ANNUAL PROGRESS REPORT

Part I: Summary

PROJECT TITLE: Scale-dependent and indirect effects of filter feeders on eelgrass: Understanding complex ecological interactions to improve environmental impacts of aquaculture
REPORTING PERIOD: 4/1/04-3/31/05 [does not include 2005 field season]
AUTHOR: Jennifer Ruesink, Sally Hacker
FUNDING LEVEL: $79,607 + $70,531 = $150,138
PARTICIPANTS: Brett Dumbauld, USDA-ARS; *Sally Hacker, Oregon State University; Steve Harbell, Washington State University extension; Bruce Kaufmann, Washington Department of Fish and Wildlife; *Jennifer Ruesink, University of Washington
Graduate students: Kirsten Rowell, ASU (2004); Heather Tallis, UW (2003-04); Lorena Wisehart, OSU (2003-05); Elizabeth Wheat, UW (2005); Eric Wagner, UW (2005)

PROJECT OBJECTIVES:
Objective 1: Test the ability of benthic filter feeders to remove particulates from marine waters, and the response of eelgrass in distribution or growth rate.
Objective 2: Test the ability of benthic marine filter feeders to increase the nutrient and organic content of sediments through production of feces and pseudofeces, and the response of eelgrass in distribution, growth rate, and tissue quality.
Objective 3: Test the response of eelgrass to filter feeders in terms of eelgrass seed recruitment, germination, and seedling success.

ANTICIPATED BENEFITS: This project focuses on the ecological impacts of two filter-feeding species: Pacific oysters (*Crassostrea gigas*) in Willapa Bay, and geoducks (*Panopea abrupta*) in Puget Sound. Both species are cultured in areas that also support native eelgrass (*Zostera marina*). Because eelgrass is an ecologically-important and protected species, it is essential to know how bivalve aquaculture affects eelgrass. Our conceptual model includes direct negative effects of aquaculture on eelgrass via disturbance, but possible indirect positive effects of bivalves themselves through fertilization and improved water clarity. The anticipated benefits from the project include documentation of positive and negative effects that allow growers to develop best management practices for coexistence of aquaculture and eelgrass.

PROGRESS AND PRINCIPAL ACCOMPLISHMENTS:

Objective 1: Test the ability of benthic filter feeders to remove particulates from marine waters, and the response of eelgrass in distribution or growth rate.

We originally planned to measure depletion of water-column particulates through long-term measurements of chlorophyll and turbidity on harvested and unharvested shellfish beds. We expected beds to have lower concentrations of particulates in overlying water before vs. after harvest. However, preliminary data from 2003 indicated two problems – low sample size because each replicate required several weeks to acquire, and low effect size because particulate concentrations varied for reasons other than bivalve density, particularly at tidal and subtidal time scales. Consequently, we redesigned the study to measure depletion in parcels of water passing over shellfish beds. We expected the rate of depletion to be directly related to bivalve density and inversely related to water flow and water depth. We began testing this hypothesis during the 2005 field season by tracking water flow (GPS drifters) and water properties (YSI datasondes) over oyster beds in Willapa Bay. Because this work was carried out after the reporting period for this annual report, the design of this study is included in the section on work planned for next year. Under the supervision of Jennifer Ruesink, UW graduate student Beth Wheat will complete this work as part of her PhD thesis.

Objective 2: Test the ability of benthic marine filter feeders to increase the nutrient and organic content of sediments through production of feces and pseudofeces, and the response of eelgrass in distribution, growth rate, and tissue quality.

We have taken two approaches to understanding how shellfish affect sediment properties: comparative studies of areas subjected to different aquaculture practices; and experimental studies at smaller scales in which we manipulate shellfish, nutrients, and eelgrass independently.

Comparative studies – Based on comparative work in Willapa Bay, two manuscripts are in preparation. In 2003, we found that sediment properties showed substantial variation among locations, and that locations with high silt content also had low reduction-oxidation potential and high densities of microbes. In contrast, the functional diversity of microbes varied significantly among aquaculture types, as measured on Ecolog plates containing 32 different carbon sources. Microbes associated with ground culture used different carbon sources than those in eelgrass beds. In 2004, we compared eelgrass densities and growth rates among locations and aquaculture types. More intensive aquaculture tended to be associated with lower eelgrass densities, in keeping with the expectation that disturbance removes eelgrass. Growth (standardized for shoot size), on the other hand, varied with oyster density, although the relationship varied among locations: in one place, growth improved with oyster density, whereas in another place growth declined as oysters reached higher density. This suggests that the impacts of bivalves on eelgrass growth are context-dependent, even within a single bay. Heather Tallis, UW graduate student, is currently writing up the comparative study for publication.

Experimental studies, Puget Sound – In June 2004, we established a three-factor design (+/- eelgrass, +/- geoducks, +/- fertilizer) in 1 m^2 plots, and we have measured sediment characteristics, eelgrass density and growth rate at seasonal intervals. Over one year, we have observed direct negative effects of disturbance and of geoducks on eelgrass density: eelgrass-removal plots remain at low density, although vegetative regrowth has occurred from the edges; and plots with geoducks have lower eelgrass densities than do those without. On the other hand, we have seen little evidence of indirect positive effects of geoducks: porewater nutrient concentrations appear slightly higher when geoducks are present, but this “fertilizer” effect does not result in enhanced growth rates of eelgrass. Jennifer Ruesink, with research technicians, will continue the project started by Kirsten Rowell, ASU graduate student.

