NATIVE OYSTER EXPERIMENTAL STUDIES IN FIDALGO BAY

FINAL REPORT

May 25, 2004

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NORTHWEST STRAITS
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Skagit MRC

Center for the Study of Coast Salish Environments
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Native “Olympia” oysters (*Ostrea lurida*) were prized by Coast Salish peoples and earlier European settlers in Puget Sound, and by the 1870s supported an important commercial shellfish farming industry with a major center in Samish and Padilla Bays. Native oysters were in decline by the 1890s, however, and have been nearly completely replaced on shellfish farms and in the wild by the introduced Pacific oyster (*Crassostrea gigas*) for nearly a century. Relic populations of native oysters remain in small patches throughout Puget Sound, however, and interest in native oyster ecology has been renewed with recent efforts to restore Puget Sound nearshore habitats and rebuild stocks of native animals and plants.

Ostrea lurida is a reef-builder, found in paleontological contexts forming massive colonies on rock anchors in sheltered bays (Miller & Morrison 1988). Unlike the Pacific oyster and other commercial shellfish, which shed eggs and sperm into warm summer waters producing clouds of planktonic larvae, native oysters fertilize their eggs internally, and harbor their larval offspring until they are nearly ready to settle (Baker 1995). Larval native oysters consequently tend to settle relatively near the parents, contributing to the growth of the reef.

The dramatic decline in native oysters a century ago has not been fully explained, leaving questions about the prospects for their restoration. There were several unusually severe winters in the 1880s, which froze the shallow standing water in commercial oyster beds; Puget Sound oyster growers also complained about logging, sawmills and industrial pollution (Townshend 1893; Baker 1995). Aggressive commercial harvesting of native oysters and log booms may have damaged reefs structurally, while diking shallow bays to expand commercial oyster production led to silting and shallower water, placing native oysters at risk.

Crassostrea gigas grows faster and larger than *Ostrea lurida*, and also appears to be more tolerant of prolonged exposure and extreme temperatures—qualities favorable to commercial aquaculture. In the years when Pacific oysters have a good set, they spread widely, possibly crowding out *Ostrea* larvae and juveniles. It is not known whether there are adverse interactions between native and Pacific oysters when they are present in the same area. The Atlantic oyster drill (*Urosalpinx cinerea*), introduced into Puget Sound waters with *Crassostrea virginica* seed from East Coast oyster farms over a century ago, has caused considerable damage to *Crassostrea gigas* culture, and may have contributed to the demise of *Ostrea lurida* as well. The relative vulnerability of native and Pacific oysters to predation by the oyster drill is not known.

The contemporary distribution of *Crassostrea gigas* in Puget Sound suggests that it is more tolerant of soft substrates than *Ostra lurida*. The geographic extent and depths of organic mud in north Skagit bays appears to have increased markedly since the 1850s, reflecting increased run-off and fine sediment loads in streams due to logging, alteration of stream courses, sawmill discharges, and the hardening of ground surfaces by roads and other structures. Growers of Pacific oysters have responded by spreading oyster shells on soft substrates to provide a firmer environment for larval settlement, or by raising oysters completely out of the substrate in suspended mesh bags. Native and Pacific oysters settle preferentially on rocks, where they are least likely to be dislodged by waves, crushed by drifting debris, or buried in the substrate.

According to Suttles (1974), Fidalgo Bay and Samish Bay were important sources of native oysters for the Samish people and their neighbors in the 19th Century. Shells of *Ostrea lurida* are visible in the exposed profile of the large archaeological site—probably the remains of a plank house village—on Weaverling Spit (45SK43), although the age of this shell midden deposit has not yet been determined. In pre-Contact times, Fidalgo Bay was connected with Similk Bay by a tidal marsh that has been drained by landowners and impounded by Highway 20. Log booms, south Anacortes lumber and plywood mills, and the hardening of shorelines by the refinery complex have increased sediment loads; while the Burlington Northern railroad causeway and trestle have restricted tidal flushing of the inner bay.[1] On the whole, bay substrates are softer than they were in the 19th Century, an increase in mud over rock, cobbles and sands. A comparison of contemporary inter-tidal fauna with the contents of 45SK43 suggests an increase in mud tolerant bent-nosed clams (*Macoma nasuta*) and a decrease in species that require hard substrates such as barnacles (in particular *Balanus nubilis*, a common traditional food), chitons, and whelks.

