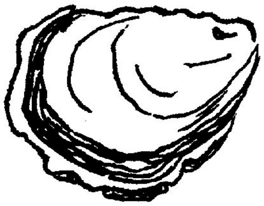
Willapa Bay Marine Ecology Research: 2002 Summary

Jennifer Ruesink and Alan Trimble, University of Washington

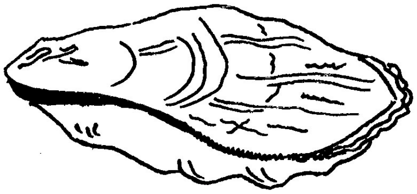


When we first began our research in Willapa Bay three years ago, we entered what were for us entirely uncharted waters. We came with virtually no background in estuarine research, having worked for a decade on exposed rocky shores and, of all things, the aerodynamics of flying insects. Of course, the structure of food webs on rocks shows many parallels with food webs on and in mud (after all, predators eat prey in every situation), and the movement of air around wings is in some senses a scaled down version of water flowing around reefs and islands. But we have to admit that our learning curve has been extremely steep, and studying the bay has been a joyful discovery of the unknown, as well as a stage for adventure and sometimes a bit more excitement than we bargained for. Actually, venturing into the “ecological unknown” is a very personal circumstance, since we have also realized, through reading old documents and talking with many of you, that much of the story of how Willapa Bay works ecologically is well known, if largely undocumented in the scientific literature. So often, we realize that we are treading paths of inquiry that were laid out many decades ago. So, we must acknowledge an enormous debt to generations of growers and researchers, but also add new perspectives on the story of Willapa Bay by recasting some questions and bringing new techniques to bear on the old questions. What we hope to do in this letter is provide short summaries of what we’ve learned recently. Much of it will be familiar to you, but we hope you find some new material as well. In any case, it will give you a sense of what motivates our science and an opportunity for feedback on what is useful. Don’t expect everything (or maybe even much of anything) we do to be useful – after all, one of the benefits of academic research is the opportunity to pursue questions that tickle our fancy. But it turns out that one of the most ticklish issues is to study the ecology of a place that people’s livelihoods still intimately depend on. Many other marine systems are too damaged to be productive, or too remote for people to be aware of much of a connection – Willapa sits gently in the middle, where the food webs that spark our scientific curiosity also matter to people.

You can track us down for conversation during high tides at the house we’ve purchased (our first home, and now empty bank accounts) just across the road and north of the Port of Peninsula (27707 Sandridge). Our jobs keep us at UW in Seattle through much of the academic year, but this house will be our base of operations for research for many years to come. We stop by and bother you often enough that we hope you feel comfortable returning the favor. Also, of course, look for us on the water in our 16-foot workskiff: Vindaloo (named after a spicy East Indian curry – a little odd, but highly serviceable means of getting around). We hope to continue in the tradition of Trevor Kincaid, one of the first scientists at the University of Washington, to build our careers in cooperation with you growers.

In the following pages, we explore five questions that we have explored in the last year. First, we have examined the spatial pattern of oyster growth in Willapa Bay. Interest in this question goes back a century, and indeed the general answer has been known at least that long: Rich oceanic waters prompt people to move oysters closer to the mouth of the bay where they grow and fatten faster. But other issues, such as why much of the land in the south is no longer productive, and the balance of productivity from the land and the ocean, remain unresolved. We've added a new technique to the study – stable isotope analysis – which can be used to ask what oysters have actually been eating.

Second, we have re-initiated weekly shellstrings that WDFW discontinued in the 1980s due to funding constraints. (There are still funding constraints; we do this 'volunteer work' entirely on our own time.) The record from the 1930s to 1980s, however, is an amazing time series to ask how natural recruitment of both native and Pacific oysters has changed. For many decades, scientists studied these records, as well as weather and water temperature reports, to try to develop effective forecasting methods to predict spatfall. These efforts were often overwhelmed by idiosyncracies of particular conditions from year to year. Many of you have told us, however, that Pacifics are spawning at lower temperatures each decade, and that spatfall is more reliable now than it has been in the past. These sorts of hypotheses are possible to test with long-term records, and it has been really exciting for us to have these hypotheses come from you. They may also have important implications for global climate change and adaptation of introduced species to new locations.