Experimental studies, Willapa Bay – In June 2004, we established six treatments in 2x2 m plots with or without eelgrass at two locations to explore the important mechanisms that may be driving the patterns found in the comparative studies above. The treatments are: bare, shell addition, fertilizer addition, shell and fertilizer addition, medium-density oysters (30-50% cover), and high-density oysters (50-80% cover). Initial impacts included negative effects of both live oysters and oyster shell on eelgrass density. At oyster densities commonly found in Willapa Bay, eelgrass occurred at about ½ the density found in undisturbed eelgrass beds. In October 2004, we added eelgrass seed packets to the plots to understand how these treatments affect seedling establishment. The experimental plots were censused for adult and seedling eelgrass abundance and growth starting in April 2004. Because this work was carried out after the reporting period for this annual report, the results will be presented in next year's annual report. This work is the responsibility of Eric Wagner (adult eelgrass and sediments), UW graduate student, and Lorena Wisehart (eelgrass seedlings), OSU graduate student under the supervision of Jennifer Ruesink and Sally Hacker.

Objective 3: Test the response of eelgrass to filter feeders in terms of eelgrass seed recruitment, germination, and seedling success.

In 2004 we surveyed eelgrass density and seedling abundance in dredged and longline culture and in eelgrass beds at different sites in Willapa Bay. At one site we found an interesting relationship between seedling densities and the time since dredging. Eelgrass seedlings were most abundant in areas that had been dredged one year prior to surveying. These areas also had the lowest densities of adult plants. To better understand these patterns we set up seed addition experiments across the bay and under different aquaculture types with and without adult eelgrass neighbors in October 2004. These experiments will allow us to understand how dredging and long line aquaculture influences early life history of eelgrass and whether this varies with location within the bay. In 2005 we are continuing to monitor seedling densities across the bay as well as collecting data on seed germination and seedling survival in our experimental plots. Under the supervision of Sally Hacker, Lorena Wisehart, OSU graduate student, has collected and compiled data on eelgrass phenology, and how seedling germination and survival vary across Willapa Bay and under different aquaculture types.

USEFULNESS OF FINDINGS: The public benefits from our research because we communicate to managers about the response of eelgrass to different aquaculture practices and to shellfish themselves. This communication has occurred primarily at scientific meetings, for instance annual shellfish meetings and the Puget Sound-Georgia Basin Research Conference. In 2004, we also met one-on-one with Squaxin tribal biologists and traveled to Humboldt Bay to discuss research results. In addition, we have responded to direct inquiries from Washington Department of Natural Resources and Department of Fish and Wildlife, both of which are gathering information relevant to geoduck aquaculture in south Puget Sound. For public outreach, we set up a booth at the Willapa Bay Seafood Festival, where attendees could watch the draw-down of phytoplankton by filter feeders.

WORK PLANNED FOR NEXT YEAR:

Objective 1: Track water properties across oyster beds in Willapa Bay to test the ability of oysters to improve water clarity. We will drift multiple times over oyster beds with different a) oyster densities, b) water flows, c) water depths, and d) initial phytoplankton concentrations. Water properties will be tracked by GPS and YSI datasondes attached to shallow drifters. Simultaneously, we will collect water samples for benchtop fluorometry, which is necessary for cross-calibration of the YSIs.

Objective 2: Continue recording sediment properties, eelgrass density and growth in experiments in Puget Sound and Willapa Bay. Seasonal monitoring will enable us to track two sorts of changes: recovery of eelgrass in eelgrass-removal plots, and sediment changes that only happen seasonally or over longer time periods.

Objective 3: Measure seedling germination and survival, from both natural and planted seeds, across Willapa Bay. We will focus particularly on recruitment into different aquaculture types, and into areas with eelgrass vs. eelgrass removed. In addition, we will record seedlings that appear in the experimental plots, where eelgrass, oyster, shell, and nutrient levels have been manipulated. Finally, we will sample eelgrass for seed production and sediments for seed bank dynamics.

IMPACTS: 1) Aquaculture in areas with eelgrass is currently more controversial in California than farther north. However, results from our research have been used to inform decision-making about aquaculture in Humboldt Bay, California. Jennifer Ruesink presented results from Willapa Bay at a public meeting on aquaculture and eelgrass at Humboldt Bay in December 2004. The take-home message from this presentation was that certain types of aquaculture, particularly fast-rotation dredging, reduce eelgrass densities, but sexual reproduction can promote recovery within a few years. 2) Brett Dumbauld attended a meeting of the habitat committee of the PMFMC in Portland, Oregon where it was clear that results from this study will be used in a programmatic Section 4 permit for aquaculture activities should that materialize. 3) Puget Sound geoduck growers are currently developing a habitat conservation plan (HCP) for aquaculture that is compatible with eelgrass and salmon habitat. Our research results may be incorporated into this HCP.