Purpose

The City of Anacortes and the Samish Indian Nation share an interest in restoring native oyster stocks in Fidalgo Bay, where according to Samish oral traditions there once were extensive family owned oyster reefs. Cultch shells seeded with native oysters were scattered under the east end of the railroad trestle in 2002 and 2003, with good survival and growth rates (Robinette & Dinnel 2003). The present study was designed to provide scientific guidance for further expansion of these efforts.

We hoped to determine: (1) whether a harder substrate (shells or rocks) makes a significant difference in the survival and/or growth of native oysters; (2) the causes of the morbidity and mortality of juvenile native oysters in Fidalgo Bay; and (3) whether the causes of oyster morbidity and mortality vary with the type of substrate.

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[1] The pattern of alteration of Fidalgo Bay hydrology by the trestle and causeway is complex. The trestle was constructed on hard fill which now forms a sill, slowing the exchange of tidal and fresh water over a large part of the inner bay while maintaining pools favorable for eelgrass and marine invertebrates; this is where the Skagit County MRC developed *Ostrea lurida* test plots in 2002-2003. The causeway also forms pools, but tidal exchange is poorer, resulting in very deep mud and eutrophic sinks.

This knowledge will inform decisions about: (1) building artificial rocky reefs to facilitate the recovery of native oysters in Fidalgo Bay; (2) measures to manage oyster pathogens and predators in the bay; and (3) addressing limiting factors on the future size and sustainability of native oyster populations in the bay.

Methods

Two bags of seeded cultch were drawn at random from the lot purchased by the Skagit County Marine Resources Committee for its August 2003 planting at the railroad trestle. All shells with six or more seed oysters were transported in buckets of sea water to the beach at our Weaverling Spit experimental site (Figure 1), where 144 seeded shells were distributed randomly among 24 wire-mesh boxes representing two treatments (clean oyster shells, local rock) and a no-treatment control group (Figure 2). The total number of seed oysters planted was 1,474 (average 10.2 per shell) at an average size of 5.3 mm.

Table 1. Data on oysters as planted (August 11, 2003).

Boxes	Treatments	Seed oysters				
		Number/shell		Mean size/shell		Number
		Mean	SD	Mean	SD	
A *to* H	No treatment	10.1	1.71	5.30	.702	477
I *to* P	Loose shells	10.4	1.55	5.21	.714	500
Q *to* X	Rocks	10.4	1.77	5.39	.758	497

Our wire-mesh boxes are pyramidal to reduce build-up of current born debris, and have a plastic coated mesh wide enough (1x2 inches) to admit small predators. Each box was secured to a specially marked yellow buoy to facilitate retrieval, and discourage any interference by recreational boaters.

Boxes were planted in a cluster at –1.0 to –2.5 feet MWL (average –1.9 feet),[2] on tidelands owned by the Samish Indian Nation. Boxes were loaded and planted in random order between noon and 5:30 pm on an incoming tide. Seed oysters on each cultch shell were counted and measured as cultch shells were drawn at random from holding buckets. In the "shells" treatment, seeded cultch was placed on a layer of unseeded shells one shell thick. In the rock treatment, cultch shells were affixed to a block of local rock with fast-drying marine putty, remaining exposed no longer than cultch in the shell treatment and control groups. To avoid crowding effects, no more than 16 seed oysters were left on any cultch shell.