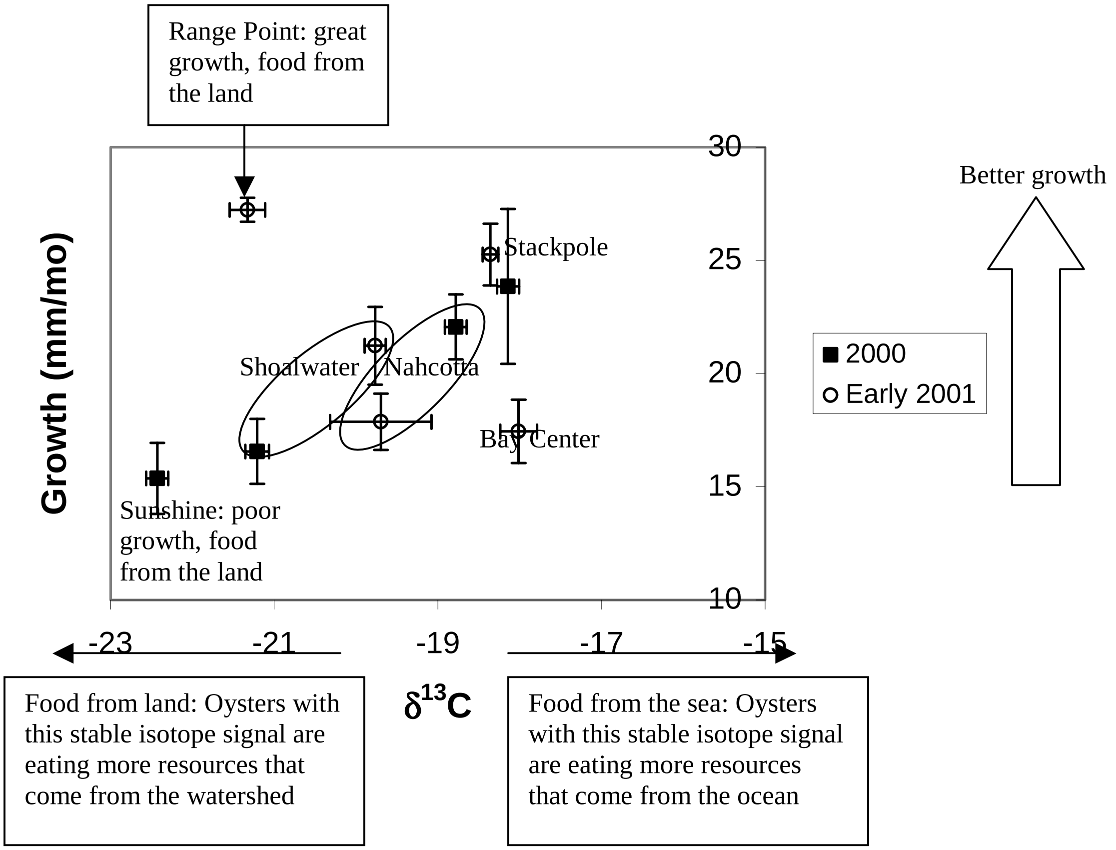
Third, we are collecting information on native oysters from the perspective of trying to understand why they remain far below population densities that supported commercial exploitation in the 1800s. These efforts include surveys of native oysters throughout the bay, as well as transplant experiments to test where they recruit, where they grow and survive best, and whether we can improve their success by protecting them from competition.

Fourth, we are collecting information on two introduced oyster drills to understand how fast their populations can change and how they might be more effectively controlled. A vast amount of research on chemical control occurred in the late 1960s and early 1970s just after Japanese drills were found in Willapa Bay. No chemicals were effective at killing drills, although research undoubtedly still needs to be done on chemicals that would attract them and improve chances of manual control. In contrast, we are studying drills from a population dynamics perspective, understanding how rapidly they reproduce, what kills them naturally, and how fast they eat different sizes and species of bivalves.

Finally, we have also gotten in on the tail end of a research project examining how aquaculture might affect other species of commercial and conservation importance, particularly salmonids and Dungeness crab. This study has probably been our most conspicuous – the enormous net near the boat launch in the Port of Peninsula. The net held acoustically-tagged juvenile salmon that were tracked by hydrophones to find out where they spend their time – in eelgrass, oyster bed, or mud flat. These measurements of individual fish will be linked with surveys over larger areas, which have been carried out with a variety of stationary and towed nets. The question of how salmonids respond to different habitats is obviously important in an era of management for endangered species. In most attempts to manage salmon, estuaries have been a “black box” between freshwater spawning habitat (where fish can be observed directly) and open ocean (where fish spend enough time that it is possible to estimate growth and survival). Mostly we’ve discovered there’s a good reason that few people have studied juvenile salmon in estuaries – it’s difficult to tell where they are and what they’re doing across vast expanses of murky water. This project has also involved surveys of eelgrass across beds used in different types of aquaculture, but we still need help understanding the history of planting and harvest on different beds.

Question 1: Where do oysters grow best, and what are they eating there?

The tiny 2-week old oysters in the first picture grow into the oysters in the second picture over two months.