SUPPORT:

Year	WRAC-USDA	Univ	Industry	Other Fed	Other	Total	Total Support
2003	79,607	>$6,000	20,000	>$3,000		>29,000	108,607
2004	70,531	>$6,000	20,000	>$3,000	>3,000	>32,000	102,531
Total	150,138	12,000	40,000	6,000	3,000	61,000	211,138

1) J. Ruesink, supported by UW, worked on the Puget Sound portion of the project. Tides and data processing required (June 04 – 30 hrs) (Nov. 10 hrs) (Feb. 25 hrs) 65 hrs. She also provided field support and data processing at Willapa Bay during most tide series.
2) S. Hacker, supported by WSU (4/04-5/04) and OSU (8/04-4/05), worked on eelgrass seedling and adult growth under natural and experimental conditions in Willapa Bay. Field dates and meetings included May 4-10 2004 (growth/survey), July 1-3 2004 (growth), July 27-28 2004 (growth), August 26-30 2004 (seed addition setup), September 14 2004 (seed addition setup), Nov 11-13 2004 (seed addition setup), February 25 2005 (meeting), March 7-8 (seed survey), and March 19-20 2004 (PERS meeting). In addition, Hacker devotes about 10-15% of her time on administrative duties of the project.
3) B. Dumbauld and technicians Roy Hildebrand and Roxanne Barker, supported by USDA-ARS, worked on eelgrass seedling and adult growth surveys in Willapa Bay (May 04 - 14 hrs, July 04- 10 hours, August 04 – 72 hours, September 04 -10 hours, March 05 (14 hours).
4) A. Trimble, supported by Mellon Foundation, worked on the drifting project. In 2004, he estimates 40 hrs. He also provided field support during most low tide series.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED:

Publications in Print and Manuscripts –

Richardson NF, Ruesink JL, Naeem S, Dumbauld BR, Hacker S, Tallis H, Wisehart L. Abundance and functional diversity of sediment microbes across natural and oyster aquaculture habitats in a northeastern Pacific estuary. In preparation for Aquatic Microbial Ecology

Tallis H, Dumbauld BR, Wisehart L, Hacker S, Ruesink J. Eelgrass density and growth across natural and oyster aquaculture habitats in a northeastern Pacific estuary. In preparation for Aquaculture.

Some data from this project were included in the following manuscript:
Ruesink JL, Feist BE, Harvey CJ, Hong JS, Trimble AC, Wisehart LM. Changes in productivity associated with four introduced species: Ecosystem transformation of a "pristine" estuary. In revision, Marine Ecology Progress Series.

Papers presented –

McCoy L, Ruesink J. What are you eating? Willapa Bay Seafood Festival, May 2004 (poster)

Wisehart, L.M., H.M. Tallis, S.D. Hacker, J.L. Ruesink, and B.R. Dumbauld. The effects of oyster aquaculture on eelgrass (*Zostera marina* L.) biomass, density, and growth rates in Willapa Bay, WA. Pacific Estuarine Research Society Meeting, Port Townsend, WA, May 2004 (talk).

Tallis H. Ecological Society of America annual meeting, August 2004 (poster)

Ruesink JL. Research projects in south Puget Sound. Meeting with Squaxin tribal biologists, September 2004 (talk)

Wisehart L., S.D. Hacker, J. Ruesink, and B. Dumbauld. Eelgrass (*Zostera marina* L.) seed dispersal and recruitment inside and outside oyster aquaculture areas in Willapa Bay, WA. PCSGA/NSA annual meeting, October 2004 (talk).

Rowell K, White JM, Ruesink JL. Interactions between geoducks and eelgrass. PCSGA/NSA annual meeting, October 2004 (talk)

Wisehart, L., S.D. Hacker, J. Ruesink, and B. Dumbauld. Eelgrass (*Zostera marina* L.) seed dispersal and recruitment inside and outside oyster aquaculture areas in Willapa Bay, WA. International Seagrass Conference, Australia, October 2004 (talk).

Ruesink JL. Direct and indirect effects of oysters and shellfish aquaculture on eelgrass (Zostera marina) in Willapa Bay, Washington. Humboldt Bay Marine Management Commission, December 2004 (talk)

Ruesink JL, Rowell K. Geoduck aquaculture and eelgrass in south Puget Sound – a preliminary report. 13th Annual Meeting for Shellfish Growers, February 2005 (talk)

Rowell K, Ruesink JL, White JM. Influences of geoduck aquaculture on eelgrass. Puget Sound Georgia Basin Research Conference, March 2005 (poster)

Wisehart, L., S.D. Hacker, J. Ruesink, and B. Dumbauld. Does oyster aquaculture influence eelgrass recruitment? Pacific Estuarine Research Society, Coos Bay, OR, March 2005 (talk).

SUBMITTED BY: ____

Jennifer Ruesink, PI Date

Part II: Detail

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Comparative studies – Based on comparative work in Willapa Bay, two manuscripts are in preparation. In 2003, we found that sediment properties showed substantial variation among locations, and that locations with high silt content also had low reduction-oxidation potential and high densities of microbes. In contrast, the functional diversity of microbes varied significantly among aquaculture types, as measured on Ecolog plates containing 32 different carbon sources. Microbes associated with ground culture used different carbon sources than those in eelgrass beds. Quantitative results were presented in last year's annual report.

