WASHINGTON SEA GRANT

washington state shellfish studies

a national leader in shellfish ....

Twenty years ago, Washington state's oyster industry suffered from uncertain seed oyster supplies, the Manila clam fishery was in its infancy, and mussel aquaculture was just a hopeful idea. Today, however, Washington is one of the few states blessed by diverse and thriving commercial and recreational shellfisheries. It leads the nation in commercial production of Manila clams, its oyster crop is surpassed only by that of Louisiana, and cultured Puget Sound mussels are the rage in West Coast restaurants. Recreational gathering, though restricted in some areas, likewise remains a flourishing and popular pursuit. Washington also maintains strong coastal and distant-water crab fleets.

These changes were made possible in part by a dynamic alliance among shellfish growers, state and federal agencies, and University of Washington scientists. Initial impetus and strong leadership were provided by Professor Kenneth K. Chew. Through cooperative efforts, a local network of oyster hatcheries and nurseries has eliminated the need for imported seed. Genetic research has produced the all-season "triploid" oyster now appearing on restaurant menus. Experimental work has greatly improved methods for culturing such valuable species as Manila clams and mussels, resulting in the rapid penetration of those products into the marketplace.

In addition, greater understanding of essential habitats for molluscs and crustaceans has fostered wiser use of shorelines and submerged lands. Coastal development, dredging, and dredge spoil disposal now can be carried out with greater environmental sensitivity, and mitigation and restoration efforts are being perfected to prevent and remedy the associated ecological impacts.

Much of the essential research that brought about these advances has been supported by the Washington Sea Grant Program. Through publications and workshops, Sea Grant also has been a primary vehicle for communicating the resulting knowledge to other researchers and to growers. Sea Grant's outstanding record in identifying, supervising, and disseminating critical shellfish research has made it an essential player in managing and enhancing this important resource.

HOW THESE STUDIES ORIGINATED

The 1989 Washington State Legislature allocated $250,000 in a special general fund appropriation to the Washington Department of Fisheries for "a grant for shellfish studies to the sea grant program of the University of Washington" in the 1989-1991 biennium. Seeking expert guidance and public input on the use of these funds, Dean G. Ross Heath of the University of Washington's College of Ocean Fishery Sciences appointed a broadly based advisory committee, chaired by Dr. Judith Freeman, assistant director of the Washington Department of Fisheries. Committee members are listed at the front of this report. The strong support of the Washington Department of Fisheries, embodied in a Memorandum of Agreement, greatly facilitated the whole process.

The committee agreed that studies should proceed on the basis of competitive awards for scientifically strong research and technology transfer projects on "aquatic invertebrates that have commercial or recreational value, or whose condition raises important ecological or public policy concerns." Proposals were widely solicited, and 34 were received and submitted to scientific review. Ten of them, judged to have the greatest value for the state, were funded. Two additional projects were later approved for seed money support from funds set aside to respond to emerging opportunities and critical needs.

Projects were selected in the subject areas of resource management, human health, and shellfish culture. Cooperative efforts among agencies and institutions were encouraged, as were efforts to involve other funding agencies and groups. Activities with both short- and long-term implications were included. Long-term efforts had to be carefully designed to produce some measurable advances quickly in order to attract further support beyond the biennium. Strong emphasis was placed on technology transfer and information dissemination, through workshops and publications, student involvement, and interactions with industry, agencies, and the public.

This report details progress during the biennium ending in 1991. Some of the efforts continue with funds from other sources.

SUPPLEMENTAL FUNDING SOURCES

Additional support for these state-funded projects during the 1989-1991 biennium was provided by:

- Tulalip Indian tribe
- Pacific County
- Washington shellfish industry
- U.S. Environmental Protection Agency
- U.S. Army Corps of Engineers
- National Marine Fisheries Service
- Washington Sea Grant Program
- University of Washington
- Washington Department of Fisheries
- Washington Department of Health
- Washington Department of Natural Resources
- Washington Department of Wildlife

The cooperative nature of the enterprise thus not only achieved a much greater funding base, but also ensured that the information from these studies would be widely disseminated and used. Follow-up funding for some of the projects has been provided by several agencies and by the Washington State Legislature.

