Appendix A-N

Shellfish at Work – Reducing Nutrient Pollution in the Budd Inlet Watershed

National Estuary Program (NEP) Toxics and Nutrients

Award No. G1300037

(12), 17, 47 Lines removed! 11 ft. depth

BUDD INLET MUSSEL BIOEXTRACTION DATA SHEET *(Monthly Sampling)*

Questions? Contact PSI staff at 360-754-2741

HF

Site (BHM, STM, [✓ POH], WBM): **Sample ID:** (e.g. 13BHM-0615-1)

Date: 7/17/13 **Arrival Time:** 9:11 AM **Leave Time:** 9:55 AM **Tide:** low

Mussel Collectors: Megan, Ashley, William, Andy, Aimee

Data Recorder: AC

SITE DESCRIPTION

Water Temp. (celcius): 17.3 **DO:** 130% **Salinity:** 26.33

pH: 8.13 **ORP:**

Site Description: UW students - breezy, overcast - some algal surface scum

LINE DESCRIPTION

Line #1

Location: (*See Site Map Attached for Reference*) **Position #** *(e.g. 9B)*: 12 center of Row 2

Top	Mussel set (heavy, medium, light, none)	Fouling Community Description
1 ft	heavy	enteromorpha - thin w/ voids) amphipods rough carpety algae - witches hair?
2 ft	↓	tiny sea star uniform
3 ft		throughout not a lot on weighted section
4 ft		
5 ft		
Bottom		

Notes: Super thick plankton - very orange

Business card - Drew - Hearth fire

Sample Data Sheet

BUDD INLET MUSSEL BIOEXTRACTION DATA SHEET *(Monthly Sampling)*

Site (BHM, [✓ STM], POH, WBM): **Sample ID**: (e.g. 13BHM-0615-1)
Date: 7/31/13 **Arrival Time:** 1051 **Leave Time:** 1130
Mussel Collectors: AS + AC
Data Recorder: AC

	Line # 3	**Line #** 48	**Line #** 62
	Length (mm)	**Length (mm)**	**Length (mm)**
1	14	15	18
2	17	8	15
3	14	15	11
4	11	16	11
5	11	6	9
6	14	14	19
7	13	11	8
8	15	3	12
9	16	17	6
10	16	7	14
11	8	14	11
12	15	8	15
13	13	14	10
14	16	16	13
15	14	11	10
16	15	20	14
17	9	18	20
18	7	8	15
19	6	12	15
20	7	19	11
21	16	10	10
22	11	15	18
23	9	9	15
24	21	15	11
25	13	10	10
26	13	10	8
27	16	12	11
28	14	12	7
29	7	15	4
30	13	13	9
Composite wt + fouling (g):	7.6g	7.6g	6.7g
Fouling wt (g):	0	0	0
Composite wt - fouling (g):	7.6	7.6g	6.7g

Entered 8/1/13

Med Med Med/Hi

med

Shellfish at Work - Phytoplankton Net Tow

Appendix C

4 m net tow

took photo

Surface of Jar, Noctiluca & Ceratium dominate

Location		WBM	BWM	HF	BHM
Date		6/19	6/19	6/19	6/19
Time		1200	1240	1320	1400
Tide (ebb, flood, slack)		IN	→	→	→
Collection Depth					
Centric Diatoms	*Actinoptychus senarius*				X
	Asteromphalus heptactis				
	Attheya spp.				
	Aulacodiscus kittoni				
	Bacteriastrum spp.				
	Cerataulina pelagica	X			X
	Chaetoceros spp.	X	X	X	X
	Corethron hystrix				
	Coscinodiscus spp.	X			X
	Dactyliosolen fragilissimus				
	Dactyliosolen blavyanus				
	Detonula pumila				
	Ditylum brightwellii				X
	Entomoneis spp.				
	Eucampia zodiacus	X			X
	Grammatophora				
	Guinardia spp.				X
	Hemiaulus spp.				
	Lauderia spp.				
	Leptocylindrus spp.				X
	Melosira spp.	X	X	X	
	Odontella spp.				
	Paralia sulcata				
	Plagiogramopsis vanheurckii				
	Proboscia alata				
	Rhizosolenia spp.	X			X🟨
	Skeletonema costatum	X			X
	Stephanopyxis spp.				
	Thalassiosira spp.	X	X	X	X
	Unidentified centric				
Pennate Diatoms	*Achnanthes spp.*				
	Asterionella formosa				
	Asterionellopsis glacialis				
	Asterionellopsis socialis				
	Bacillaria paxillifera				
	Cylindrotheca closterium	X		X	X
	Fragilaria crotonensis				
	Fragillariopsis spp.				
	Licmophora sp.				
	Navicula spp				X
	Nitzschia			X	X
	Nitzschia acicularis	X	⊗	X	X
	Petrodictyon/Raphoneis				
	Pleurosigma spp.	X	X	X	X
	P-N Pungens/multiseries	X🟨	⊗	⊗	⊗🟨
	P-N Australis/fraudulenta				
	P-N Delicatissima/p-delicate.				
	Striatella unipunctata				
	Thalassionema nitzschioides				X
	Tropidoneis antarctica				
	Unidentified pennate	X	X		X

		WBM	BWM	HF	BHM
Dinoflagellates	*Akashiwo sanguinea*				
	Alexandrium spp.		X		
	Amphidinium spp.				
	Amylax triacantha	⊗	X	X	
	Ceratium spp.	X🟨	⊗	X🟨	X
	Cochlodinium spp.				
	Dinophysis spp.	⊗	X	⊗	X
	Dissodinium pseudolunula				
	Gonyaulax spp				
	Gyrodinium/Katodinium spp.			X	X
	Heterocapsa triquetra	⊗		⊗	X
	Kofoidinium velleloides				
	Minuscula bipes				
	Nematodinium armatum				X
	Noctiluca scintillans	X	X	⊗	X
	Oxyphysis oxytoxoides	X			X
	Prorocentrum spp.				
	Protoceratium reticulatum				
	Protoperidinium spp.		X	X	X
	Pyrophacus horologium				
	Scrippsiella trochoidea	⊗	X🟨	⊗	X
	Unidentified Dinos	X	X	X	
Others	*Meringosphaera mediterranea*	X	X		X
	Coccolithus pelagicus				
	Dictyoca spp	X	X	X	X
	Heterosigma akashiwo				
	Euglenoids				
	Ebria tripartita	⊗	X		X
Zooplankton	*Tintinnids*	X	X	X	X
	copepoda		X		X
	barnacle nauplii		X		
	crustacean nauplii	X	X		X
	rotifers			X	
	tiarina		X	X	X
	Urochordata	X	X		
	other	X	X	X	X

← pictures

🟨 = Dominant

⬭ = Prominent

Polychaete larvae

really long wormlike creature full of plankton esp Protoperidinium

fish like

gyrodinium w/ spike coming off side!

Pictures and Notes:

WBM + BWM + HF

Sub dom.

Fish-like? worm-like

Entered 11/9 - AM

Fouling Community Species List	**WBM**	**HF**	**BW**	**BHM**
Algae				
Brown Diatomaceous	X	X	X	X
Filamentous reds (*Polysiphonia sp.*)		X	X	
Green Ulvoids (*Ulva sp.*)	X	X	X	X
Porphyra (Porphyra sp.)			X	
Sugar Kelp (*Saccharina latissima*)				X
Witch's hair (*Desmarestia aculeata*)		X	X	
Fish				
Gunnel (*Pholidae spp.*)			X	
Shiner perch (*Cymatogaster aggregata*)	X		X	
Pacific Herring Eggs (*Clupea pallasii*)			X	
Sticklebacks (*Gasterosteus aculeatus*)		X	X	X
Invertebrates				
Ascidians (*Ascidiacea spp.*)			X	
Amphipods (*Amphipoda spp.*)	X	X	X	
Anemones (*Actiniaria spp.*)	X			X
Annelids (*Annelida spp.*)	X	X	X	X
Barnacles (*Balanus glandula*)	X	X	X	X
Bryozoans (*Bryozoa spp.*)				X
Calcareous tube worm (*Serpula spp.*)				X
Caprellid (Caprellidae spp.)	X	X	X	X
Crangon shrimp (*Crangon spp.*)	X			X
Flatworms (Platyhelminthes spp.)	X	X	X	X
Fried egg/Egg yolk jellyfish (*Phacellophora camtschatica*)	X			X
Hydroid (*Obelia longissima*)		X		X
Kelp crab (*Pugettia producta*)				X
Shore crab (*Hemigrapsus spp.)*	X		X	
Hermit crab (*Pagurus spp.*)	X			
Isopods (*Isopoda spp.*)			X	
Moon jellyfish (*Aurelia sp.*)	X	X		X
Nudibranchs (*Nudibranchia spp.*)	X	X	X	X
Ribbon worms (*Paranemertes spp.* , *Cerebratulus spp* .)		X	X	
Scale worm (*Harmothoe spp.*)	X		X	X
Seastars (*Asteroidea spp.*)	X	X	X	X
Tunicate (*Tunicata spp.*)			X	
Total #	18	16	23	19