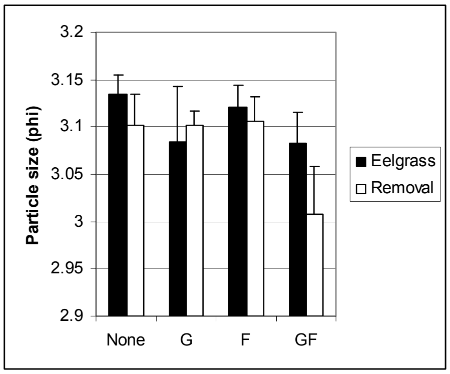
In 2004, we compared eelgrass densities and growth rates among locations and aquaculture types. More intensive aquaculture tended to be associated with lower eelgrass densities, in keeping with the expectation that disturbance removes eelgrass. Growth (standardized for shoot size), on the other hand, varied with oyster density, although the relationship varied among locations: in one place, growth improved with oyster density, whereas in another place growth declined as oysters reached higher density. This suggests that the impacts of bivalves on eelgrass growth are context-dependent, even within a single bay. Heather Tallis, UW graduate student, is currently writing up the comparative study for publication. Salient statistical results are presented in the following table, which shows model selection variable weights (wAICc values) for the eelgrass growth survey. All variables present in at least one of the best models are italicized. Variables with wAICc values ≥ 0.5 are considered strong predictors (bold). Symbols in parentheses show the direction of linear relationships.

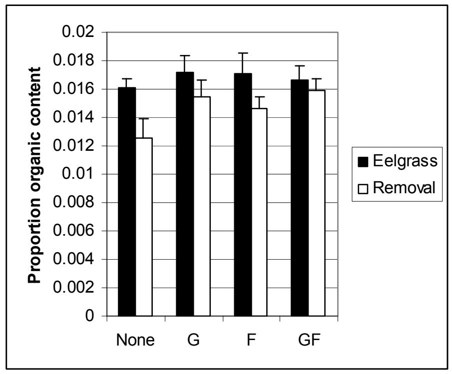
Variable	**Density (shoots m^{-2})**	**Plant Size (g)**	**Productivity (g g^{-1} d^{-1})**	**Production (g m^{-2} d^{-1})**
Oyter Density	**0.75(-)**	**0.59(-)**	**0.96(+/-)**	0.16
Culture	**0.66**	*0.34*	0.02	**0.99**
Site	*0.34*	**0.82**	**0.92**	**0.97**
Site*Culture	0.00	0.00	0.00	0.01
Oyster Density*Site	0.02	*0.12*	**0.89**	0.01
Oyster Density*Culture	0.00	0.00	0.00	0.00

Both plant density and plant size were lower when oysters were present, and the type of aquaculture also influenced density: dredged beds and longlines tended to have lower amounts of eelgrass than did hand-picked beds. These results are consistent with aquaculture constituting a disturbance of eelgrass. The question of primary interest, however, is how oysters influence eelgrass on a per-plant basis, or productivity in the above table. At Long Island, eelgrass growth improved with oyster density, but at Nemah, eelgrass growth declined with oyster density.

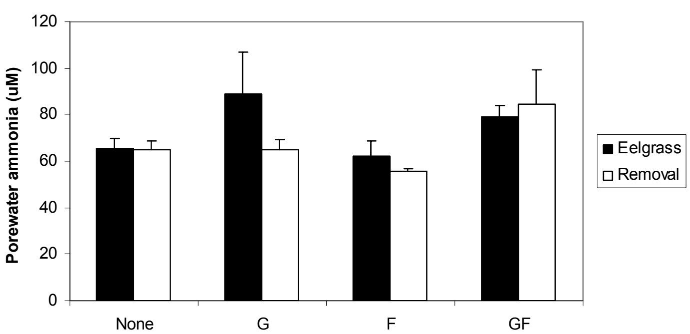
Experimental studies, Puget Sound – In June 2004, we established a three-factor design (+/- eelgrass, +/- geoducks, +/- fertilizer) in 1 m^2 plots, and we have measured sediment

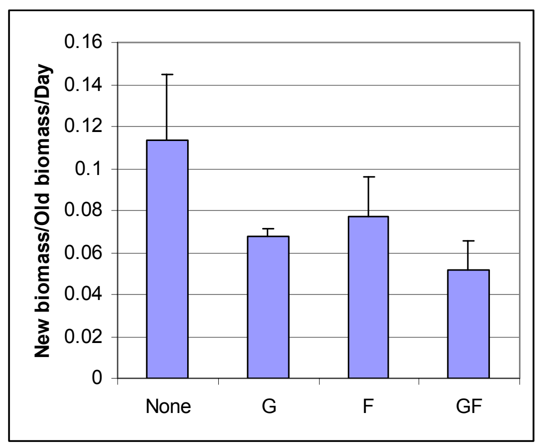
characteristics, eelgrass density and growth rate at seasonal intervals. Over one year, we have observed direct negative effects of disturbance and of geoducks on eelgrass density: eelgrass-removal plots remain at low density, although vegetative regrowth has occurred from the edges; and plots with geoducks have lower eelgrass densities than do those without. On the other hand, we have seen little evidence of indirect positive effects of geoducks:
The graphs below show that sediment properties – the size of particles and the organic content – were not affected by any treatment. Treatments are: None (without geoducks or fertilizer), G (with geoducks), F (with fertilizer) and GF (with geoducks and fertilizer).