WATER QUALITY EDUCATION

Simultaneously with these studies, Washington Sea Grant Marine Advisory Services was implementing a complementary series of education and technology transfer activities. These activities include mounting a water quality field agent program, facilitated by the Puget Sound Water Quality Authority and by the legislature through SB 6326 passed in 1990. A progress report on these efforts is included in this report.

SUMMARY OF RESULTS

Given a relatively modest funding base and short time of existence, the Washington State shellfish projects achieved remarkable success and demonstrate the ample benefits of investment in shellfish studies. The momentum from these studies should propel shellfish research and management in the state for years to come. In the field of science, progress is unpredictable and often difficult to measure. Nevertheless, the shellfish studies provided the state an impressive array of tangible results:

- a published strategy, developed at a workshop, for combatting the *Spartina* cordgrass infestation which threatens to upset the ecological balance of tidelands in Willapa Bay and other state estuaries
- a new genetic fingerprinting procedure, now being tested for broad national application, which can identify the sources of bacteria that contaminate shellfish beds
- a new hatchery and quarantine facility that gives the University of Washington the capability to address advanced research questions on oyster culture and genetics
- documented gains in Puget Sound geoduck and Manila clam enhancement resulting from improved laboratory and field practices
- the published record of a technical workshop held to pool knowledge of oyster growers on the emerging

technique of setting hatchery-reared larvae at the growers' sites to reduce costs and increase survival

- promising preliminary versions of new experimental methods to control ghost and mud shrimp that infest oyster beds and to routinely detect the toxic plankton that causes paralytic shellfish poisoning
- books for shellfish growers on mollusc diseases and on Manila clam culture, as well as a report on potential overharvesting of Puget Sound "nongame" marine life by both recreational and commercial users
- initial implementation of the water quality field agent network envisioned by the Puget Sound Water Quality Authority and SB 6326

The success of these projects is also demonstrated by their ability to attract continued funding. So far, two projects have attracted continued support:

- The Washington State Legislature has funded the state's share of a federal/state interagency task force to confront the *Spartina* problem, and additional federal funding is being sought.
- The National Marine Fisheries Service is supporting continued work to improve and apply the new technique for identifying sources of bacterial contamination in shellfish.

CONCLUSIONS AND RECOMMENDATIONS

These studies funded by the 1989 Washington State Legislature have already led to significant improvements in our understanding of Washington's shellfish resources and to broad dissemination and use of the information by industry and agencies. Though this short-term, one-shot effort was limited in initial scope and follow-through capability, the cooperative nature of the funding and of the research substantially expanded the range of the activity and provided a base for continuing efforts. Several of the key projects will continue with additional funding from state and federal sources, and these investments will substantially exceed the original $250,000 state appropriation.

Appended to this report is a bibliography of all shellfish-related publications supported by Washington Sea Grant projects since the inception of the program. This substantial body of work, which has profoundly benefited Washington's industrial, governmental, and human resource capabilities, was largely supported by the federal government and private industry. Sadly, however, national investment in marine resources has been declining, and it is no longer possible to sustain efforts of this magnitude purely on the basis of federal government resources.

Given the magnitude of Washington's marine resources and the problems and opportunities facing them, it is certain that future state-supported studies of the kind described in this report could yield significant benefits for the state and its citizens. This report is merely an example of what could be expected from sustained state support of research and technology transfer efforts on a broad range of fishery and marine resources. Returns on such investments by the state far exceed the costs, but most importantly they lay a firm foundation for a healthy and productive marine environment.