All boxes were raised for a preliminary examination on September 27, 2003. As each box was pulled aboard our inflatable, a GPS reading was taken for comparison with

[2] A rigid measuring rod was used to determine water depth at the time each box was planted; these depths were adjusted by subtraction of the Padilla Bay tides for the times of planting.

its original location, and it was examined immediately on the boat deck for animals such as crabs. Once on shore, each box was opened and examined more thoroughly for flora, fauna, and overall condition. Two cultch shells were removed from each of 16 boxes for enumeration and measurement of surviving seed oysters. Each of the selected shells was flushed gently with seawater before counting, and then returned to its box. All organisms found on, or inside the boxes were recorded but left undisturbed. Each box was returned to the water within 30 minutes.

Boxes appeared to have drifted a very small distance to the west (0.005 minutes is approximately 6.25 meters or just over 20 feet), as a group and with no appreciably wider scattering. Two-thirds of the 24 boxes contained thick organic mud, and most contained loose eelgrass blades or fronds of *Sargassum.* No vegetation or animals were attached to the mesh boxes, however.

Table 2. Change in position of apparatus (August 11 – September 27)

	Mean latitude	SD (minutes)	Mean longitude	SD (minutes)
Planting	48º 29.022	0.00574	122º 35.150	0.0238
First pull	48º 29.021	0.00644	122º 35.155	0.0196
Change	-0.001		+0.005	

Boxes were raised again on January 24, 2004, and May 8, 2004. The focus of the mid-winter pull was infauna. Boxes were retrieved in shallow water, and hoisted quickly into a deep tub aboard our inflatable where the contents were flushed with seawater. All animals found in the tub were recorded and collected live. Each box was then opened on shore and examined for animals attached or clinging to the cultch, cage, and rocks, which were recorded and collected. Before the box was returned to the water, one seeded cultch shell was drawn randomly, bagged in seawater, and transported the same day to Shannon Point Marine Center. Retrieved cultch shells were examined carefully under a dissecting microscope for fauna, and the attached oysters were measured (shell length and dry meat weights) and examined for parasites and other visually apparent pathology.

Two boxes were missing in January, and two had been dragged c. 300 m from the study site, to which they were returned. There was a substantial loss of cultch shells from most boxes, suggesting manipulation by large predators such as crabs, and/or tumbling by currents during the unusually severe fall 2003 storm season. Most of the boxes contained less mud in January than we had seen in September, consistent with strong tidal flushing.

Boxes were retrieved and examined again in May on a low tide (-2 MWL), with a view to exploring the natural substrate around the experimental site for fauna, flora, and the scattered remains of seeded cultch that may have fallen from our mesh boxes. Boxes were examined *in situ*, then hand carried approximately 50 m to a firm sand bar where they were stripped of encrusting vegetation, opened, and flushed with seawater. Visible macrofauna were recorded, and all cultch shells found inside were examined for juvenile oysters. If two or more cultch shells still bore live oysters, one was removed at random and bagged in seawater for further examination at Shannon Point Marine Center. Each box was resealed and returned to where it had been found within 30 minutes.

The substrate varied from mixed fines to mud, and the study site was surrounded by *Zostera marina* in patches of variable density—which is to say typical of conditions in most of the lower intertidal zone of Fidalgo Bay. Invertebrates observed included *Cancer magister*, *Cancer productus*, *Hemigrapsus spp*., the large isopod *Idotea wosnesenskii* and the invasive mudflat snails *Batillaria cumingi* and rarer *Nassarius fraterculus*. Numerous shows and shells of horse clams (*Tresus nuttallii*), cockle (*Clinocardium nuttallii*), butter clams (*Saxidomus giganteus*), and Manila clams (*Venerupis philippinarum*) were seen as well throughout the area.

Unusually warm, dry spring weather exposed our juvenile oysters to greater than average heat at low tides, which may explain the relatively high mortality observed in all three experimental conditions. Eight mesh boxes are missing, moreover, presumably due to the heavy poaching of clams reported this spring on Weaverling Spit. One box in the "no treatment" group (believed to be "C") lost its float, and was reassigned float marked "E". One box ("R") was partly buried in mud.