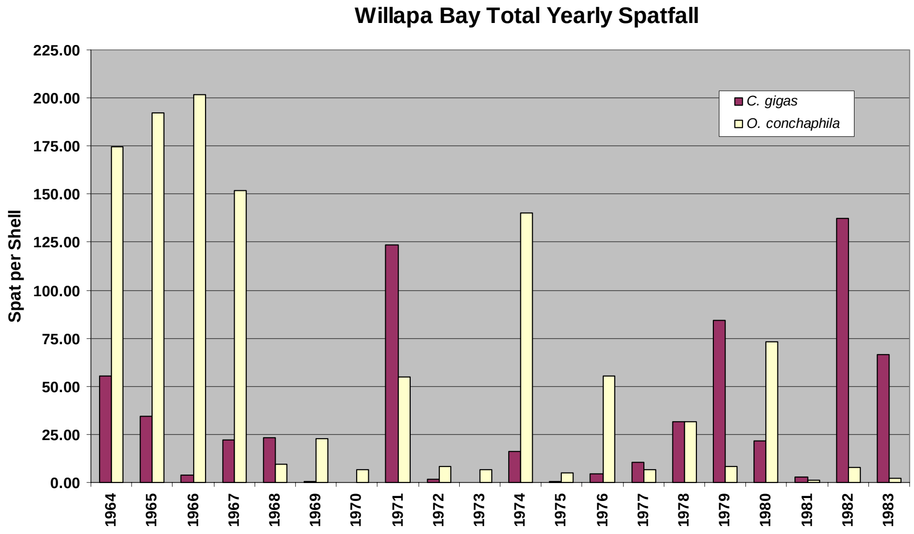
Range Point: great growth, food from the land

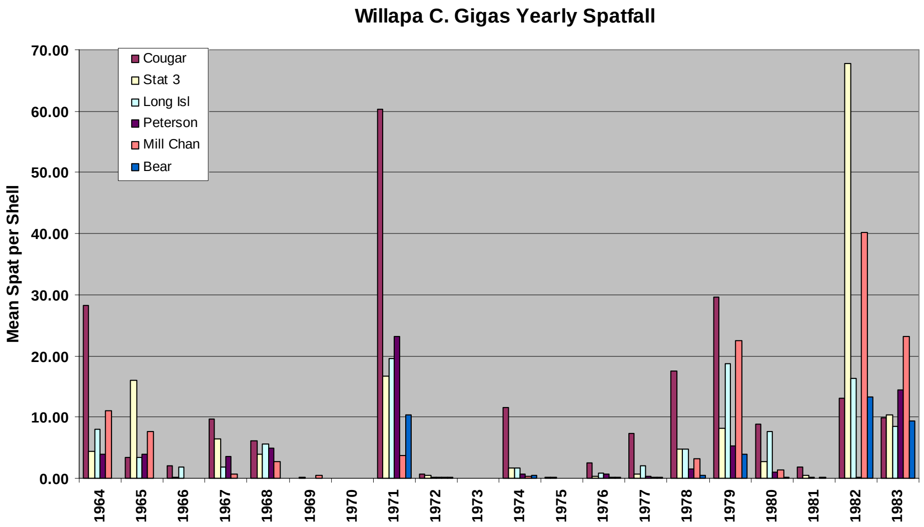
Sunshine: poor growth, food from the land

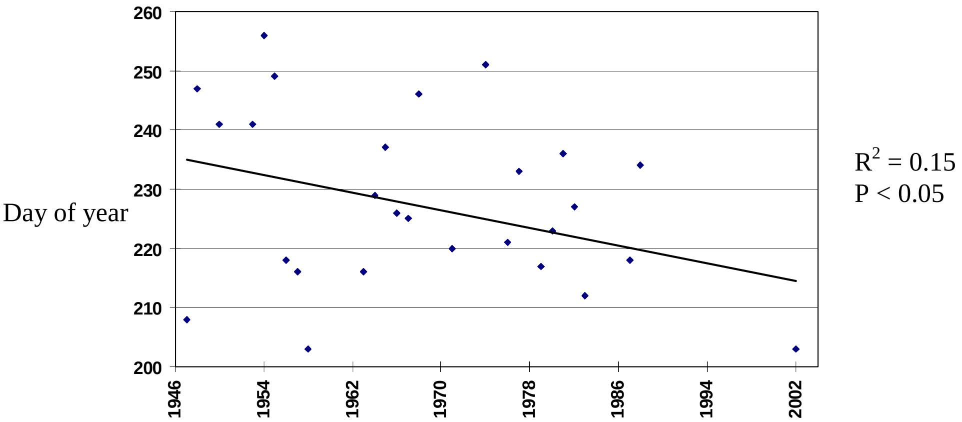
Food from land: Oysters with this stable isotope signal are eating more resources that come from the watershed

Food from the sea: Oysters with this stable isotope signal are eating more resources that come from the ocean

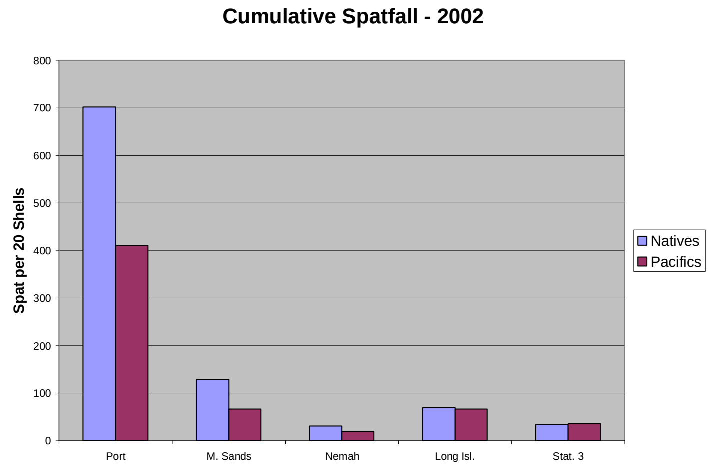
Question 2: What are the historical patterns of oyster recruitment in Willapa Bay?