SHELLFISH STUDIES ADVISORY COMMITTEE, 1989-1991

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resource management

Resource managers not only must weigh economic and political constraints in choosing their actions, they also must understand the workings of the natural systems they oversee. A solid scientific foundation remains essential to wise decision making. The following studies were undertaken to provide data specifically oriented to aid managers who grapple with the issues of dredging, overharvesting, and plant and animal pests in the nearshore environment.

IMPACTS OF CORDGRASS ON OYSTERS, CRABS, AND CLAMS

Workshop, November 14-15, 1990, Seattle, Washington

Thomas F. Mumford, Jr., Washington Department of Natural Resources

Steve Harbell, Washington Sea Grant Program

James Sayce, Pacific County Department of Planning

Spartina alterniflora, a prolific alien cordgrass that grows on mudflats, threatens to take over virtually the entire intertidal zone of Willapa Bay, on the Washington coast, within 15 years. If it does, it will probably crowd out existing plants and alter the food web, degrading wildlife habitat, jeopardizing oyster, clam, crab, sole, and ling cod harvests worth $27 million annually, and posing a threat to salmon runs that transit the bay.

Native to and revered on the U.S. East Coast, *Spartina* was introduced to Willapa Bay (Washington's largest coastal estuary) accidentally with a shipment of oysters in 1894. It covered 430 acres by 1984 and more than 1,200 acres by 1990, and now threatens to cover all 30,000 intertidal acres by 2005. Two other *Spartina* species have invaded areas of Port Susan and Hood

Canal, with the potential to cover much of Puget Sound's intertidal zone.

A two-day workshop was organized and held in Seattle on November 14-15, 1990, to discuss the *Spartina* problem and possible responses. More than 100 people heard 16 experts from Washington and Oregon, California, the U.S. East Coast, England, and New Zealand. They were told that methods do exist to limit the extent and impacts of *Spartina* invasions, but that total eradication is not feasible in many cases. The possible defenses include digging up plants, mowing them, covering them, spraying with herbicides, introducing natural pests, and using some combination of these.

Following group discussions, the participants agreed on a series of resolutions stating that immediate action was warranted. They also recommended forming a West Coast regional task force, creating a Washington *Spartina* coordinator position, conducting an immediate inventory of *Spartina* infestation in Washington, and preventing the spread of *Spartina* to uninfested areas in Puget Sound, Grays Harbor, the San Juan Islands, and the lower Columbia River.

The workshop and the issue have received considerable press coverage and have heightened public awareness of *Spartina*. The text of the talks given and the resolutions passed, along with an extensive bibliography, have been published and widely distributed by Washington Sea Grant. More recently, the state has appropriated funds to hire a *Spartina* coordinator, and federal funding is being sought to aid the effort. Thus, a coordinated approach involving local, state, and national resources is blossoming out of the seeds sown at the initial workshop.

ASSESSMENT OF NONGAME MARINE INVERTEBRATES HARVEST

Robert Paine, UW Department of Zoology

Steve Jeffries, Washington Department of Wildlife

In recent years more and more people have been gathering intertidal animals classified as nongame marine invertebrates (NGMI). Of about 3,000 NGMI species, fewer than 50 are managed, as commercial and recreational species such as oysters and clams are, by the Washington fisheries and wildlife departments. Zoologists conducted this survey of gathering patterns and NGMI populations to determine whether NGMI are in danger of being depleted and should be considered for stricter regulation.

People gathering NGMI were surveyed along 13 mostly urban public beaches on central Puget Sound, from Steilacoom to Rosario Beach, during summer 1990. The results show that NGMI are very actively gathered for food, bait, and souvenirs, and that some of the animals that are less commonly collected but sensitive to disturbance may be declining on popular beaches. In addition, the survey found that some species are collected heavily for research, education, and commercial uses by schools and universities, aquaria, biological supply houses, and private consulting firms, with or without permits.

The survey also reveals the types of people who gather on the shore. More than half of individual gatherers were of Korean, southeast Asian, or Filipino birth or ancestry, and many did not speak English. Seventy percent of those gathering in organized groups were from schools; an estimated 10,000 school children from five Seattle area public school districts, or 12% of the student body of those districts, visited the surveyed beaches. More than 90% had been told to help seashore life survive by replacing animals and rocks carefully.