All remaining boxes will be retrieved, and all surviving oysters measured (length and dry weight) in September 2004. The data will be available as a supplemental report.

Results

- *Oyster growth and survival*:

Table 3 summarizes changes in the number and mean size of live juvenile oysters in each of the three experimental conditions. Figure 3 presents these data graphically.

After six weeks of the experiment, seed oyster survival was 71 percent for the shell treatment, 65 percent for rocks, and 38 percent for the control group (no treatment). Growth was highest in the rock treatment (101 percent), but the shell treatment was not far behind (94 percent); the controls grew much more slowly (58 percent). Size range was roughly consistent with survival and growth: the *largest* individuals were 21 mm in the rock treatment, 23 mm in the shell treatment, and 17 mm in the control group.

Five months into the experiment (i.e. January 2004), seed oyster survival was 85 percent for the shell treatment, 76 percent for rocks, and 75 percent for the control group; oysters in all three conditions survived better in fall and early winter than in late summer. Growth data were ambiguous. Oysters in the control group appeared to have grown by a modest 13 percent, while oysters in the shell treatment appeared to have decreased in size by 21 percent; there was no change in the rock treatment. Only the apparent *decrease* in size of the shell treatment group was statistically significant (t=2.54, $p < .02$), however, and we interpret this as evidence of selective predation on larger oysters, which would affect sample mean in the direction observed.

Between winter and late spring (i.e. May 2004), there was little appreciable loss of oysters in the rock treatment and control groups, but only 62 percent of the remaining oysters in the shell treatment survived. Growth from January to May appeared to be high (76 percent) in the shell treatment, but this may be an artifact of the early winter selective predation on larger oysters in this group suggested above (the removal of a small number of the largest oysters).[3] Oysters in the rock treatment group grew another 45 percent, and the controls by another 40 percent.

Dry meat weights were not measured until the size of the seed oysters exceeded the limits of precision and reliability of our preparation technique and electronic scales. January and May dry meat weights pooled by treatment are set out below:

Table 4. Dry weights of juvenile oysters (January 24 – May 8, 2004)

TREATMENT	Mean dry weight in grams	
	January 2004	May 2004
None	.0012	.017
Shell	.0011	.016
Rock	.0016	.021

In contrast to mean shell length, dry weight data shows similar growth rates in all three groups: 45 percent for the shell treatment, 31 percent for the rock treatment, and 42 percent in the controls. Differences between the growth rates reflected in shell length and meat weights indicate the importance of combining these measures, and of treating short-term change data with caution—especially where derived from relatively small samples.

Over three seasons of the experiment (late summer 2003 through late spring 2004) survival and growth were greatest in the rock treatment group, as predicted, although the differences were relatively small (Table 5).

Table 5. Survival and growth of juvenile oysters (August 2003 – May 2004)

TREATMENT	Percent survival	Percent growth
None	30	149
Shell	38	171
Rock	42	191

[3] Sample variance was relatively high throughout this experiment, hence comparisons of isolated values (as opposed to evidence of consistent trends) should be treated with caution.

Differences in May 2004 mean size between the rock treatment and the controls were just statistically significant (t=2.31, p< .05), as were differences in size between the shell treatment and the controls (t=2.04, p< .05). Differences between the two treatments were not significant, however (t=0.845). The general hypothesis that hard substrates are preferable to the soft ones typical of Fidalgo Bay was confirmed, albeit weakly, while the specific hypothesis that a rock foundation is preferable to shell was not confirmed despite some suggestive data.

- *Infauna, incrustation, and predation*:

Cultch shells in just over half of the mesh boxes had been colonized by tunicates, sponges, and tubeworms within the six weeks of the experiment. Four small proliferating anemones (*Epiactis prolifera*) were found on cultch after five months (January 2004). A few mussels (*Mytilus trossulus*) and two Pacific oyster spat were seen on cultch as well. A float cable was encrusted with herring eggs, but no egg masses were found on cultch. At nine months (May 2004) we saw five green anemones (*Anthopleura xanthogrammica*) and two white aggregating anemones (*Metridium senile*) on cultch, and 11 Pacific oyster spat.[4] No encrusting organisms were seen on native oysters at any time.