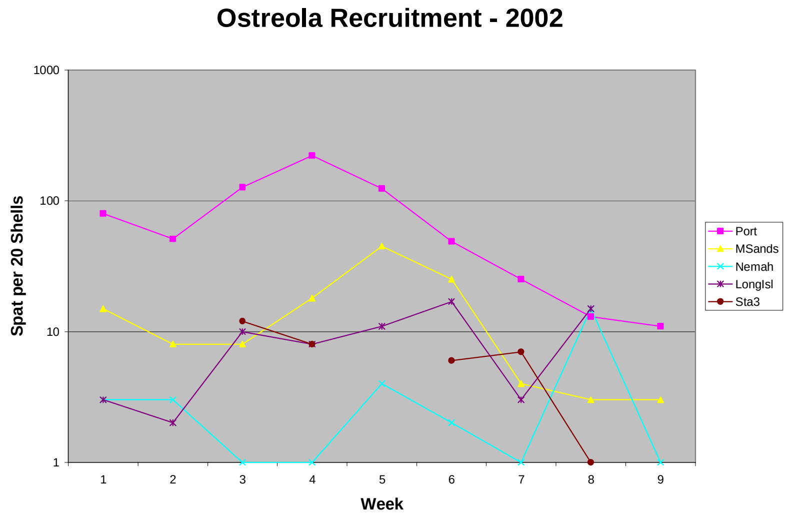


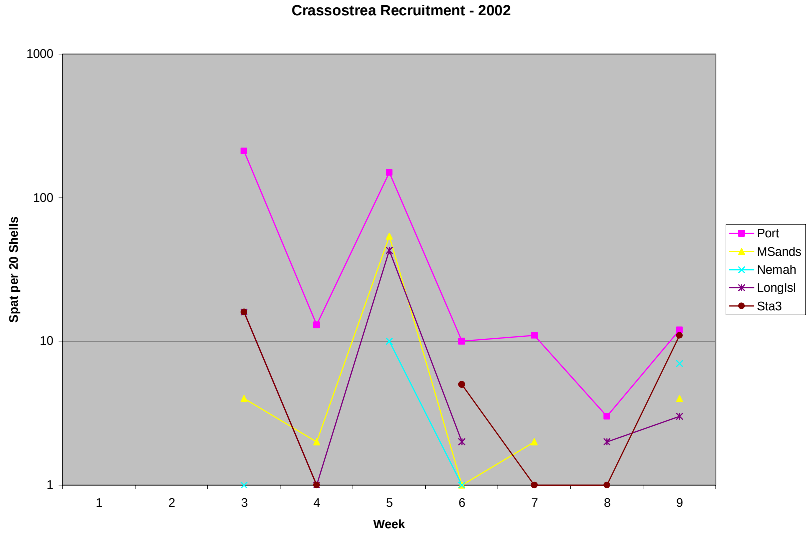




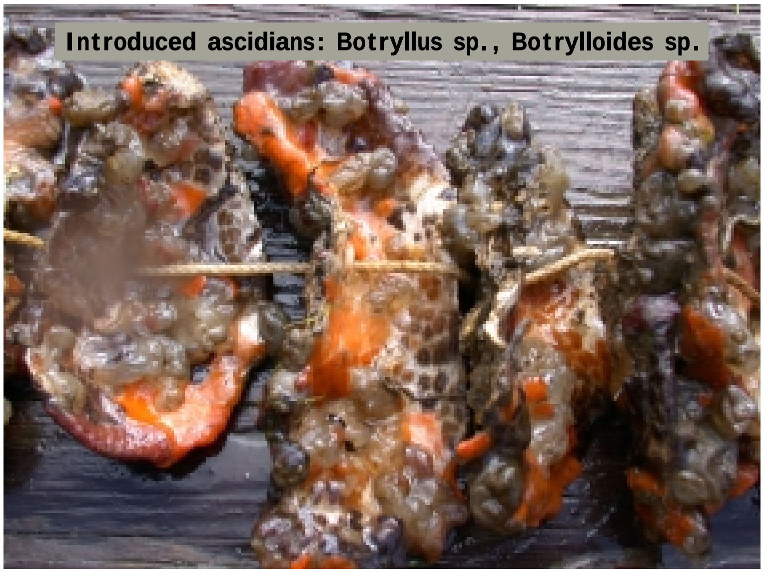
Date of first C. gigas spatfall is 4.5 days earlier/decade since 1946; first set on July 22 in 2002