Lab Analysis Averages Based on mussel dry weight			
Nutrients (ug/g) n=3	**WB**	**HF**	**BW**
Total Nitrogen	64666.67	61000.00	54000.00
Phosphorus	5580.00	5296.67	4096.67
Carbon (%) n=3			
Total Carbon	32.333	31.667	28.000
Metals (ug/g) n=3			
Arsenic	3.467	3.207	2.290
Cadmium	0.862	0.725	0.608
Lead	0.604	0.406	0.442
Copper	28.500	21.467	21.400
Nickel	<3.623	<2.747	<4.217
Mercury	0.061	0.067	0.074
PAH's (ug/Kg) composite			
2-Methylnaphthalene	<2.8	<2.97	<2.86
Acenaphthene	<2.8	<2.97	<2.86
Acenaphthylene	<2.8	<2.97	<2.86
Anthracene	<2.8	<2.97	<2.86
Benzo(a)anthracene	<2.8	<2.97	<2.86
Benzo(a)pyrene	<2.8	<2.97	<2.86
Benzo(b)fluoranthene	<2.8	<2.97	<2.86
Benzo(ghi)perylene	<2.8	<2.97	<2.86
Benzo(k)fluoranthene	<2.8	<2.97	<2.86
Chrysene	<2.8	<2.97	<2.86
Dibenzo(ah)anthracene	<2.8	<2.97	<2.86
Fluoranthene	<2.8	<2.97	<2.86
Fluorene	<2.8	<2.97	<2.86
Indeno(123-cd)pyrene	<2.8	<2.97	<2.86
Phenanthrene	<2.8	<2.97	<2.86
Pyrene	<2.8	<2.97	<2.86
PCB's (ug/Kg) composite			
PCB-1016	<87.5	<84	<88
PCB-1221	<87.5	<84	<88
PCB-1232	<87.5	<84	<88
PCB-1242	<87.5	<84	<88
PCB-1248	<87.5	<84	<88
PCB-1254	<87.5	<84	<88
PCB-1260	<87.5	<84	<88

Lab Analysis Averages **Based on mussel wet weight**			
Nutrients (ug/g) n=3	**WB**	**HF**	**BW**
Total Nitrogen	10266.67	10833.33	8100.00
Phosphorus	888.33	938.67	627.33
Carbon (%) n=3			
Total Carbon	5.167	5.633	4.300
Metals (ug/g) n=3			
Arsenic	0.556	0.569	0.351
Cadmium	0.137	0.129	0.093
Lead	0.094	0.072	0.069
Copper	4.510	3.800	2.815
Nickel	<0.57	<0.487	<0.657
Mercury	0.010	0.012	0.011
PAH's (ug/Kg) composite			
2-Methylnaphthalene	<0.45	<0.52	<0.46
Acenaphthene	<0.45	<0.52	<0.46
Acenaphthylene	<0.45	<0.52	<0.46
Anthracene	<0.45	<0.52	<0.46
Benzo(a)anthracene	<0.45	<0.52	<0.46
Benzo(a)pyrene	<0.45	<0.52	<0.46
Benzo(b)fluoranthene	<0.45	<0.52	<0.46
Benzo(ghi)perylene	<0.45	<0.52	<0.46
Benzo(k)fluoranthene	<0.45	<0.52	<0.46
Chrysene	<0.45	<0.52	<0.46
Dibenzo(ah)anthracene	<0.45	<0.52	<0.46
Fluoranthene	<0.45	<0.52	<0.46
Fluorene	<0.45	<0.52	<0.46
Indeno(123-cd)pyrene	<0.45	<0.52	<0.46
Phenanthrene	<0.45	<0.52	<0.46
Pyrene	<0.45	<0.52	<0.46
PCB's (ug/Kg) composite			
PCB-1016	<14	<14.9	<14.1
PCB-1221	<14	<14.9	<14.1
PCB-1232	<14	<14.9	<14.1
PCB-1242	<14	<14.9	<14.1
PCB-1248	<14	<14.9	<14.1
PCB-1254	<14	<14.9	<14.1
PCB-1260	<14	<14.9	<14.1

Shellfish at Work
On Evergreen's Organic Farm

Helen Dziuba
The Evergreen State College
2013

Credit: Aimee Christy, Pacific Shellfish Institute

Acknowledgements

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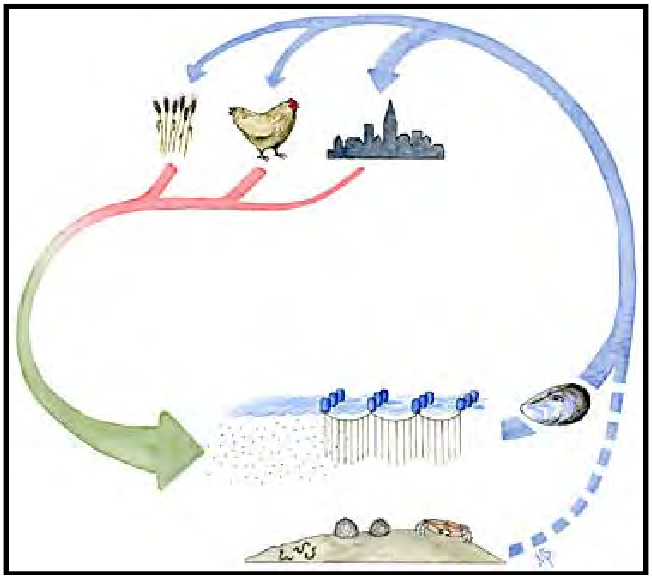
Introduction

Growing mussels to combat eutrophication has proven effective in projects across the globe, and is now being tested in South Puget Sound's Budd Inlet. Nutrient pollution can increase the occurrence of harmful algal blooms (HABs), which is especially concerning considering that Washington State leads the U.S. in shellfish production, an industry valued at over $184 million annually. Olympia's Pacific Shellfish Institute (PSI), with funding from the United States Environmental Protection Agency (USEPA) through a grant from the Washington Department of Ecology, has initiated a project to explore the potential for addressing anthropogenic nutrient pollution in Budd Inlet through extractive mussel aquaculture. The project, known as "Shellfish at Work", will explore the environmental impact of growing mussels and seek a market for the resulting mussels.

Study Area

Parts of the Deschutes River, Capitol Lake, and Budd Inlet are currently on the Clean Water Act Section 303(d) list for fecal coliform bacteria, temperature, dissolved oxygen, pH, and fine sediment (Ecology 2012). As the region is still rapidly growing, it is immediately necessary to find long-term solutions to the issue of eutrophication caused by dense human populations and agricultural activity. Budd Inlet in particular has been closed to shellfish harvesting for several decades. Dissolved inorganic nitrogen from both the LOTT alliance wastewater treatment center and non-point sources like discharge from Capitol Lake and the Deschutes River enters South Puget Sound in significant numbers every day, impacting an already sensitive waterway.

Nutrient Bioextraction



Lindahl 2005

Mussels filter nitrogen and phosphorus from the surrounding water, which can then be harvested, a process known as nutrient bioextraction. It is projected that, for every unit of nitrogen actively consumed, the equivalent amount is also removed from the water column and converted to sediment in the form of feces, pseudofeces, and in die-off (Newell 2004). This information is important to consider in calculating both the total potential for nitrogen removal and the effects of mussel aquaculture with high stocking densities on the benthic community. Extremely high stocking densities can have negative consequences for the sediment layer immediately below the farm, which must be considered in planning the farming operation.

Financial Incentives

While it is understood that improving water quality is in the best interest of Washington State's successful shellfish industry, further market incentives are necessary to ensure the implementation of extractive aquaculture on a scale large enough to have positive environmental impacts. PSI is seeking to gather a network of interested farmers to encourage the composting of the raw product as a fertilizer for organic farming systems. This is especially appropriate, as a portion of the problem is created by farmland run-off of high-nitrogen fertilizers. The mussels in this case serve as a recycling engine to bring nitrogen back to the farms. Another product worth mentioning is mussel meal as a replacement for fish meal, especially in chicken feed. The straightforward process is described by Odd Lindahl (2011), and the product carries some added benefits. Mussel meal is a high-value, shelf-stable product with considerably less bulk than compost, and also allows the processor to separate the shells from the meat. While keeping the shells integrated in the compost increases the calcium content and is ideal for those looking to lime rain-leached soils anyway, there may be other uses for the shells themselves. Lindahl points out the opportunity to use the shell meal as a separate liming product, but intuitively I have to wonder whether it is responsible to include the shells in our extractive aquaculture at a time when calcium carbonate is a difficult thing to come by in an acidified ocean. It is worth exploring the impact of shell removal in extractive aquaculture.

Further financial incentives discussed by Lindahl (2005) include the potential for job creation (large-scale mussel farming requires more employees than more expensive wastewater treatment plants) and the concept of a nutrient trading scheme. This model is based largely on trading schemes currently used in carbon emissions. It would require those creating nutrient pollution to be directly responsible for paying mussel farmers for removing the substances from the water, on a unit-by-unit basis. This quickly becomes complicated in addressing diffuse sources, such as farmland run-off in rivers, but is one model for making nutrient bioextraction financially viable.

Contaminants of Concern

In 2008, the Washington Department of Health issued a Health Consultation for Budd Inlet (WDOH 2008), to evaluate the potential human health hazard posed by contaminants in sediments, clams, and bottom fish tissue. Three compounds were found to exceed standards: Dioxins, Polychlorinated biphenyls (PCBs), and Polycyclic Aromatic Hydrocarbons (PAHs). Dioxin contamination likely results from historical industrial use and stormwater runoff of shore areas. PCBs were historically used as hydraulic fluids, plasticizers, adhesives, fire retardants, way extenders, de-dusting agents, pesticide extenders, inks, lubricants, cutting oils, in heat transfer systems, and carbonless reproducing paper, while PAHs result from the incomplete combustion of organic materials. All three of these contaminants are important to consider as they are large organic molecules which are very hydrophobic and remain stable in the environment. They cannot be metabolized by shellfish, nor through a composting process. Throughout composting trials, it will be important to keep a watchful eye on the levels in our shellfish of these contaminants, to avoid accumulating them in the field.