The survey provides first-of-a-kind information for understanding the condition of seashore animals on Puget Sound, the biological pressures on them, and the nature of the gatherers responsible for those pressures. The results were published in a report, *Assessment of Nongame Marine Invertebrate Harvest in Washington*, by the Washington Department of Wildlife. They will be used by officials of wildlife and other agencies to help determine whether to monitor and establish handling and harvesting limits on some beaches and seashore species.

ELECTROFISHING

A Potential Technique for Managing Burrowing Shrimp

David Armstrong and Brett Dumbauld, UW School of Fisheries

Robert Donnelly, UW Fisheries Research Institute

Washington's growing oyster industry contributes 10 percent of the nation's supply and is worth $10-$15 million annually. It is troubled, however, by two crustaceans, ghost shrimp and mud shrimp, that burrow in the sediment and degrade the quality of the habitat for oysters and other species. Shrimp are harvested commercially as bait, but the harvest method is not suitable for oyster beds, so shrimp populations currently are controlled by spraying with the pesticide carbaryl.

Because electrofishing does not introduce synthetic chemicals into the environment, this technology was studied as an alternative means of controlling shrimp populations and/or providing shrimp for the bait market. It was speculated

that electric pulses would drive shrimp out of their burrows to be captured and sold as bait for sportfishing. Impacts on other species were expected to be minimal because the area and season of use would be limited and the smaller organisms should be less sensitive to electricity.

Initial tests used equipment rented from Texas scientists who developed the technology to improve the efficiency of Gulf Coast penaeid shrimp trawls. When placed in an open aquarium without sediment, mud and ghost shrimp reacted with tail flips similar to those reported for Gulf Coast shrimp. When placed in artificial mud burrows, mud shrimp reacted by moving toward the source of the electric pulse. This equipment was ineffective in initial field tests, however.

Next, the UW scientists built a new instrument with adjustable pulse rate and voltage output and tested it by setting up a uniform electrical field in an aquarium. Optimal voltage and pulse rates to induce ghost shrimp to move rapidly toward the tank surface were determined to be lower for these thalassinid shrimp than for the larger penaeid shrimp, and the uniform field in the tank appeared to be more effective than the spatially variable field emitted by the Texas device.

Further laboratory studies of both the behavior of shrimp and electrical fields in sediments, and later field trials, are recommended to determine whether this success can be exploited for practical use. If it proves successful, it could create a win-win situation in which pesticides are kept out of natural waters and the pesky shrimp can be sold to offset the cost of removing them.

OYSTER AND *MYA* SHELL AS HABITAT FOR BIVALVES AND CRAB

David Armstrong, Jose Orensanz, Kay McGraw, Raul Palacios, and Oscar Iribarne, UW School of Fisheries

The habitat afforded by empty oyster and clam shells on tideflats enhances the survival of juvenile crabs by protecting them from predators. For this reason, the U.S. Army Corps of Engineers (COE) is covering intertidal areas in the Grays Harbor navigation channel with oyster shell to mitigate crab losses caused by dredging. But shell may also affect other animals living on the tideflats.

This study focused on softshell clams (*Mya arenaria*). Newly deposited shell may encourage the settlement of clam larvae, but the juvenile clams may themselves become prey for crab. Field studies during spring and summer 1990, conducted at the COE mitigation sites in Grays Harbor and in the laboratory, investigated and compared the recruitment and survival of softshell clams in areas containing shell with similar data from other habitats, such as mud and eelgrass.

Several species of bivalves were found to recruit in both oyster shell and open mud habitats, but experiments about which was the preferred habitat gave conflicting results. Two contrasting factors appear to be affecting bivalve densities in the shell assemblages: physical factors enhance recruitment, but biological factors decrease the survival of newly settled bivalves. Softshell clams and another clam species (*Macoma balthica*) transplanted in shell appear to suffer higher mortality because of increased predation by juvenile Dungeness crab that settle, reside, and forage in the shell.