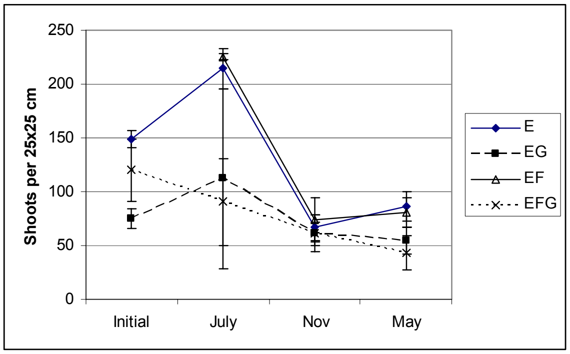


In contrast, porewater ammonia concentrations were statistically higher with geoducks than in other treatments. Ammonia is easily used by plants as a source of nitrogen, and other work has shown that eelgrasses tend to be nitrogen-limited below 100 uM. Thus, although the increase in porewater ammonia found in November 2004 (~20%) is small, it may be biologically significant because ambient levels are below the level required by eelgrass, as shown below (left).



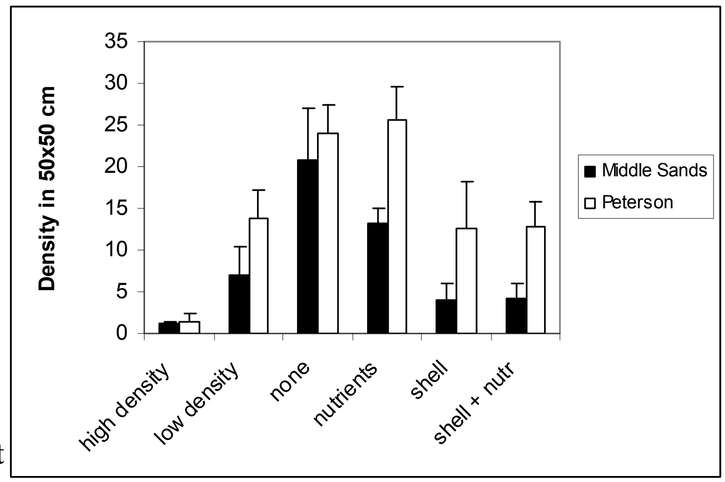


Nevertheless, eelgrass growth rates did not differ statistically across treatments in November 2004 (above right), and in fact the trend is towards higher growth in the absence of geoducks. Thus, no fertilization effect was evident for eelgrass at this point in the experiment. On the other hand, geoducks appeared to have a slight negative effect on eelgrass density. The large difference in density between treatments with and without geoducks in July 2004 mostly reflects disturbance during the transplant process. By November, all plots had low densities of eelgrass, which is a common phenomenon during winter. In spring 2005, however, differences in density reappeared: plots containing geoducks contained about 30% fewer eelgrass shoots than those without. (See graph on next page)



Jennifer Ruesink, with research technicians, will continue the project started by Kirsten Rowell, ASU graduate student.

Experimental studies, Willapa Bay – In June 2004, we established six treatments in 2x2 m plots with or without eelgrass at two locations to explore the important mechanisms that may be driving the patterns found in the comparative studies above. The treatments are: bare, shell addition, fertilizer addition, shell and fertilizer addition, medium-density oysters (30-50% cover), and high-density oysters (50-80% cover). Initial impacts included negative effects of both live oysters and oyster shell on eelgrass density (graph at right, from March 2005). The "low density" oyster treatment was set up to mimic densities used in aquaculture in Willapa Bay. Probably due to space competition with oysters, eelgrass occurred at about ½ the density found in undisturbed eelgrass beds; higher densities of oysters nearly eliminated eelgrass.



In October 2004, we added eelgrass seed packets to the plots to understand how these treatments affect seedling establishment. The experimental plots were censused for adult and seedling eelgrass abundance and growth starting in April 2004. Because this work was carried out after the reporting period for this annual report, the results will be presented in next year's annual report. This work is the responsibility of Eric Wagner (adult eelgrass and sediments), UW graduate student, and Lorena Wisehart (eelgrass seedlings), OSU graduate student. under the supervision of Jennifer Ruesink and Sally Hacker.

Objective 3: Test the response of eelgrass to filter feeders in terms of eelgrass seed recruitment, germination, and seedling success.