Project

The Organic Farm at The Evergreen State College is a living laboratory, meant to teach the next generation of farmers about best practices in the field while providing a grounds for experimentation. Recycling is an important aspect of Evergreen’s environmental mission, and integrating mussel compost into the farm fits well with the roles of both institutions. A single compost trial will be conducted to explore the potential for Evergreen’s involvement in the Shellfish at Work project.

Method

Mussels

In May of 2013, PSI secured 101 lengths (3-5 feet each) of weighted nylon webbing to the underside of docks at Budd Inlet's West Bay Marina (PSI's Quality Assurance Project Plan, "Nutrient Bioextraction: Shellfish at Work") Pilings treated with creosote and other treatments were avoided. The straps were monitored to ensure natural set by native mussel populations of *Mytilus trossulus*, which were allowed to grow throughout the summer for a harvest date of September 25th, 2013. At this point each of the straps had accumulated a biomass of around 40lbs.

Harvest

On September 25th, 2013, the nylon straps were cut and the mussels stripped from the lines by hand for collection. Several samples were removed for lab analysis, and those remaining were packaged in bins for immediate transport to the composting site.

Compost

Prior to the mussel harvest date, the base of a commercial compost reactor at The Evergreen State College's Organic Farm was lined with a 6-inch layer of wood chips.

Mussels arrived at the compost site within two hours of harvest, and were processed in a wood-chipper. It is important to note that a "2-inch" wood-chipper was used, rather than a "6-inch" model. The larger model requires upward transport of the chipped material, which is not possible for samples with high moisture content. The chipping was done on to a plastic drop-cloth, for ease of cleaning. Samples were collected into 5-gallon buckets for ease of measurement and weighing.

A total of 741.7 lbs of mussels were mixed with other feedstocks at a rate of:
1 part mussels
1 part finished on-farm compost (unsifted)
2 part green field waste (mostly eggplants at the time)
2 parts wood chips.
(all by volume)

All feedstocks were loaded into a manure spreader to be distributed in the aerated compost reactor. Negative aeration was maintained at a setting of "-11", except for days 3-5, due to a power outage. Compost was turned 8 and 19 days after initiation, then removed from the reactors on the 28th day to a covered storage bay.

Pile temperature was monitored every week day for the duration of the 28 days spent within the aerated reactors, using dial-type probe thermometers, viewed by opening the reactor door. Compost was finally removed as it cooled to ambient temperatures and demand for the reactors required.

Upon completion, triplicate samples of the finished compost were collected from several random points in the pile using clean gloves, sifted through sieves with an opening of 0.375 inches, and sent to Soiltest Farm Consultants for analysis.

Credit: Aimee Christy, Pacific Shellfish Institute

C:N Ratio Analysis

On the date of compost initiation, several feedstock samples were collected using clean gloves and frozen in clean Ziploc bags. Finished compost, field waste, freshly chipped mussel slurry, and wood chips were all sampled and frozen. Mid-November, the samples were removed from the freezer and dried in paper bags in an incubator set to 37 degrees Celsius, along with a fresh sample of the completed compost.

Upon drying, feedstocks were carefully processed through soil sieves to remove any rocks, then processed in a Wiley mill. Selections from these samples were homogenized further in a ball mill. This work was performed in a fume hood to minimize risk from inhalation of fine particulate matter.

For each unique sample, three replicates weighing between 1.00 and 2.50 mg were loaded into tin capsules. The capsules were carefully folded to avoid breakage and minimize potential contamination. Standards for sample prep advise using a balance offering a level of precision to the thousandth of a milligram, but the available balance experienced a malfunction during sample prep and precision was only available to the hundredth of a milligram.

The new Perkin-Elmer CHN analyzer is currently not functioning properly. Actually running the analysis for C:N ratio will consequently have to wait, and this data will not be available for this report, but will still be useful for informing future compost trials.

Results

Mussels

Test results from the West Bay mussels are quite promising. While metals were present and should continue to be monitored, all contaminants are well within tolerable limits, and all organic contaminants (PAH's) were below detectable levels. If The Organic Farm chooses to pursue mussels as a compost feedstock, it would be worthwhile to maintain records on the total amount of inorganic contaminants applied to any one field, to avoid accumulation over time. Knowing the biomass of mussels used (741.7 lbs chipped mussels), it is possible to calculate the approximate totals introduced in the original compost mix.

The Washington Department of Health has collected data for dioxin content in shellfish tissues for several regions in the sound. With a higher lipid content than other shellfish, mussels could be expected to accumulate more of these hydrophobic pollutants and those with related structures. This does not appear to be the case, however, with dioxin concentrations tested in shellfish tissue in Oakland Bay and Shelton Harbor averaging .11 ppt (manila clams), .26 ppt (Pacific oysters), .45 ppt (Kumo oysters), and .17 ppt (mussels) (WDOH 2010). These contaminants tend to settle in sediment rather than remain suspended in the water column. Clams and oysters residing in sediment would consequently have more exposure than mussels grown in suspended culture and away from creosote-treated pilings. This could also help explain our test results for PAH's in West Bay mussels. The average dioxin levels in sediment are 19 ppt, well over the acceptable risk of <4.0 ppt, so the issue is still worth consideration going forward.

Our mussels successfully removed at least 7lbs of nitrogen from Budd Inlet. Having a nitrogen content approaching 1%, it is easy to test this in terms of nitrogen accumulated in tissue. It is also speculated that approximately the equivalent amount is removed from the water column in the form of feces, pseudofeces, and die-off (Newell 2004). Mussel farming certainly shows promise as a low-input means of reducing anthropogenic nutrient pollution, and Evergreen would do well to maintain involvement with this field.

Compost

The compost produced is of good quality for growing crops and lacks any major contamination concerns. Low levels of arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc were detected, but all are well within allowable limits for compost as established in WAC 173-350-220. Temperatures above 130 degrees Fahrenheit were reached and maintained for over three days, meeting the requirements of the U.S. EPA's process to further reduce pathogens (PFRP). For this reason, bacterial contamination should not be a concern in the final product.

Calcium content in the final product is high due to the presence of the chipped mussel shells, which is especially relevant to organic farmers working leached, acidic soils. The balance between calcium and magnesium should be considered when applying the compost to the field.

Salt content is somewhat high in the finished product, and this should be considered in choosing appropriate crops for this amendment.

The moisture content of the original mix was high, upwards of 60% when tested with the farm's Koster moisture tester. Our trial began with a 6-inch layer of wood chips lining the aerated reactor, which was introduced into the mix upon the first turning. Both of these factors may have played a role in the pile's inability to regain high temperatures after being turned for the first time.

In the future, it would be informative to perform a truly comparative trial for several variables, perhaps beginning three piles at once (if mussels are available). Some variables to assess include considering the original layer of wood chips while devising the compost recipe, to avoid introducing too much carbon later on, varying the recipe generally to seek the best mix, and perhaps draining the mussels well before chipping to reduce both moisture and salt content. It should be noted in considering the wood chip dilemma that the final mix actually had a very satisfactory C:N ratio of 22:1.

Smell was not an issue as soon as the feedstocks were mixed and the area pressure washed. It is highly recommended that several people be on hand to complete the entire clean-up process on the same day that the compost is made, as the job becomes increasingly less pleasant with time.

In order to determine application rates and further test the quality of the compost produced, I recommend that the Organic Farm conduct growth trials alongside our regular compost. Raw mussel slurry has been widely used as a fertilizer for cereal grain crops, but is less suitable for crops such as potatoes, which do not grow well with salt. If a student wanted to take this on as a project, it would be informative to compare general crop health (disease and deficiency symptoms) and total biomass accumulated. It would be important to include a control plot with no fertilizer applied, and advisable to replicate the trials in different areas of the field to avoid bias by soil type.

Conclusion

The compost produced using Budd Inlet mussels is high-quality, non-toxic, and was fun to make (not every compost day begins with harvest from the bay). Intuitive contamination concerns caused some hesitation at the outset of this project, but the results are convincing and our fears have been pacified. “Nutrient pollution” sounds like an ironic term to a farmer, and it is ideal that farmers be an integral part of this recycling process. In a field where nitrogen is a limiting factor in high demand, there is no excuse to allow the valuable nitrogen leached from our soils to become a pollutant elsewhere. Evergreen is excited to be part of this trial and will enthusiastically pursue future opportunities.