More experiments are in progress to refine understanding of how the physical structure of the bottom and its biological composition interact to regulate bivalve abundance. In addition to shedding light on how dredging mitigation may affect the ecology of Grays Harbor, the results should provide insights on the effectiveness of using shell with gravel to enhance the yield of clam beds in Puget Sound, and on the interaction between oyster culture practices and juvenile crab survival in Willapa Bay.

human health

Popular as shellfish gathering is, shellfish consumption can pose a serious human health hazard under some circumstances. Some shellfish beds in Puget Sound are contaminated with fecal coliform bacteria that can cause gastrointestinal illness, and some are afflicted with a deadly natural neurotoxin derived from plankton. The following studies were designed to help health officials stay on top of the problem through better monitoring of the sources of these biochemical nuisances.

BACTERIAL CONTAMINATION OF SHELLFISH BEDS

Tracing Sources in Northern Port Susan Using Ribosomal RNA Typing and Restriction Fragment Length Polymorphism

Jerry E. Ongerth and Mansour Samadpour, UW Department of Environmental Health; and Gino Luchetti, Tulalip Tribe

Fecal contamination of nearshore waters, as indicated by the coliform bacterium *E. coli*, is one of the most pervasive and most intractable pollution problems facing Puget Sound today. Bacterial contamination from such sources as sewage treatment plants, wild and farm animal waste, faulty septic tanks, and urban surface runoff is causing closure of more shellfish beds every year. In most cases, however, the contamination is hard to control because of the difficulty in pinpointing its source.

This project used an innovative new biotechnological tool, ribosomal RNA typing (ribotyping), to match clonal types of *E. coli* bacteria in seawater to those originating from various sources. Ribotyping uses fragments of genetic material to identify specific strains of bacteria by comparing genomic markers in their chromosomes. The procedure is analogous to the DNA finger-

printing method now being introduced as evidence in the courtroom.

Ribotyping was tested first in northern Port Susan, a large Puget Sound bay whose potential annual production of 500,000 pounds of shellfish per year is currently restricted by the state health department because of bacterial contamination. According to initial results, each source has a narrow range of clonal types of *E. coli* bacteria; bacterial clones of human origin can be differentiated from those of animal origin; and similarities between some contaminated Puget Sound samples and one or more source samples suggest associations between the sites.

The National Marine Fisheries Service is funding longer follow-up studies to improve ribotyping and its potential for widespread use. When perfected, the technique should be useful for pinpointing contamination sources in Puget Sound and in other water bodies worldwide where shellfish contamination may pose a serious public health hazard.

EARLY DETECTION OF *GONYAULAX CATENELLA* BY AN IMMUNOCHEMICAL AND FLOW CYTOMETRIC METHOD

Mary Jane Perry, UW School of Oceanography

Every summer, miles of shoreline in Washington must be closed to shellfish gathering because of the threat of paralytic shellfish poisoning (PSP). Certain species of phytoplankton, the major diet of filter-feeding shellfish, contain toxins that can fatally poison people consuming the shellfish. The goal of this project was to develop an immunological method for rapid identification of cells of the toxic phytoplankton, *Alexandrium catenella* (formerly named *Gonyaulax catenella*), at low concentrations. Such a method would be an advance in basic oceanographic technique and could serve as an early warning system to detect waters afflicted by PSP.

Proteins from the cell wall of *Alexandrium* were injected into mice, and the antibodies produced in the animals' bloodstreams were successfully isolated. Labeled with a tracer dye, the antibodies bound to *Alexandrium* cells in field samples. The samples were then run through an automated instrument which rapidly detected and counted to dye-labeled particles.