We have been exploring the influence of aquaculture practices on the early life history stages of eelgrass in the Pacific Northwest. Early life history stages can be critical to the maintenance of viable populations, particularly when adults experience regular disturbance regimes characteristic of oyster aquaculture. In particular, we want to know whether different oyster aquaculture practices, such as bottom culture (with dredging) versus off-bottom culture (i.e., long lines), influence eelgrass recruitment. In addition, we want to understand whether the location of such practices within Willapa Bay, Washington, play a role in recruitment.

To understand the pattern of eelgrass seedling recruitment within Willapa Bay, we conducted observational surveys at 3 different sites (Nemah, Oysterville, and Stony Point) in Spring 2004. Within eelgrass beds, we found more than twice as many seedlings at Stony Point compared to the other sites (Figure 1A). This difference could be controlled by seed supply and/or physical conditions that influence germination. We found that flower production was essentially equal at all three sites suggesting that seed supply does not vary (Figure 1B). However, Stony Point, due its proximity to the Willapa River, experiences lower salinity; eelgrass germination is known to be higher when salinities are lower, possibly explaining the differences we observed at this location.

More importantly, our surveys of different aquaculture types show eelgrass recruitment to significantly vary with particular practices. We surveyed the number of seedlings in a variety of oyster aquaculture conditions (newly dredged, 1 year post-dredge, 2 years post-dredge, long lines, and no aquaculture) at Nemah. As expected, we found that eelgrass seedling abundance was low in newly dredged and seeded areas (Figure 2A).

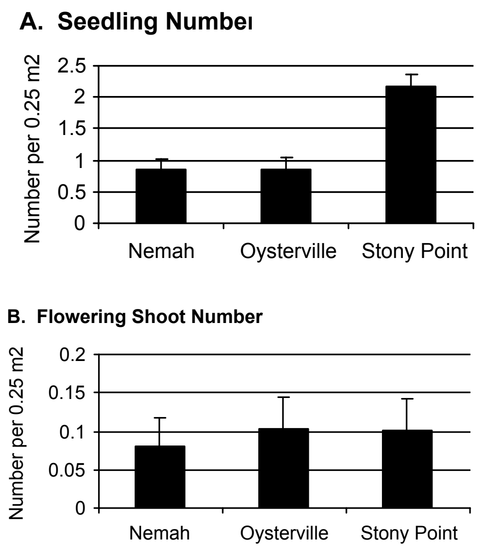


Figure 1. Numbers of eelgrass (A) seedlings and (B) flowering shoots at 3 sites in eelgrass beds in Willapa Bay, WA (April 2004). Stony Point had significantly more seedlings than the other two sites, which did not differ (Kruskal Wallis; df=2, H=37, P< 0.01). There was no difference in flowering shoot number (K–W; df=2, H=1, P=0.75).

However, within a year after dredging, seedling recruitment was high suggesting that recovery via newly germinated eelgrass was robust. Areas that had not experienced dredging for 2 years had seedling numbers similar to areas that were not exposed to aquaculture (Figure 2A). Surprisingly, seedling numbers were lowest in long line aquaculture compared to other treatments (Figure 2A). In the case of seedling recruitment in different aquaculture types, the likely factors controlling seedling number may be numerous. The most obvious possibility is that of dredging which, by removing adult competitors, creates light or nutrient conditions conducive to seed germination. Alternatively, the absence of adult oysters may play a role. Our surveys suggest that the former process is more important than the later. For example, adult eelgrass shoots were virtually absent in the newly dredged and one year dredged areas, where seedling abundance was high, but very abundant in the two year dredged and no aquaculture areas where seedlings were less numerous. However, oyster abundance was unrelated to seedling number; for example, there were no oysters in the unfarmed areas compared to the

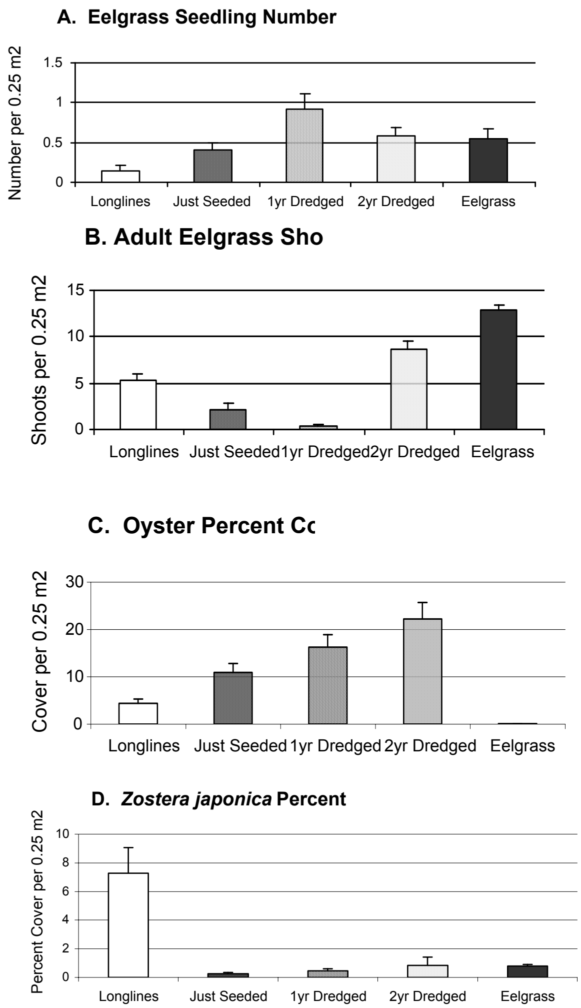


Figure 2. (A) Eelgrass seedling number, (B) oyster percent cover, (C) Adult eelgrass shoots, and (D) Zostera japonica percent cover under different aquaculture conditions at Nemah, Willapa Bay, WA (April 2004).