Works Cited

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Shellfish at Work! – Reducing nutrients in Budd Inlet with mussel power

Pacific Shellfish Institute: Contact Aimee Christy (aimee@pacshell.org), 360-754-2741

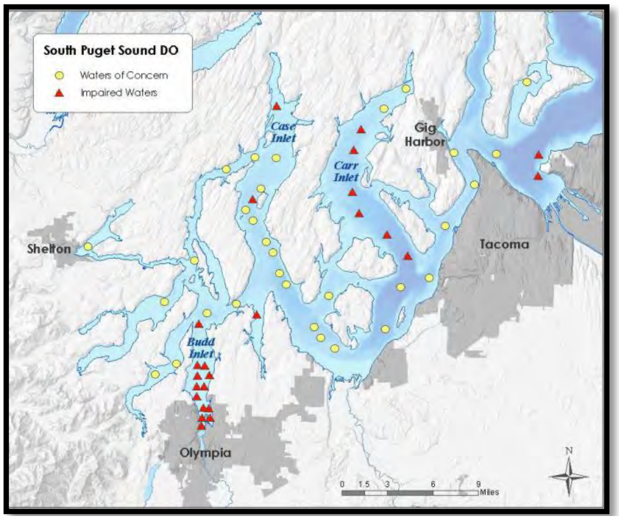
Introduction

Mary and I are shellfish biologists from the Pacific Shellfish Institute. We often study water quality because water must be clean for shellfish to survive and because so many of us (humans and wildlife) depend on shellfish for food. What do you think of when you hear the word "water pollution?" (e.g. oil, trash, sediments, metals, etc.). Today, we are going to focus on a different type of pollution – nutrient pollution.

Background

Budd Inlet is one of five shallow, dead-end inlets in Puget Sound's southernmost marine water body. The Inlet looks clean and healthy when viewing it from downtown Olympia, but unfortunately, portions of the Deschutes River, Capitol Lake, and Budd Inlet currently do not meet water quality standards for fecal coliform bacteria, temperature, DO, pH, and fine sediment. Shellfish harvest is presently not allowed for consumption in most of the inlet.

The Deschutes River was identified as having the 4th largest nutrient load in Puget Sound. Excess nutrient loads, particularly in shallow, dead-end inlets, can result in excessive algae growth, which robs water of oxygen upon decomposition. In fact, Budd, Case, and Carr Inlets were identified as "most impaired" for dissolved oxygen (DO). Low oxygen levels can be harmful to marine life and raises concerns about the Bay's overall health.



Results from Washington Department of Ecology's 2008 Water Quality Assessment for Dissolved Oxygen in South Puget Sound

Eutrophication Explained

What causes low dissolved oxygen levels?

Low oxygen levels occur when excess nutrients stimulate the growth of microscopic phytoplankton. When they die, the decay process depletes oxygen levels in the water column. The term for this process is EUTROPHICATION. Let's explain this process in a bit more detail with the help of visual props and volunteers.

What are nutrients and where do they come from?

Nutrients are substances that provide nourishment essential for growth and the maintenance of life. When we talk about "excess nutrients in Puget Sound" we are referring to substances that fuel the growth of phytoplankton such as nitrates and phosphates. These substances make their way into Budd Inlet in several ways. First, nutrients are naturally found in the deep bottom waters of the Pacific Ocean and are carried into Puget Sound especially during summer upwelling events. Nutrients also come from human and animal wastes (*hold up fake poop*) and can enter Puget Sound via waste treatment facility effluent, failing septic and sewer systems, and stormwater runoff containing wild and domestic animal waste. Finally, nutrients are found in fertilizers, grass clippings, and soapy runoff from washing cars. (*Read the nutrients listed on a bag of fertilizer for examples of more nutrients*). These nutrients will not only cause your house plants and lawn to grow, but also the microscopic plants found in lakes, streams, and Puget Sound. (*Call on one volunteer to pretend that they are applying fertilizer to their lawn. Then, have audience make it rain – rub finger together, rub hands together, snap together, pat thighs.)* Demonstrate how the rain travels over the surface of the land and carries nutrients and other substances into lakes, streams, and ultimately Puget Sound.

What are phytoplankton?

Phytoplankton are microscopic plants that drift in the sea and serve many important functions. (*Hold up images of diatoms and dinoflagellates*). Phytoplankton are the basis of the food chain. (*Have students take a deep breath*) Phytoplankton also produce oxygen and are estimated to produce over half of the oxygen that we breathe today – thank you, phytoplankton! That said, sometimes there can be "too much of a good thing." Phytoplankton require sunlight and nutrients to grow. They do particularly well in calm, stratified waters (warm, fresh water sitting on a layer of cold, salty water) that allow plankton to "hang out" in the surface layer, get plenty of sun, and multiply very quickly. Blooms can turn the water so murky that visibility is limited for other organisms and sunlight is unable to reach bottom dwelling plants. (*Call on volunteer to hold up a model of the sun. Have another student hold up a sign depicting plankton blooms*).

How does too much phytoplankton result in low dissolved oxygen levels?

During late summer/early fall, waters are warm and calm with very little mixing. Phytoplankton eventually deplete nutrient levels in surface waters and inhibit further growth. Blooms die-off and phytoplankton slowly sink to the ocean floor creating a thick matt of organic matter. Bacteria (the "clean-up crew") break down this matter, releasing nutrients back into the deep waters. In the process they respire, or use oxygen. This decay process can decrease oxygen levels in the water to dangerously low levels. The fact that warm water holds less oxygen makes matters even worse. (*Have student holding plankton sign act out the process of sinking to the ocean floor. Call on volunteers to act like bacteria, "huffing and puffing" while they work to decompose the plankton*). Marine life, such as wolf eels, rock fish, and organisms that cannot move to a new location are stressed by these conditions and may not survive. Fish may come to the surface to obtain more oxygen and get eaten by birds or other predators. Areas with long persistent periods of hypoxia, or low oxygen levels, are termed "dead zones." Fortunately, fall and winter storms eventually cool and mix waters returning dissolved oxygen levels to a healthy state. (*Have students make the sound of the wind and rain to promote mixing and restore oxygen levels*).

Fear not! It's not all Bloom and Doom – Solutions!

How can we prevent the harmful impacts of eutrophication?

1) The easiest way to avoid the harmful impacts of eutrophication is "source control", or preventing excess nutrients from entering Puget Sound in the first place. (*Remind students that nutrients are found in fertilizers, detergents, animal and human manure. Ask students to identify ways that they can keep nutrients out of PS*). Actions students might take may include: Picking up their dog's poop – Scoop It, Bag It, Trash It; reading labels to make sure laundry and dish detergents are phosphate-free; washing cars at the carwash or on your lawn. Additional ways that adults can keep nutrients out of waterways include: using fertilizer sparingly and keeping off hard surfaces like sidewalks, using slow-release organic fertilizers, maintaining home's septic or sewer system, and managing farm manure.

Passing laws to remove phosphates from detergents and fertilizer and developing technology to remove nutrients from waste water treatment plants are other source control methods.

2) Source control is a critical step in reducing nutrient pollution into Puget Sound. But can nutrients be removed once they enter the marine environment? Perhaps so with the help of Nature's filter feeders! Over the past couple of years, Pacific Shellfish Institute, using NEP funds, has addressed this question with its "Shellfish at Work" project. The project evaluates nutrient bio-extraction (bio-harvesting), or the practice of farming and harvesting shellfish or seaweed for the purpose of removing nitrogen and other nutrients from the water. In spring, over 300 3-5 foot nylon straps were attached to existing dock structures at West Bay Marina, the Hearthfire Restaurant dock and Boat Works providing an attractive home for blue mussel larvae to settle upon and grow (*hold up nylon strap*). Throughout the summer, these mussels filtered phytoplankton from the inlet improving water clarity and incorporating nitrogen into their tissues. In fall, the mussels (and their incorporated nutrients) were harvested, tested for contaminants and turned into nutrient rich, organic compost (*pass around a sample of the compost*). These initial trials suggest that nutrient bioextraction might be an appropriate solution for specific PS regions. (*Call on student to add phytoplankton concentrate to a jar of mussels. Have students observe how mussels filter phytoplankton from the water, improving water clarity and incorporating nutrients into their tissues.*) Did you know that one mussel can filter 10 gallons of water per day (hold up an empty 1-gallon milk jug)?

3) Finally, in addition to targeting source control and nutrient bioextraction, are there other ways to increase oxygen levels in bottom waters? Engineering solutions can sometimes be an additional "tool in the toolbox." For example, underwater paddle wheels and sub-surface aerators were both considered as ways to artificially increase oxygen levels in Hood Canal during anoxic episodes. Increasing water flow or cooling water temperatures are other options. Department of Ecology models suggest that removing the Capitol Lake dam would improve river flow into Budd Inlet resulting in increased oxygen levels. Planting vegetation along stream banks to cool water temperatures might allow water to hold more oxygen at some locations.

Conclusion

Eutrophication in Budd Inlet (or other locations like Hood Canal, Long Island Sound, Gulf of Mexico, globally!) provides an example of how scientists (and someday, perhaps you!), address complex environmental issues. It is important to identify the problem and who is impacted. It is important to understand how the biological, chemical, and physical processes interact with one another. It is important to use creativity, technology, ingenuity, social marketing, and any other potential tools to identify and test possible solutions. Most of all, it is important to not give up, to remember why we love Puget Sound, and why it's important to take good care of it.

STATION ROTATIONS – Hand out worksheet (document attached and italicized below). Adapt as needed for various age groups. Allow 4-5 minutes per station. Depending on the age of the students or group size, one station can be eliminated.

Classroom Worksheet

Station 1: Nutrient Sources (appropriate for all ages)

For this station, lay out several types of dish soap, laundry detergent, fertilizers, and fake dog poop. Make sure that some products contain phosphorus and some are phosphate-free.