Cumulative Spatfall - 2002


Ostreola Recruitment - 2002

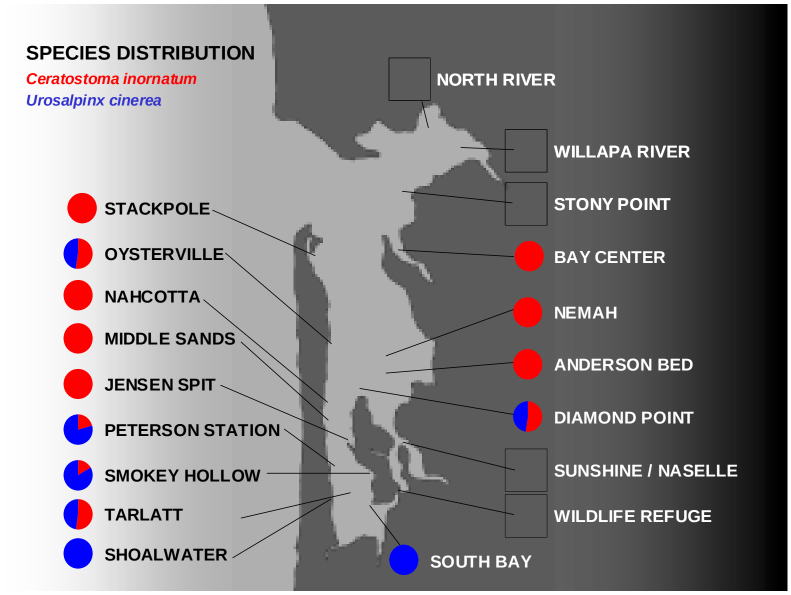

Crassostrea Recruitment - 2002

Question 3: Where do native oysters recruit, grow and survive best, and what are the effects of competitors?



Oly's grow well without competitors (left); they thrive compared to spat that have been smothered on the shell string above and the plate below by non-native fouling animals.

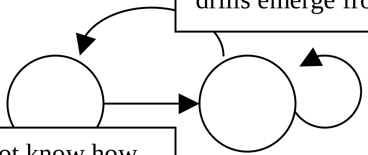
Question 4: What are the population dynamics of two species of introduced oyster drills? Specifically, how much do they reproduce, how well do they survive, how fast do they grow, where are they found, and how much do they eat?



Ceratostoma inornatum (possibly *Ocinebrellus inornatus*): introduced accidentally from Japan or Puget Sound about 1960

Urosalpinx cinerea: introduced accidentally from eastern North America before 1920

If you find either species outside of the distribution we've documented (especially in the areas marked by empty boxes, where we've seen no drills), we would like to know!



Reproductive rates probably differ between the species. *Ceratostoma* starts laying eggs in March, *Urosalpinx* not until June. About 8 new drills emerge from each egg case. Pink egg cases contain dead drills.

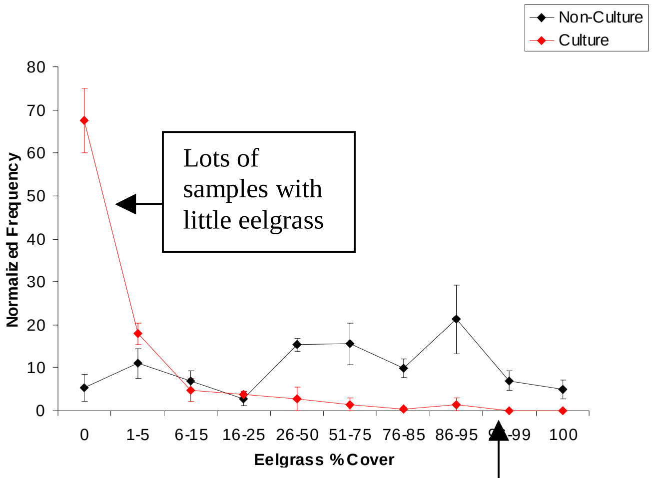
Adult survival for both species is about 30% per year. Crabs probably eat many of them at low tide levels.

We do not know how well the new drills survive, but we'll try to find out this year.

And now the news you've been waiting for: Both species eat about two oyster spat per week in the spring, dwindling to less than one per week in the fall. But, since their densities can reach almost 100 per square meter in dense oysters, their impact definitely adds up.

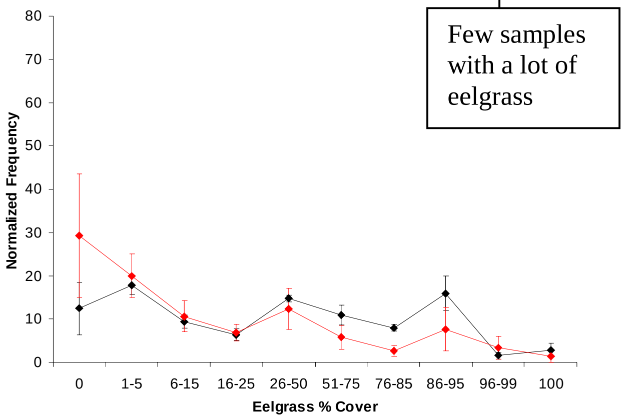
Finally, we tested whether burying drills effectively kills them. We pushed drills into anoxic mud inside a PVC tube with mesh on top. Only one of about 50 that were pushed more than 3 inches below the surface ever re-emerged alive.