Potential predators were found in 25 percent of the boxes in September 2003, and included 6 green shore crabs (*Hemigrapsus oregonensis*), 3 small sea stars (*Evasterias troscheli* and possibly a *Pisaster brevispinas*), and a small brittle star (*Ophioplocus spp*). A larger number and diversity of infauna were observed in January (Table 6). All shrimp and crabs were found in the rock and shell treatments, significantly.

Table 6. Major fauna found in experimental boxes (January 24, 2004)

Species	Number	Size range (mm)
Kelp crabs (*Pugettia producta, P. gracilis*)	22	11 – 57
Shore crabs (*Hemigrapsus spp*)	23	8 – 17
Cancer gracilis, C. magister, C. productus	3	17 – 37
Pandelid and hippolytid shrimp[5]	142	26 – 49
Sea stars (all *Evasterias troscheli*)	3	83-87
Anemones (*E. prolifera, A. xanthogrammica*)	5	-
Skeleton shrimp (*Caprella spp*)	2	-

[4] The spat observed in January were roughly 5 mm in length, while those seen in May were 2-3 mm.

[5] Dominated by *Heptacarpus brevirostis* and *Pandalus hypsinotus*. Stomach dissections revealed that they had been feasting on *Ulva fenestrata*..

In May 2004, we found two kelp crabs, two shore crabs, a Dungeness crab, and four *Evasterias* (ranging from 70 to 100 mm).[6] Sea star abundance therefore remained at a relatively constant level throughout the experiment whilst crustacean abundance peaked in mid-winter.

Other infauna included polychaetes, isopods, amphipods, copepods, and only seen in January, several skeleton shrimp, sea mites, and a single nudibranch (*Flabellina spp*). A number of anthomedusae were found hung up in the mesh of boxes in August 2003 and May 2004, and at least two hooded nudibranchs (*Melibe leonine*) in August 2003. Three saddleback gunnels were hiding in rock treatment boxes in May 2004.

Small whole native oyster valves were commonly seen floating on the mud covering the rocks and cultch shells treatments; few empty oyster shells were found with the upper valve still attached, and no evidence of boring was seen, nor were any parasites, deformation, or discoloration seen when live oysters were opened and examined in the laboratory.

Although blades of eelgrass were hung up in the mesh of most of the boxes in fall 2003, only a month after planting, no encrusting vegetation was observed until spring when most of the boxes were heavily overgrown with bull kelp (*Nereocystis leutkeana*). Kelp holdfasts were found attached to 14 of the 16 remaining boxes, completely covering seven of them. Up to 3 cm of viscous organic mud was found in two-thirds of our boxes in September 2003, entombing many live oysters. Only six boxes had appreciable mud in January but most contained mud again by May. Mud accumulated to a greater depth and extent in the rock treatment boxes; rock slabs blocked the bottoms of these mesh boxes and helped mud accumulate.

As noted earlier, two of our boxes were missing in January 2004, and six more had disappeared by May 2004, for a combined loss of one-third of the boxes placed in the study site in August 2003. The float on one of the boxes found displaced from the study site in January appeared to have been sliced by a propeller; another box was found in May with its float cable cut. Staff at the Fidalgo Bay Resort reported several instances in March and April 2004 when they chased poachers from the vicinity of the study site at night; gangs of poachers arrived at night by boat, landed on the sand spit near the study site, and dug for clams until discovered and chased off. The fact that most of our losses occurred in spring 2004, when there was relatively mild weather, rather than during the unseasonably severe storms of fall 2003, suggests that people rather than wind or waves were chiefly responsible for missing gear.

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[6] All were seen in the shell and rock treatments, but small animals could easily have fallen through the mesh of the control boxes when they were raised in September and January. In May, boxes were observed in situ before being moved and flushed, and we still found predators only in the rock and shell treatments.