This station displays various nutrient sources that can travel from our homes and neighborhoods into lakes, streams, groundwater and ultimately Puget Sound where they fuel phytoplankton (algae) growth. As algae die, bacterial decomposition can rob bottom waters of oxygen placing stress on marine life.

1. *Which products contain phosphates?*
2. *Which products are phosphate-free?*
3. *Name several actions that people can take to prevent nutrients from flowing into our waterways?*

Station 2: Phytoplankton Observations (appropriate for all ages)

Set up microscopes and collect fresh plankton samples. Prepare slides or allow students to prepare their own depending on time. Provide plankton keys/photographs.

1. *Draw 1-2 phytoplankton species from the Budd Inlet water sample.*
2. *Can you tell which are zooplankton or phytoplankton? Diatoms or dinoflagellates? Species? If so, label as such.*

Station 3: Shellfish Filtration (appropriate for all ages)

Collect 2-3 clumps of mussels the night before and keep them in a bucket of seawater with adequate aeration (small pump/air stone). For the presentation, fill a large glass jar or small aquarium with seawater, place mussels inside, and transfer the aerator to the jar. Have a student add approximately 2-3 mls of Shellfish Diet 1800 (available through Reed Mariculture – keep cold) to the jar using a plastic 5-ml pipette. The aeration will quickly mix the water turning it a brownish green color. Have students observe what happens to the water after 5-10 minutes. Observe the mussel's short siphons as they open their valves to feed. Notice other marine creatures that may be feeding (barnacles), or using the mussels as shelter (crabs, isopods, etc).

1. *What are these mussels filtering out of the water?*
2. *How can shellfish filtration impact the surrounding marine environment?*

Station 4: Data Collection: Mussel lengths and weights (better for middle school students, adaptable)

Place a clump of live mussels on a plastic tote lid or tray. Students may notice other organisms living among the mussels (worms, isopods, amphipods, shore crabs). Place laminated invertebrate cards next to mussels for species identification. Provide 2-3 mussel length measuring devices, calculator, and growth charts. Have students randomly measure 5 mussels and record their lengths in cm. Then, have the students place the mussels on a scale and record the combined weight. Calculate the average mussel length and weight per individual mussel and compare to charts. (For younger students, simply have them record mussel lengths and combined weight. May also consider eliminating weight measurements altogether).

1. Working in small groups, randomly select 5 mussels and record their lengths in cm. What is the average mussel length?

   Mussel 1 _________

   Mussel 2 _________

   Mussel 3 _________

   Mussel 4 _________

   Mussel 5 _________ Average Mussel Length __________(cm)

2. Press the tare button on the scale. Place the 5 mussels in the dish and record their weight in grams. Divide the weight by 5 to obtain the weight per individual mussel.

   Weight of 5 mussels ________(g) Weight per Mussel _________(g)

3. Compare your data to the graphs. To maximize the nitrogen content in the mussels, we want the average mussel length to be at least 3 cm (or 30 mm) before harvesting. We want the weight per mussel to be at least 1.5 grams. Is it time to harvest or should we wait longer?

Station 5: Water quality equipment and data

Place water quality equipment on the table: depth gun (depth to bottom – prevents net and YSI probe from hitting bottom while sampling), plankton net, secchi disk (for water clarity), YSI unit (temperature, salinity, pH, oxygen). Set 2 jars on the table labeled A and B. Fill one with fresh water and one with seawater.

1) What do you think each piece of sampling equipment is used for?

2) Use the YSI probe (or refractometer) to measure the salinity in each jar. Which jar contains seawater and which is fresh?

Fresh water	Brackish water	Saline water	Brine
< 0.5 ppt	0.5 – 30 ppt	30-50 ppt	>50.0 ppt

Budd Inlet Water Quality

Heidi Kirk
Environmental Studies
September 13, 2013

Station A. Mussel Filtration Display

1. What do mussels filter out of the water column? algae diet suspended in the water, Pathogens.
2. How does mussel filtration impact the surrounding marine environment?
They process and recycle natural materials, which make them available for other livingthings.
- improve water clarity.

Station B. Phytoplankton

3. Draw 1-2 phytoplankton species from the Budd Inlet water sample.

Coscinodiscus

Protoperidinium

4. Which dinoflagellate is blooming right now?
dinoflagellate Akashiwo

Station C. Nutrient Sources

This station displays various sources of nutrients that can flow into lakes, streams, groundwater and ultimately Puget Sound where they fuel phytoplankton growth. As blooms die, bacterial decomposition leads to depleted oxygen levels which can be stressful to marine life.

5. Which products contain phosphates?
Miracle grow, finish
6. Which product is phosphate-free?
Dish washing liquid
7. List at least 2 nutrients found in Miracle Grow.
Nitrogen, Iron, copper

Station D. Mussel Growth Measurements (work in small groups)

This strap contains thousands of native blue mussels from Boat Works Marina in Budd Inlet. Randomly select 5 mussels and record their lengths in cm.

Mussel 1 3.2 cm
Mussel 2 2.1 cm
Mussel 3 3.5 cm
Mussel 4 3.6 cm
Mussel 5 3.1 cm

8. What is the average mussel length?

2.26

9. Compare your length to the graph. Are the mussels still growing?

Yes

Station E. Seasonal Water Quality Data

The following graphs depict seasonal water quality data (temperature, salinity, pH and dissolved oxygen) from the 4 sites: BHM = Boston Harbor Marina, WBM = West Bay Marina, HF = Hearthfire Restaurant, STM = Swantown Marina

10. Which station is the coldest and saltiest?

BHM Boston Harbor Marina

11. Does pH and oxygen tend to increase or decrease as the summer progresses? Why? decrease, because tides are lower and the water is mixing less as organisms die, more O_2 is being used. PH decreases as CO_2 is diffusing into the water lowers pH.

Bonus Question!!!!

Department of Ecology is offering $100,000 to the organization with the best plan for reducing nutrient levels in the Deschutes River/Budd Inlet watershed. What's your plan?

[redacted]

B

Budd Inlet Water Quality Worksheet

Pacific Shellfish Institute
Olympia, WA
www.pacshell.org

Station A. Phytoplankton

1. Draw 1-2 phytoplankton species from the Budd Inlet water sample.

Akashiwo Sanguinea

2. Can you tell which are zooplankton or phytoplankton? Diatoms or dinoflagellates? Species? If so, label as such.

Station B. Mussel Growth Measurements (work in small groups)

3. Select 5 mussels and record their lengths in cm. What is the average mussel length?

Mussel 1 3,1 cm

Mussel 2 4,3 cm

Mussel 3 2.4cm

Mussel 4 1.9cm

Mussel 5 3.3cm

Average Mussel Length 3.0 (cm)

Press the tare button on the scale. Place the 5 mussels in the dish and record their weight in grams. Divide the weight by 5 to obtain the weight per individual mussel.

Weight of 5 mussels 14.7 (g) Weight per Mussel 2.94 (g)

4. Compare your data to the graphs. To maximize the amount of nitrogen removed, we want the average mussel length to be at least 3 cm (or 30 mm) and the weight per mussel to be at least 1.5 grams. Is it time to harvest or should we wait longer?

they are ready to harvest

[redacted]

Station C. Water Quality Sampling

5. What do you think each piece of sampling equipment (A-D) is used for?

A- for visibility
B- Depth gun
C- for getting samples
D- tell salinity and temperature

6. Use the YSI probe (or refractometer) to measure the salinity in each jar. Which jar contains seawater and which is fresh?

Fresh water	[✓ Brackish water]	Saline water	Brine
< 0.5 ppt	0.5 – 30 ppt	30-50 ppt	>50.0 ppt

A=1.0 ppt B = 26.7 ppt

Station D. Solutions to Nutrient Pollution

This station displays various nutrient sources that can travel from our neighborhoods into lakes, streams, and ultimately Puget Sound where they fuel phytoplankton (algae) growth. As algae die, the process can rob bottom waters of oxygen placing stress on marine life.