farmed areas even though seedling abundance was similar in both of these areas (Figure 2C). Finally, the low seedling abundance in long line areas was unexpected but may be influenced by increased sedimentation around the aquaculture structure (Rumrill, personal communication) and the increased presence of the non-native eelgrass, *Zostera japonica* (Figure 2D), which not only prefers higher elevations, but is also very dense and might compete with seedlings.

To explore the mechanisms important to seedling recruitment under different aquaculture types, we conducted two separate eelgrass seed addition experiments that were censused over the summer of 2005 (data not included here). Seed addition experiments allow us to exclude the influence of differential seed supply and allow us to focus on factors that effect germination only. Below are descriptions of the three experiments.

1. What is the influence of eelgrass removal (simulated dredging) on seedling recruitment across Willapa Bay? In this experiment, 15 paired plots were created at 7 separate sites (Oysterville, Stackpole, Nahcotta, Nemah, Long Island, Stony Point, and Peterson) that either have eelgrass removal or eelgrass presence (control). Into each these plots, we placed 15 cm diameter mesh packets (1 mm) stuffed with biodegradable paper towel bags filled with 50 eelgrass seeds. We surveyed these plots in April 2005 to determine seedling germination both at different sites and under different eelgrass treatments (data not included in this report). If we find increased germination without eelgrass, it is strong evidence that dredging may trigger eelgrass colonization and possible recovery.

2. What is the effect of aquaculture on seedling recruitment? In this experiment, we placed seed packets in different aquaculture treatments created by oyster aquaculturalists at Stony Point. The treatments included bottom culture, long lines, and eelgrass controls. Seed packets were placed in paired plots with and without eelgrass. We surveyed these plots in April 2005 to determine seedling germination in the different culture types (data not included in this report). Our prediction is that eelgrass will germinate in areas where mature eelgrass is removed regardless of the presence of oysters. In addition, we predict that germination will be low in long lines with or without eelgrass stands due to the increased sedimentation present under these structures.

Objective 3 is being conducted by Lorena Wisehart, OSU graduate student, under the supervision of Sally Hacker.

USEFULNESS OF FINDINGS: The public benefits from our research because we communicate to managers about the response of eelgrass to different aquaculture practices and to shellfish themselves. This communication has occurred primarily at scientific meetings, for instance annual shellfish meetings and the Puget Sound-Georgia Basin Research Conference. In 2004, we also met one-on-one with Squaxin tribal biologists and traveled to Humboldt Bay to discuss research results. In addition, we have responded to direct inquiries from Washington Department of Natural Resources and Department of Fish and Wildlife, both of which are gathering information relevant to geoduck aquaculture in south Puget Sound. For public outreach, we set up a booth at the Willapa Bay Seafood Festival, where attendees could watch the draw-down of phytoplankton by filter feeders.

WORK PLANNED FOR NEXT YEAR:

Objective 1: Track water properties across oyster beds in Willapa Bay to test the ability of oysters to improve water clarity. We will drift multiple times over oyster beds with different a) oyster densities, b) water flows, c) water depths, and d) initial phytoplankton concentrations. Water properties will be tracked by GPS and YSI datasondes attached to shallow drifters. Simultaneously, we will collect water samples for benchtop fluorometry, which is necessary for cross-calibration of the YSIs.

Objective 2: Continue recording sediment properties, eelgrass density and growth in experiments in Puget Sound and Willapa Bay. Seasonal monitoring will enable us to track two sorts of changes: recovery of eelgrass in eelgrass-removal plots, and sediment changes that only happen seasonally or over longer time periods.

Objective 3: Measure seedling germination and survival, from both natural and planted seeds, across Willapa Bay. We will focus particularly on recruitment into different aquaculture types, and into areas with eelgrass vs. eelgrass removed. In addition, we will record seedlings that appear in the experimental plots, where eelgrass, oyster, shell, and nutrient levels have been manipulated. Finally, we will sample eelgrass for seed production and sediments for seed bank dynamics.

IMPACTS: 1) Aquaculture in areas with eelgrass is currently more controversial in California than farther north. However, results from our research have been used to inform decision-making about aquaculture in Humboldt Bay, California. Jennifer Ruesink presented results from Willapa Bay at a public meeting on aquaculture and eelgrass at Humboldt Bay in December 2004. The take-home message from this presentation was that certain types of aquaculture, particularly fast-rotation dredging, reduce eelgrass densities, but sexual reproduction can promote recovery within a few years. 2) Brett Dumbauld attended a meeting of the habitat committee of the PMFMC in Portland, Oregon where it was clear that results from this study will be used in a programmatic Section 4 permit for aquaculture activities should that materialize. 3) Puget Sound geoduck growers are currently developing a habitat conservation plan (HCP) for aquaculture that is compatible with eelgrass and salmon habitat. Our research results may be incorporated into this HCP.