Discussion

Over nine months (late summer to late spring), survival and growth data matched our hypothesis that harder substrates would have a protective effect on native oyster seed. Differences in growth between the two treatments (rock or shell) and controls were small but statistically significant. A more complex pattern emerges if we compare survival and growth seasonally.

Oyster growth was greatest during the warm summer and early fall of 2003; seed oysters in the rock and shell treatments roughly doubled their size. Oysters grew another 50 percent or more during the usually early warm spring of 2004. Predation appears to have been greatest at the beginning of the experiment (August-September), but was great enough even in fall and winter to reduce the average size of oysters in the shell treatment group. Survival remained consistently higher in the two treatment groups over the course of the experiment; however, there was a gradual convergence of survival rates among the two treatments and controls, as oysters grew larger (Figure 3).

Most boxes accumulated viscous organic mud. Mud accumulation was greatest in summer 2003 and spring 2004, and may have been a factor in the high level of mortality observed during the first six weeks of this experiment. Mud has been accumulating in the bay since the early 20th Century, and now covers former commercial oyster plots south of the railroad trestle to depths of several feet. Elevating native oysters safely over the mud substrate is presumably the reason for the relative success of the two treatments, rock and shell, which were statistically indistinguishable in their protective effects. Establishing a firm attachment of juveniles to a motionless foundation to prevent tumbling and breakage was a hypothesized additional advantage of the rock treatment; however, most cultch was eventually detached from the marine putty we used to build the rock treatment condition, leaving much less of a difference between the rock and shell treatments.[7]

Our data do not allow us to compare the contributions of predation, heat, and mud accumulation to oyster mortality. Disarticulated oyster shells are consistent with starfish predation, and articulated unoccupied shells are consistent with mortality from heat, but while both were observed, neither can be quantified reliably. The loss of large number of cultch may either represent crushing by crabs, or mechanical stress from being tumbled by strong winter tides and currents. Starfish and kelp crabs are the main predators seen in commercial oyster beds in the north Skagit Bays (Bill Dewey, personal communication), and were attracted to our experiment. Oyster drills are reportedly absent in Fidalgo Bay, and we did not encounter any.

[7] It should be noted that the 2002-2003 native oyster plantings under the Fidalgo Bay railroad trestle take advantage of a narrow band of artificially hardened substrate: a gravel bar was built to provide more stable footings for the pilings that support the century-old trestle, and now forms a sill over which tidewater flows continuously. A natural sand bar located on the west side of Fidalgo Bay just north of the railroad trestle, on Weaverling Spit, has been identified as an expansion planting site because it is relatively firm and high-current. Part of Crandall Spit (on the northeast entrance to Fidalgo Bay) also shares these characteristics.

Fall 2003 brought record rains, severe winds and unseasonable cold, while spring 2004 was unseasonably warm and dry. To the extent that native oysters are sensitive to temperature extremes, our results from 2003-2004 may not be representative of "typical" oyster performance in north Skagit bays.

Conclusions

Results suggest that the substrates typical of contemporary Fidalgo Bay and other north Skagit bays (i.e. deep organic mud) are not inimical to *Ostrea lurida*, but survival and growth can be improved by providing elevation above the mud on a firmer substrate, such as rocks and/or shells. Movement of cultch should be minimized by attachment to a stable foundation, or alternatively by securing cultch in mesh bags or under mesh sheets. Exposure of oysters during daytime low tides should be avoided by planting cultch in the upper sub-tidal zone (below –3 feet MWL), or in pools or channels that flow even during the year's lowest tides. Staking, signage, and vigilance to deter vandalism are indicated.

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Figure 1: PROJECT SITE

Project site (yellow) looking east from Weaverling Spit (oblique air photo from 2000 feet).

Figure 2: EXPERIMENTAL TREATMENTS

Experimental box J

Seeded cultch on shells

Experimental box X

Cultch on rock base

Experimental box H

No treatment (Control)