7. Name one product that contains phosphates and one that is phosphate free.

phosphate- electrosal
non phosphate - dish soap

8. List several actions that you can take to prevent nutrients from flowing into Puget Sound?

not over fertalizing, clean up petwaste, don't use soap w/ phosphates

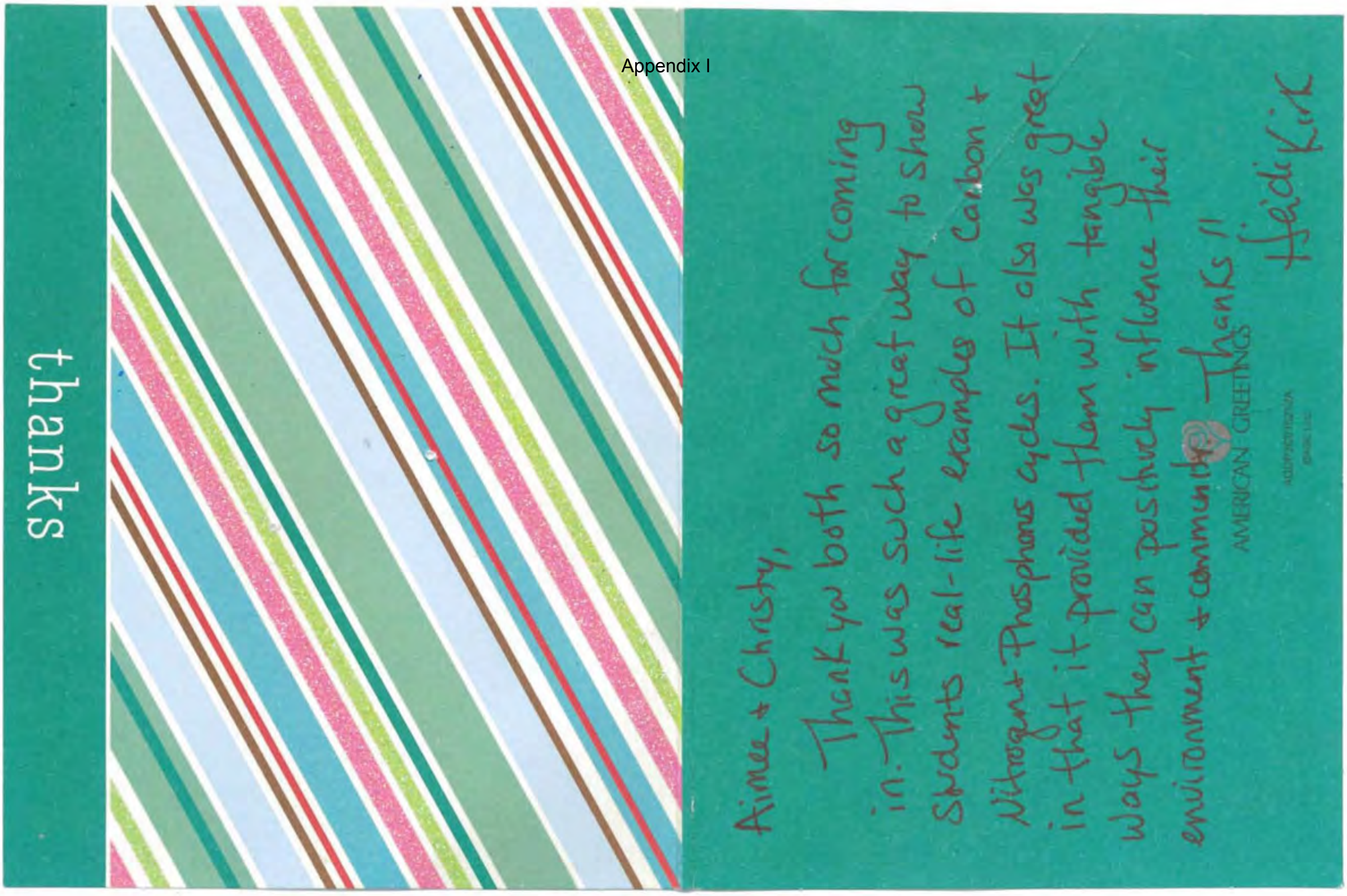
Nutrient Bioextraction is the process of growing and harvesting shellfish to remove nutrients from natural water bodies. Pacific Shellfish Institute has been testing this idea as a way to improve water quality in Budd Inlet. The mussels are then harvested and turned into nutrient rich, organic compost.

9. What are these mussels filtering out of the water?

Plankton

10. How can shellfish filtration impact the surrounding marine environment?

It can remove the nitrates and nutrients from the water



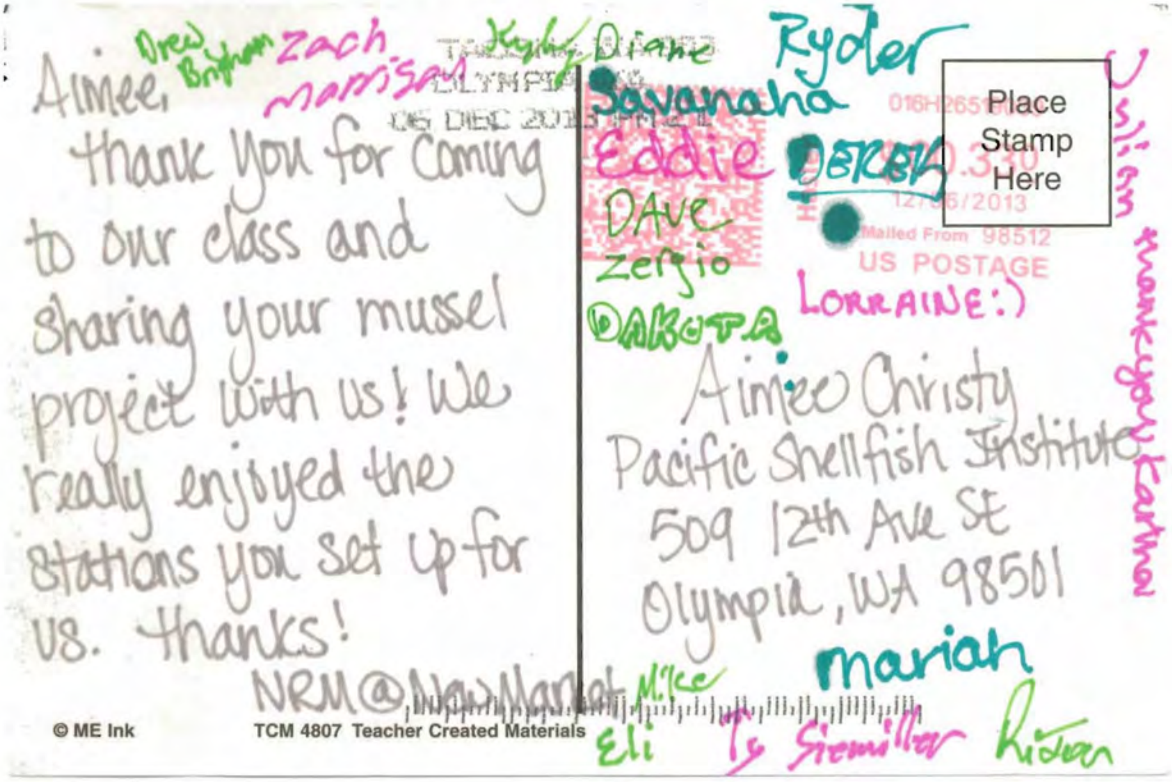
thanks

Aimee + Christy,

Thank you both so much for coming in. This was such a great way to show students real-life examples of Carbon + Nitrogen + Phosphorus cycles. It also was great in that it provided them with tangible ways they can positively influence their environment + community. Thanks!!

Heidi Kirk

AMERICAN GREETINGS



Aimee,

thank you for Coming to our class and sharing your mussel project with us! We really enjoyed the stations you set up for us. thanks!

NRM@New Market

Drew
Brighton
Zach
marrisa
Kyle
Diane
Ryder
Savanaha
Eddie
DEREK
DAVE
Zergio
DAKOTA
LORRAINE :)
Julian
thank you Kartina
Mike
mariah
Eli
Ty Siemiller
Rider

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Aimee Christy
Pacific Shellfish Institute
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Olympia, WA 98501

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TCM 4807 Teacher Created Materials

WET
Science Center
Come Explore · Discover More

Spring Activities & Events

2013

The WET Science Center is a fun, free, family-friendly place to learn all about water – one of our most precious resources. We offer interactive exhibits, weekend family activities, and environmental presentations. Check out our upcoming events and mark your calendar!

April 6

Shellfish at Work!

Spring is here and the plankton are blooming! Biologists from the Pacific Shellfish Institute will walk you through three hands-on stations that explain why excess nutrients (from pet waste, fertilizers, etc.) are a problem in Budd Inlet and demonstrate how bivalve shellfish, as nature's filterers, can lend a helping hand. You'll get to view plankton under a microscope and watch mussels feast on an aquarium full of plankton, clearing the water right before your eyes! Then plant a seed in mussel compost and take it home to watch it grow. The activities start at 2:00 p.m.

April 13

Budd Inlet Treatment Plant Tour

The Budd Inlet Treatment Plant has been cleaning up our urban wastewater since the early 1950s. Come and learn how we do it! A slideshow followed by a treatment plant tour will begin at 1:00 p.m. Tour participants must be ten years or older, dress for outdoor weather, and wear closed-toe, closed-heel shoes.

Olympic Mudminnow Presentation and Field Trip

Join Stream Team and fisheries biologist Jamie Glasgow to learn about this small fish that resides only in Western Washington! The lecture takes place from 10:00-11:30 a.m. at the WET Science Center, and the field trip is from 12:00-1:30 p.m. at Evergreen Park Drive and Kaiser Road. For more information, and to register online, visit www.streamteam.info.

Stream Team NEWSLETTER

Olympia • Lacey • Tumwater • Thurston County

FREE

FALL EDITION
Sept–Oct–Nov 2013

Inside...

Pacific Shellfish Institute's: "Shellfish at Work!"

A stroll along Olympia's downtown waterfront, an afternoon sail or a visit to one of several amazing waterfront parks are just a few ways to enjoy the beauty and splendor of southern Budd Inlet. The unsuspecting observer might be surprised, therefore, to learn that water quality in the Deschutes River, Capitol Lake and Budd Inlet is below state standards for many monitoring parameters. In particular, the Department of Ecology has listed Budd Inlet as an "impaired" waterbody for dissolved oxygen (DO) levels. Similar to Hood Canal, Budd Inlet experiences dangerously low levels of DO in late summer and early fall. This condition is caused by eutrophication, or the manner in which a waterbody becomes enriched in dissolved nutrients (nitrates and phosphates) stimulating the explosive growth of algae. As the algae die and settle to the bottom, they are decomposed by bacteria that utilize oxygen in the process. Low DO levels can be harmful to fish and other marine life, raising concerns about the overall health of the Puget Sound ecosystem. In fact, scientists have identified eutrophication as one of the most serious threats to coastal environments worldwide.