Question 5: What are the effects of aquaculture on eelgrass?



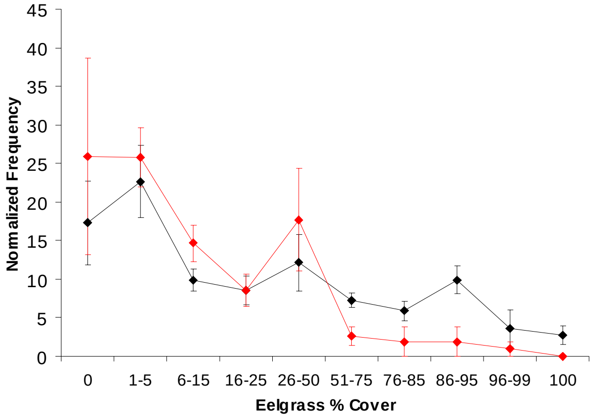
Lots of samples with little eelgrass

The red line shows how much eelgrass occurs inside dredged bottom culture, compared to the black line outside. In general, it is more common to find high eelgrass cover outside than inside. We think it would be useful to compare different intensities and frequency of dredging, because we know from other studies in Willapa that eelgrass can recover within a year in some areas.



Few samples with a lot of eelgrass

The red line shows how much eelgrass occurs inside hand-picked bottom culture, compared to the black line outside. In general, eelgrass distributions are very similar inside and outside. In both cases, eelgrass is patchy, with around 20% of the samples containing no eelgrass.



The red line shows how much eelgrass occurs inside longline culture, compared to the black line outside. In general, eelgrass distributions are very similar inside and outside, although very high cover seems slightly less frequent inside.

The good news is that oysters per se grown at standard densities are not incompatible with high eelgrass cover. It is probably not a surprise that regular dredging tends to remove eelgrass. We are beginning to explore whether oysters actually benefit eelgrass by improving water clarity and light penetration, and by fertilizing sediments.

Question: Where do oysters grow best, and what are they eating there?

Methods: We transplant oyster spat, which we set in the hatchery on to 4x4 inch ceramic tiles, to different locations and let them grow for about two months. We photograph the tiles before they are placed in the Bay and after we recover them to measure oyster growth (shell length). We also collect and dry the tissue for stable isotope analysis. Stable isotope analysis capitalizes on the fact that "you are what you eat." Different primary producers (phytoplankton, eelgrass, algae, benthic microalgae, terrestrial or marsh plants) have different characteristic signatures of naturally-occurring isotopes of common elements, such as carbon and nitrogen. When we look at the stable isotope signatures of oysters, we can tell, in a general sense, which ones have been eating more "stuff" that comes from the ocean vs. comes in through rivers from the land. We have put out PVC poles with tiles in 2000 (August – October, south Willapa Bay), 2001 (June – August and August – October throughout Willapa Bay), and 2002 (July – August, October, February, and May in Willapa Bay and Grays Harbor, July – August in Puget Sound).

Results: In Willapa Bay and Grays Harbor, the results from stable isotope analysis map very well onto how close oysters are to the ocean: Oysters close to the ocean have stable-carbon isotope ratios similar to marine phytoplankton, whereas oysters far from the ocean have ratios that are closer to terrestrial plants (they may be eating detritus from rivers and marshes or, more likely, phytoplankton that grow in the rivers). We don't know yet how much eelgrass detritus oysters are eating, but eelgrass detritus is one possible explanation for stable-carbon isotope ratios outside the range of either marine or terrestrial food sources. Interestingly, even though oysters near the Naselle River and Willapa/North Rivers eat similar food (their stable isotope ratios are similar), they have very different growth. Essentially, the river-based food from the large Willapa/North Rivers fuels very productive oysters, but the same food from the small Naselle River cannot support fast growth of oysters in the south-east part of Willapa Bay. In Grays Harbor, the gradient from the ocean to the Elk River seems most like the North/Willapa River arm of Willapa Bay (better growth further up the river).

Answer: Oysters grow best close to estuary mouths in coastal estuaries, fueled by marine inputs, and also near large river mouths, fueled by terrestrial inputs. In Puget Sound, from Olympia to Whidbey Island, oysters eat similar food, except for a slightly more marine signal in oysters transplanted near Kingston and a slightly different nitrogen signal (indicative of urban inputs) and higher growth in Budd Inlet.

Plans for 2003: The past three years, of course, have been relatively good years for oyster growth. We plan to continue these oyster transplants, perhaps on a more limited basis, in 2003. If you are interested in knowing what oysters on your beds eat, or if you think you have a particularly "hot" spot for oyster growth, we may be able to add your location – please let us know.

Funding and collaborators: Pacific Northwest Coastal Ecosystems Regional Study, Washington Sea Grant, Northwest Fishery Science Center, Brett Dumbauld (WDFW), Curtis Roegner (NMFS), Jan Newton (DOE), Blake Feist (NMFS), Chris Harvey (NMFS)

Question: What are the historical patterns of oyster recruitment in Willapa Bay?

