with the sediment and it is necessary to float these in trichloroethylene before they can be picked. We have also run up against scheduling conflicts in the isotope lab and have thus far not been able to run any of our foraminifera for isotopes. We are planning to do this within the next month.

It had also been our intention to have the "Atlas of Puget Sound Foraminifera" well on the way to publication by this time, but we have been unable to do this. We do, however, have a student doing the photography for this at present, thus we hope to finish this and submit it to *Paleontologica Electronica* for publication before the end of the academic year.

Development of a monitoring tool is also challenging; the heterogeneity in the different areas of the Sound makes a universal tool unlikely. In addition, researchers on the Gulf and east coast have used a pollution index that utilizes species not present in Puget Sound. Thus, our monitoring tool will be unique to this area, but will add substantially to the body of knowledge using foraminifera as tools for environmental assessment.