Where do the nutrients come from?

The nutrients that fuel the proliferation of phytoplankton in Budd Inlet come from a variety of sources including ocean inputs (coastal upwelling), sediments, the Deschutes River, smaller tributaries and wastewater treatment facilities. In 1994, to address nutrient loading in southern Puget Sound, the LOTT Clean Water Alliance implemented state-of-the-art advanced nitrogen removal treatment, which runs April through October each year. Still, ever-increasing growth pressure throughout the watershed over the past decade has resulted in many small, uncontrolled sources of nutrient pollution, largely from fertilizers, septic systems and animal waste that enter Budd Inlet via groundwater and stormwater that flows into the Deschutes River and other tributaries.

Fear not! It's not all Bloom and Doom!

Reducing sources of nutrients, or source control, has become a top priority for many jurisdictions. By decreasing nutrient loading, widespread problems with thick algae blooms and oxygen depletion can be prevented.

Shellfish at Work – A Nutrient Bioextraction Experiment

Source control is a critical step in reducing nutrient pollution into Puget Sound. But can nutrients be removed once they enter the marine environment? In spring, Pacific Shellfish Institute (PSI) initiated the "Shellfish at Work" project that uses a combination of nutrient bioextraction principles and community engagement to meet the goal of reducing nutrients in Budd Inlet. Over three hundred nylon straps were affixed to existing dock structures at Swantown, Boston Harbor, Port of Olympia and West Bay Marina to provide an attractive home for blue mussel larvae to settle upon and grow. Throughout the summer, these mussels filter phytoplankton from the inlet improving water clarity and incorporating nitrogen into their tissues. In September and October, the mussels (and their incorporated nutrients) will be harvested, tested for contaminants, and, if acceptable, turned into rich compost. By doing so, the project creates a closed loop nutrient cycle that embraces the 3 R's (reduce, reuse, recycle) by reducing nutrient loading, reusing excess nutrients to build mussel tissue and recycling mussels into valuable compost.

What is Nutrient Bioextraction?

Nutrient bioextraction, or nutrient bioharvesting, is the practice of farming and harvesting shellfish and seaweed for the purpose of removing nitrogen and other nutrients from natural water bodies.

About the author: Aimee Christy is a research biologist at Pacific Shellfish Institute where she enjoys viewing plankton under microscopes, dreaming up ways to convert dog waste into energy and compost, and promoting a clean and healthy Puget Sound for all to enjoy. She can be reached via e-mail at aimee@pacshell.org.

Get Involved!

The Shellfish at Work project offers many ways to get involved. While biologists at PSI have been keeping track of the mussels and water quality since spring, the majority of sampling will take place in September and October. Come visit one of the sites, collect real data (mussel growth rates, biomass measurements, water quality data, species diversity) and assist with end-of-season mussel harvesting. For questions or more information, contact the Pacific Shellfish Institute at 360-754-2741 or aimee@pacshell.org.

Household Tips to Protect Our Water from Nutrient Pollution

☑ **Use fertilizer sparingly and keep it off hard surfaces such as sidewalks.** Look for slow-release fertilizers with at least 50% insoluble nitrogen on the label. Read labels and buy phosphate-free fertilizers, laundry detergent and dish detergent.

☑ **Properly dispose of pet waste.** Scoop It, Bag It, Trash It....every dog, every doo, every time!

☑ **Manage farm manure responsibly.** Keep animals out of creeks and manure off the ground and under cover.

☑ **Maintain your home's septic system.** Have septic system inspected and pumped every 3-5 years.

☑ **Pick up a free portable pet waste bag holder for leashes** (pictured above) and/or pet waste sign and bag dispenser for your neighborhood from your local Stream Team Coordinator. For more info., go to www.streamteam.info/actions/petwaste/

Don't Let Your Pooch Pollute

Did you know...?

- Based on 2007 census data, dogs generate approximately 6 TONS OF FECES PER DAY in Thurston County (that's the weight of a full size Killer Whale!).
- A single gram of pet waste (the weight of a business card) contains an average of 23 million fecal coliform bacteria.
- Bacteria in pet waste creates a health risk to people in parks and yards, especially children who often play in the grass and dirt.
- Waste from dogs and humans contains more fecal coliform bacteria per gram than cows, horses and other wildlife. The following table shows that, on average, a dog will produce over 7 billion fecal coliform bacteria per day and a human will produce close to 2 billion fecal coliform bacteria per day.

Anmimal Type	Fecal coliforms per gram of animal feces	Fecal coliforms per day
Dog	23,000,000	7,728,000,000
Human	13,000,000	1,921,920,000
Cow	230,000	5,358,080,000
Horse	12,600	293,529,600
Wild Rabbit	20	No data availalbel
Mouse	330,000	No data avilaalbel

Source: www.co.thurston.wa.us/shellfish

This is why it is so important to properly maintain home septic systems and to bag and trash pet waste – every dog, every doo, every time!

Stream Team can help! Stream Team can supply you with a free pet waste bag dispenser for your dog's leash and/or you can get a **free** pet waste bag station (includes sign and durable bag dispenser) to install in your neighborhood community space area, multi-family housing complex or other approved community space. Contact your local Stream Team Coordinator (page 2) to find out how you can receive your **free** bag dispenser and/or pet waste station.

PSI Offers OA Monitoring

By Andy Suhrbier, Pacific Shellfish Institute

PSI is maintaining monitoring stations at Bay Center, Tokeland and Nahcotta. Live data for Bay Center and Nahcotta are available at http://nvs.nanoos.org/Explorer along with many other resources. Data provided from all locations include: temperature, pH, salinity, and dissolved oxygen. Bay Center houses a real time CO2 meter ("Burkolator") tied into a pH system to deliver real time salinity, temperature, pCO2 and calculated aragonite saturation and alkalinity. WDFW and Ekone Oyster Company staff continue to assist in CO_2, DO, nutrient and bacterial sample collection.

This water quality data is valuable to local oyster and clam growers as they raise larvae and nursery seed. For example: data from Bay Center points to the last hour of the incoming tide and high tide as the best water as it commonly has the highest pH, salinity and aragonite saturation. These stations are slated to be maintained for the next two years via funding directed by the Governor and State Legislature via the Center of Ocean Acidification.

PSI is pursuing the funding of additional sites in Washington, especially in the Puget Sound where multiple small hatchery, setting and nursery sites are in operation. Until this happens, PSI staff are available for contract work using in house water quality meters and supplies for studies customized to individual growers and their needs.

Shellfish at Work! – Reducing Nutrients in Budd Inlet With Mussel Power

by Aimee Christy, Pacific Shellfish Institute

A stroll along Olympia's downtown waterfront, an afternoon sail, or visit to one of several amazing waterfront parks are just a few ways to enjoy the beauty and splendor of southern Budd Inlet.

The unsuspecting observer might be surprised, therefore, to learn that water quality in the Deschutes River, Capitol Lake and Budd Inlet is below state standards for many parameters. In particular, the Department of Ecology has listed Budd Inlet as an "impaired" water body in terms of dissolved oxygen (DO).

Similar to Hood Canal, Budd Inlet experiences dangerously low levels of DO in late summer and early fall. This condition is caused by eutrophication, or the manner in which a water body becomes enriched in dissolved nutrients (nitrates and phosphates) stimulating the growth of phytoplankton. As the algae settle to the bottom, they are decomposed by bacteria

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Mussels hanging from the dock at West Bay Marina in Budd Inlet, Olympia, WA. Photo by Aimee Christy, Pacific Shellfish Institute

Shellfish at Work

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that utilize oxygen in the process.

Low DO levels can be harmful to fish and other marine life, raising concerns about the overall health of the Puget Sound ecosystem. In fact, scientists have identified eutrophication as one of the most serious threats to coastal environments worldwide.

The nutrients that fuel the proliferation of phytoplankton in Budd Inlet come from a variety of sources including ocean inputs (coastal upwelling), sediments, the Deschutes River, smaller tributaries, and waste treatment facilities. In 1994, to address nutrient loading in southern Puget Sound, the LOTT Clean Water Alliance implemented state-of-the-art advanced nitrogen removal treatment which runs April through October each year. Still, ever-increasing growth pressure throughout the watershed over the past decade has resulted in many small, uncontrolled sources of nutrient pollution, largely from fertilizers, septic systems and animal waste that enter Budd Inlet via groundwater and stormwater that flow into the Deschutes River and other tributaries.

Reducing sources of nutrients, or source control, has become a top priority for many jurisdictions. By decreasing nutrient loading, widespread problems with thick algae blooms and oxygen depletion can be prevented. Source control is a critical step in reducing nutrient pollution into Puget Sound. But can nutrients be removed once they enter the marine environment?

In spring, Pacific Shellfish Institute initiated the "Shellfish at Work" project that uses a combination of nutrient bioextraction principles and community engagement to meet the goal of reducing nutrients in Budd Inlet. Over 300 four-foot nylon straps were affixed to existing dock structures in downtown Olympia to provide an attractive home for blue mussel larvae to settle upon and grow.

Throughout the summer, these mussels filter phytoplankton from the inlet improving water clarity and incorporating nitrogen into their tissues. In October, the mussels (and their incorporated nutrients) will be harvested, tested for contaminants, and, if acceptable, turned into rich compost. By doing so, the project creates a closed loop nutrient cycle that embraces the 3 R's (reduce, reuse, recycle) by reducing nutrient loading, reusing excess nutrients to build mussel tissue, and recycling mussels into valuable compost.