SUPPORT:

Year	WRAC-USDA	Univ	Industry	Other Fed	Other	Total	Total Support
2003	79,607	>$6,000	20,000	>$3,000		>29,000	108,607
2004	70,531	>$6,000	20,000	>$3,000	>3,000	>32,000	102,531
Total	150,138	12,000	40,000	6,000	3,000	61,000	211,138

1) J. Ruesink, supported by UW, worked on the Puget Sound portion of the project. Tides and data processing required (June 04 – 30 hrs) (Nov. 10 hrs) (Feb. 25 hrs) 65 hrs. She also provided field support and data processing at Willapa Bay during most tide series.
2) S. Hacker, supported by WSU (4/04-5/04) and OSU (8/04-4/05), worked on eelgrass seedling and adult growth under natural and experimental conditions in Willapa Bay. Field dates and meetings included May 4-10 2004 (growth/survey), July 1-3 2004 (growth), July 27-28 2004 (growth), August 26-30 2004 (seed addition setup), September 14 2004 (seed addition setup), Nov 11-13 2004 (seed addition setup), February 25 2005 (meeting), March 7-8 (seed survey), and March 19-20 2004 (PERS meeting). In addition, Hacker devotes about 10-15% of her time on administrative duties of the project.
3) B. Dumbauld and technicians Roy Hildebrand and Roxanne Barker, supported by USDA-ARS, worked on eelgrass seedling and adult growth surveys in Willapa Bay (May 04 - 14 hrs, July 04- 10 hours, August 04 – 72 hours, September 04 -10 hours, March 05 (14 hours).
4) A. Trimble, supported by Mellon Foundation, worked on the drifting project. In 2004, he estimates 40 hrs. He also provided field support during most low tide series.

PUBLICATIONS, MANUSCRIPTS, OR PAPERS PRESENTED:

Publications in Print and Manuscripts –

Richardson NF, Ruesink JL, Naeem S, Dumbauld BR, Hacker S, Tallis H, Wisehart L. Abundance and functional diversity of sediment microbes across natural and oyster aquaculture habitats in a northeastern Pacific estuary. In preparation for Aquatic Microbial Ecology

Tallis H, Dumbauld BR, Wisehart L, Hacker S, Ruesink J. Eelgrass density and growth across natural and oyster aquaculture habitats in a northeastern Pacific estuary. In preparation for Aquaculture.

Some data from this project were included in the following manuscript:

Ruesink JL, Feist BE, Harvey CJ, Hong JS, Trimble AC, Wisehart LM. Changes in productivity associated with four introduced species: Ecosystem transformation of a “pristine” estuary. In revision, Marine Ecology Progress Series.

Papers presented –

McCoy L, Ruesink J. What are you eating? Willapa Bay Seafood Festival, May 2004 (poster)

Wisehart, L.M., H.M. Tallis, S.D. Hacker, J.L. Ruesink, and B.R. Dumbauld. The effects of oyster aquaculture on eelgrass (*Zostera marina* L.) biomass, density, and growth rates in Willapa Bay, WA. Pacific Estuarine Research Society Meeting, Port Townsend, WA, May 2004 (talk).

Tallis H. Ecological Society of America annual meeting, August 2004 (poster)

Ruesink JL. Research projects in south Puget Sound. Meeting with Squaxin tribal biologists, September 2004 (talk)

Wisehart L., S.D. Hacker, J. Ruesink, and B. Dumbauld. Eelgrass (*Zostera marina* L.) seed dispersal and recruitment inside and outside oyster aquaculture areas in Willapa Bay, WA. PCSGA/NSA annual meeting, October 2004 (talk).

Rowell K, White JM, Ruesink JL. Interactions between geoducks and eelgrass. PCSGA/NSA annual meeting, October 2004 (talk)

Wisehart, L., S.D. Hacker, J. Ruesink, and B. Dumbauld. Eelgrass (*Zostera marina* L.) seed dispersal and recruitment inside and outside oyster aquaculture areas in Willapa Bay, WA. International Seagrass Conference, Australia, October 2004 (talk).

Ruesink JL. Direct and indirect effects of oysters and shellfish aquaculture on eelgrass (Zostera marina) in Willapa Bay, Washington. Humboldt Bay Marine Management Commission, December 2004 (talk)

Ruesink JL, Rowell K. Geoduck aquaculture and eelgrass in south Puget Sound – a preliminary report. 13th Annual Meeting for Shellfish Growers, February 2005 (talk)

Rowell K, Ruesink JL, White JM. Influences of geoduck aquaculture on eelgrass. Puget Sound Georgia Basin Research Conference, March 2005 (poster)

Wisehart, L., S.D. Hacker, J. Ruesink, and B. Dumbauld. Does oyster aquaculture influence eelgrass recruitment? Pacific Estuarine Research Society, Coos Bay, OR, March 2005 (talk).

SUBMITTED BY: ____

Jennifer Ruesink, PI Date