Methods: From 1936 to 1987, Washington Department of Fisheries (later Fish and Wildlife) recorded spatfall at multiple locations on shellstrings replaced weekly during the summer. We reinitiated these weekly shellstrings in 2002, hanging strings of 20 shells at the Port of Peninsula, Mill Channel, northwest Long Island, Nemah, and Station 3 (near Lewis Slough) from mid-June through early September. We counted all new recruits that appeared on the smooth (down-facing) side of each shell, including *Crassostrea gigas* (Pacifics) and *Ostreola conchaphila* (Olys).

Results: Analysis of the historical "Oyster Bulletins" and other sources have revealed that *Crassostrea* has recruited on average 4.5 days earlier per decade in Willapa Bay. In addition, *Ostreola* has out-recruited *Crassostrea* in many years, including cumulative counts at all our sites in 2002. Sites vary: highest Pacific recruitment occurred at Middle Sands and Long Island with 67 spat/shell for the season beginning July 22; this was more than four times the spatfall we measured at Station 3 near Lewis Slough and Nemah. Highest native recruitment occurred at the Port on shellstrings hung from the dock all summer.

Answer: Oyster spatfall is variable from year to year and spatially throughout the Bay. Water temperatures have the most significant effect on spawning, larval survival and spatfall, but many other factors are likely to be critical at any particular time. No analysis of predation, competition or food limitation has been done for oyster larvae here, but these factors are known to be important in other systems.
We do see a trend in the long term data for Pacifics to start setting earlier (on average) each decade, with 15% of the variation associated with this trend. However, the other 85% of the variance is related to other factors. We are attempting to gather enough historical climate and water temperature data (daily from 1930 to present, if possible) to begin to tease out these relationships.

Plans for 2003: We plan to repeat these weekly shellstrings beginning in late-May. We may add sites in the northern parts of the bay, and additional sites near hopeful/useful culching areas in the southern sections. We may be able to start larval water column sampling if time and personal funding allow.

Special Request: We are trying very hard to collect a complete set of data from 193x to present. We are missing may issues of the Willapa Bay Oyster Bulletin, and these do not appear to be archived in the State Records in Olympia. If you have company records of historical spatfall that you would be willing to share or any old copies of the Bulletin we would REALLY appreciate being able to include these in our data analysis…. (besides, we are getting pretty good at going through moldy old boxes of papers!)

Funding and collaborators: Personal funding, WDFW

Question: Where do native oysters recruit, grow and survive best, and what are the effects of competitors?

Methods: In August 2002, we received hatchery-set Willapa native oysters from the Point Whitney Lab; natives were set on cultch in bags and on 4x4 inch ceramic tiles. Using cultch, we set up a grow-out experiment at four sites (Willapa River Rogers Bed, Nemah Reserve, Long Island Reserve, and south Middle Sands Reserve). Cultch were placed in four ways at each site: directly on-bottom, on-bottom on a layer of Pacific shell, slightly off-bottom attached to wooden stakes, and slightly off-bottom in bags. Using tiles, we transplanted 2-mm native oysters to five sites (Port, Long Island, Middle Sands, Parcel A, Peterson Station). Tiles on poles were placed at about –1' and +1' MLLW, and we also hung tiles from a nearby mooring. We periodically removed potential competitors from half of the tiles. We photographed plates initially (in August), in October, February, and April 2003.

Results: Because these experiments are in progress, we have few results to date. Under optimal conditions (-1' tiles at Long Island), Ostreola grew rapidly in its first summer to a shell length of 2 cm, with 40% survival. Overwinter survival was high (75%), but growth slowed. However, conspicuous settlers on tiles included numerous introduced species (ascidians, hydroids, oysters) as well as native barnacles and algae. In general, the oysters that are lower on the poles (-1') appear to be growing and surviving better than the oysters on the plates at +1'.

Answer: Numerous mentions by Trevor Kincaid in the Oyster Bulletins of the 1940's talk about catching Oly sets intertidally and then moving the culch subtidally, for grow out. Our experiments seem to support these statements, so far. The most compelling evidence we have is that the mooring bases (cinderblocks chained together) had terrific natural Oly sets, growth and very low fouling in 2002. These mooring bases were at -12 to -20ft; below the depth of good light penetration, and below the depth of fouling by most problematic space competitors (barnacles, ascidians and hydroids.)

Plans for 2003: This experiment will continue through 2003 with regular photography and cleaning of tiles. We will also start a subtidal culching and grow-out study to quantify the apparent positive effects of using deep water as a 'refuge' for juvenile Oly's.

Funding and collaborators: Personal funding, WDFW, NOAA

Question: What are the population dynamics of two species of introduced oyster drills? Specifically, how much to they reproduce, how well do they survive, how fast do they grow, where are they found, and how much do they eat?