Mussels Reduce Nutrients in Budd Inlet

By Aimee Christy, Pacific Shellfish Institute

In southern Puget Sound, Budd Inlet water quality is below state standards for a number of parameters, particularly dissolved oxygen. To address this issue, Pacific Shellfish Institute (PSI) is testing nutrient bioextraction, or the practice of growing and harvesting shellfish to remove nitrogen from natural water bodies. Over 225 nylon straps were placed under 3 existing dock structures to provide an attractive home for planktonic mussel larvae to attach to. By summer's end, over 8000 pounds of adult mussels were filter-feeding on these straps, improving water clarity and incorporating nutrients into their tissues.

These mussels were harvested, chipped, and delivered to The Evergreen State College's Organic Farm, WSU-Puyallup Research and Extension Center, and Cedar Creek Correctional Center for ongoing compost trials. Next spring, over 15 cubic yards of rich, organic compost will be available to students, small farms, and inmates for plant growth trials.

While laboratory results are pending, the mussels removed an estimated 125 pounds of nitrogen, or 1 pound of nitrogen per day, from lower Budd Inlet over the course of 4 months. A scaled up version of this project could potentially serve to complement the Lacey Olympia Tumwater Thurston County (LOTT) Clean Water Alliance's current nitrogen removal efforts.

Assessing biomass, growth rates, and biodiversity during a community sampling day. Photo by Bobbi Hudson

In addition to directly removing nitrogen from Budd Inlet, the mussel demonstration sites provided hands-on opportunities for the community. Over the summer, PSI hosted citizen monitoring events, K-12 field trips and classroom presentations. Outreach efforts focused on improving public understanding of local water quality issues, ecosystem services of shellfish, and controlling upland sources of nutrients that flow into Puget Sound.

Shellfish at Work: Nutrient Bioextraction

Researchers and UW-Tacoma students examine a mussel line and record growth measurements in July 2013.

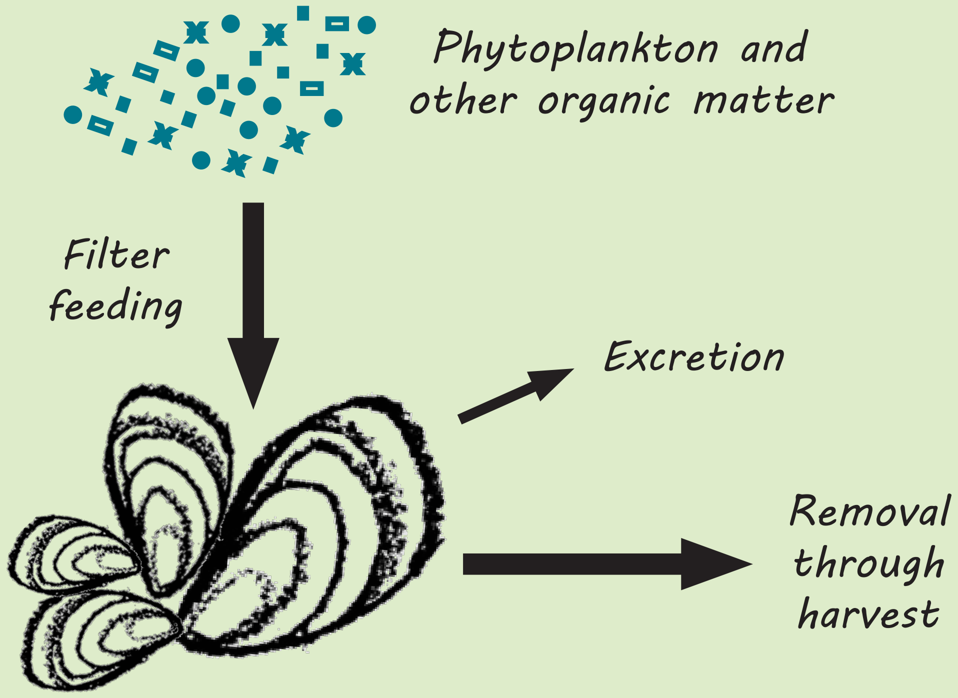
Under this dock thousands of mussels are growing. A single mussel can filter 13 gallons of water in a day, improving water clarity and incorporating nutrients into their tissues.

As part of an innovative research project here in Budd Inlet, these mussels will be harvested, tested and turned into rich compost. Researchers will then be able to calculate the amount of nitrogen and phosphorus removed from Budd Inlet.

Nutrient Bioextraction:

Growing and harvesting shellfish or seaweed to remove nutrients from natural water bodies. Also called nutrient bioharvesting.

Nutrient Removal by Shellfish



Phytoplankton and other organic matter

Filter feeding

Excretion

Removal through harvest

Budd Inlet experiences low dissolved oxygen in late summer and early fall, similar to Hood Canal. Low dissolved oxygen, or hypoxia, can be harmful to marine life and raises concerns about Budd Inlet's overall health. Low oxygen levels occur when excess nutrients stimulate the growth of microscopic phytoplankton. When they die, the decay process depletes oxygen levels in the water column.

You Can Help Reduce Nutrient Pollution

1. Choose organic, slow release fertilizers & phosphate-free cleaning products
2. Properly dispose of pet waste: Scoop it, Bag it, Trash it!
3. Maintain septic systems & responsibly manage farm manure

Pacific Shellfish Institute
www.pacshell.org
(360) 754-2741

Fostering sustainable shellfish resources and a healthy marine environment through research and education

Shellfish at Work: Nutrient Bioextraction

Nutrients flow into Puget Sound from many sources including ocean currents, fertilizers, human and animal wastes. Excess nutrients can fuel blooms of microscopic phytoplankton in fresh and marine waters. When plankton die, the decay process depletes oxygen levels in the water column, which can harm marine life.

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Wild mussels grown and harvested from southern Puget Sound, on straps under existing docks.

After lab testing to ensure safety, mussels were chipped, mixed with additional carbon sources (like wood chips) and turned into compost.

Plant growth trials comparing various products, including the Surf to Turf Mussel Compost.

Low oxygen levels also raise concerns about Puget Sound's overall health. To address these concerns, researchers placed hundreds of straps under existing docks as an attractive home for mussel larvae to settle and grow. The mussels filtered phytoplankton from the water, improving water clarity and incorporating nutrients into their tissues.

Mussels were harvested, tested and turned into rich organic compost. This closed loop cycle naturally removes nutrients from Puget Sound and returns them to the upland environment where they can be reused. Results demonstrate that bioextraction is a promising way to remove nutrients from Puget Sound while yielding a potentially marketable product: Surf to Turf Mussel Compost!

Nutrient Bioextraction:

Growing and harvesting shellfish or seaweed to remove nutrients from natural water bodies. Also called nutrient bioharvesting.

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Funding provided by US EPA thru Puget Sound Ecosystem Restoration & Protection to the Washington Dept. of Ecology (PC-00J20101) and the Russell Family Foundation.

Shellfish at Work – Nutrient Bioextraction Trials in Budd Inlet & Thea Foss Waterway

Project Summary: Eutrophication has been identified as one of the most serious threats to coastal environments worldwide. During this process, excess nutrients fuel phytoplankton growth that, upon decay, results in low oxygen levels in bottom waters of oftentimes poorly flushed inlets. Hypoxic conditions are harmful to marine life and raise concerns about the overall health of the watershed. This project evaluates the use of nutrient bioextraction, or growing and harvesting shellfish to remove nutrients from natural water bodies, as a strategy for mitigating anthropogenic nutrient loads in urban watersheds.

Andy Suhrbier leads a team of UW-Tacoma students to measure and record growth parameters and the community assemblage on mussel lines at West Bay Marina in Budd Inlet. Water quality parameters were also measured during these twice monthly assessments.

In spring 2013, over 400 nylon straps were placed under existing docks at 7 locations in lower Budd Inlet and the Thea Foss Waterway to provide a home for blue mussel larvae to settle upon and grow. In fall 2013 and spring 2014, over 5,000 pounds of mussels were harvested, tested for contaminants, and turned into rich compost at The Evergreen State College Organic Farm, Washington State University Extension in Puyallup, and two Washington Department of Corrections facilities: Cedar Creek and the Washington Correctional Center for Women. These pilot trials removed over 50 pounds of nitrogen from the two inlets converting it into approximately 6 cubic yards of rich compost.

Compost structures at The Evergreen State College Organic Farm, including green, enclosed bioreactors in the background.

Vegetative growth trials demonstrate high performance with "Surf to Turf" mussel compost created by this research project.

This project also serves as a way to provide outreach about nutrient sources and reduction strategies via community citizen monitoring and harvest events; student mentoring; and interactive workshops. Fieldtrips and hands-on classroom presentations were provided to over 500 K-12 and college level students in the Olympia region and are ongoing at Foss Waterway Seaport Museum. Discussions are also underway to explore bioextraction as a complement to traditional waste treatment.

Funding for this work was provided by two grants: the Russell Family Foundation (for Thea Foss) and the US EPA under Puget Sound Ecosystem Restoration and Protection to the Washington Dept. of Ecology (PC-00J20101). More research is recommended to better understand nutrient dynamics and oxygen concentrations below and around these types of nutrient bioextraction systems.

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