Methods: During the summer of 2002, we surveyed sites throughout Willapa Bay for oyster drills (Ceratostoma inornatum, the Japanese drill introduced about 1960, and Urosalpinx cinerea, the Eastern drill introduced about 1900). Two regions of the bay contained very few drills: the region around Toke and Stony Points at the north end of the bay, and the region east of Long Island. Urosalpinx apparently does not persist when moved north of the Port of Peninsula. On the other hand, Ceratostoma has a broad distribution from Stackpole and Bay Center to the south past Smokey Hollow; there were only a few places at the very southern part of the bay where we found only Urosalpinx. Oyster drills were also generally rare on deep beds (<+1'), probably eliminated by crabs. To study growth and survival, we individually marked and measured 1,000+ Ceratostoma and 500+ Urosalpinx on hummocks in two areas of the bay: Nemah and Peterson Station. By searching over time for marked individuals, we could calculate how fast they grew and how well they survived. To study reproduction, we placed individuals in small containers, counting the number of egg capsules they produced and the number of small snails emerging from each capsule. Finally, to study feeding rates, we placed individuals in small containers with food and recorded food consumption over time. The food items tested in 2002 included seed oysters on cultch, single oysters of a variety of sizes, and adult and juvenile native oysters.

Results: For both species, about 20% of adult drills died (predation and ?)every month during the summer. Shells grew in length at least 1 cm over a year, but growth stops about at about 2.5 cm for Urosalpinx, whereas Ceratostoma can exceed 5 cm. Feeding rates were not high on an individual basis, about 1-2 oysters per drill per week. This rate varied seasonally, and, in these experiments, Pacific oysters were highly preferred over natives, but feeding did not vary with drill species or size.

Answer: We are just beginning to integrate all of this information about the two drill species into population models. These models will allow us to compare rates of population increase for the two species (right now, Urosalpinx is winning because it reproduces after 2 years, whereas Ceratostoma probably takes 3). Models will also help identify "weak links" in the life cycle that could be targeted for better control of drills. According to our current models, drills can be reduced more easily by removing egg cases than by removing adults – however, the models do not include how easy it is to find and pick up each stage.

Plans for 2003: We will continue recapturing marked drills to measure growth and survival over an entire year. A huge uncertainty in the life cycle is the growth and survival of newly-hatched drills; we also do not know how many times each year drills actually reproduce. One of our main drill-related activities is a large-scale experiment to test for ways of completely removing drills from small areas. We hope that barnacle-encrusted PVC will be so attractive that, resting just about the mud, it will serve as an effective barrier to keep drills out of cleared areas.

Funding and collaborators: National Sea Grant Aquatic Nuisance Species program, Eric Buhle (grad student), Brett Dumbauld, Brian Pickering, Bruce Kauffman (WDFW)

Question: What are the effects of aquaculture on eelgrass?

Methods: Eelgrass is protected at both state and federal levels because of well-documented benefits for fished species and because it is an indicator of good water quality. We are pretty sure that Willapa Bay has the largest amount of eelgrass of any place in Washington (and probably anywhere on the coastal US) – so eelgrass is strong evidence of high environmental quality. Over the past several years, WDFW and UW scientists have been comparing how fish and crab use different habitat types: eelgrass, oyster ground culture, and bare mudflat. About every two weeks from June to September 2002, two boats towed a net above different habitat types, and all fish were counted. You may also have noticed the large net hung from poles near the boat launch at the Port of Peninsula in September 2001 and July 2002. This net was set up to hold fish with acoustic tags, allowing their movements to be tracked as they moved throughout the pen. We were interested in how they behaved in different habitats – did they move slow or fast? – and in their preferences for different habitats. Inside the pen were two small patches of oysters, several eelgrass patches, and bare mud.

In 2002, we also did a short descriptive study of eelgrass inside and outside oyster beds, simply by walking across areas and recording the cover of eelgrass inside and outside areas of dredged ground culture, hand-picked ground culture, and longline culture.

Results: So far, chinook smolt densities have not been different between eelgrass and ground culture. Tidelands that are regularly dredged tend to have less eelgrass than surrounding undredged areas. Hand picking and growing oysters on longlines are compatible with high eelgrass densities.

Answer: Aquaculture activities create patches of different habitat types across tidelands. From other research, we know that the organisms living in eelgrass, oyster beds, and mudflats vary considerably, as do physical and chemical characteristics of the sediment. These habitat patches currently appear compatible with use by chinook salmon smolts.

Plans for 2003: This will be the first field season for a new WRAC-funded project to examine indirect effects of filter feeders on eelgrass via clearing of water and fertilization of sediments. One of our plans if for large-scale experiments in collaboration with growers. We hope to be able to measure how much particulate matter is in the water before and after oysters are planted on growout beds. We will also measure the growth of eelgrass with different densities of oysters, relating patterns to the nutrients in the sediment.

Funding and collaborators: USDA Western Regional Aquaculture Center, Brett Dumbauld (WDFW), Brice Semmens (grad student, fish hydroacoustics), Geoff Hosack (grad student, fish and invertebrate sampling), Heather Macrellis (grad student, eelgrass)