Several protocols were developed for screening the many antibodies generated to see which were most useful for detection purposes. The criteria for this evaluation include an ability to tightly bind a dye and yield a strong detection signal, and a high specificity for binding to *Alexandrium* rather than to other species. Several clonal antibody lines look promising, but work remains to be done on the the ability of the detection method to discriminate *Alexandrium* from other phytoplankton species before this method can be put to practical use. If perfected, however, the technique would be much quicker and more sensitive than injecting shellfish extracts into mice and observing the mortality rate, the best existing means of detecting PSP.

shellfish culture

Improved culture methods are at the root of the spectacular increase in Washington's shellfish production over the last 20 years. Several of the following projects continue the high quality applied research that is essential to maintain progess. But several other projects target an equally vital goal: the need to communicate this research, when it bears fruit, to private growers to sustain and expand shellfish harvests, and to state agencies to sustain and protect public shellfish resources.

MOLLUSC DISEASES

Guide for the Shellfish Farmer

Ralph Elston, Battelle Marine Research Laboratory

Disease takes a heavy toll on shellfish around the world. Parasites, for example, have destroyed oyster beds in France and in Delaware and Chesapeake bays on the U.S. East Coast, and have now appeared in oysters on the Washington coast. Diseases such as nocardiosis and hemic neoplasia cost oyster and mussel growers millions of dollars every year.

Shellfish farmers may call such destruction "natural mortality," but the diseases responsible for widespread mortality among shellfish often can be prevented, controlled, or managed. By learning about the diseases and the aquaculture practices that encourage or inhibit them, shellfish farmers and hatchery managers can enhance productivity and profit. The key is knowledge.

Mollusc Diseases: Guide for the Shellfish Farmer is an inexpensive, illustrated guide to specific mollusc diseases written with the shellfish farmer in mind. The author, Dr. Ralph Elston, a senior research biologist at the Battelle Marine Research Laboratory in Sequim, Washington, is respected worldwide for his expertise in shellfish pathology. He presents concepts in a logical, straightfor-

ward style that avoids jargon.

The guide is organized by species and by major diseases to which that species is vulnerable, with an emphasis on the major cultivated bivalves. Each disease is described in its historical and geographical context, with details on mortality rates, environmental factors, seasonality, diagnosis, and preventive measures. One section lists pathologists in the U.S., Canada, and Australia who can diagnose diseases; another tells readers how to collect, preserve, and deliver tissue samples for diagnosis. References and a glossary are also provided.

Commercial shellfish farmers, hatchery operators, scientific researchers, and students in all parts of the world have purchased this book and are finding it a valuable addition to their working reference libraries. A letter from one of the major shellfish growers in the Pacific Northwest proclaims the guide to be "just what this industry needs."

WASHINGTON SHELLFISH CULTURE

Kenneth K. Chew and Sandra Downing, UW School of Fisheries

Conrad Mahnken, National Marine Fisheries Service

During the last fifteen years, commercial oyster operations in Washington, including hatcheries, have become more innovative and profitable. For these gains, the industry owes much to UW scientists, who conducted some of the most advanced shellfish studies in the world despite being hampered by temporary facilities and outdated equipment.

When the temporary facilities were no longer available, the search began to find a new home for the research. The National Marine Fisheries Service generously offered space in its new laboratory being built at Manchester on Puget Sound. With shellfish funds and additional support from the University of Washington and the shellfish industry, the space was equipped with a suite of high quality instruments. As a result, the new University of Washington Experimental Shellfish Hatchery is now in operation. The instruments have been put to immediate use to scrutinize the lab's water quality, a critical factor in maintaining healthy shellfish specimens.

The new hatchery will expand the ability of UW's internationally recognized shellfish program to apply the most modern knowledge and technology to aquaculture research needs. The program will pursue its outstanding experimental breeding and genetic analysis of Pacific oyster stocks, which produced the all-season triploid oyster now entering the marketplace. It also determines nutritional needs of broodstocks, conducts hatchery and culture pilot projects, and teaches shellfish hatchery management. The laboratory includes a quarantine facility used for screening new species that might be introduced into the region, such as the Kumamoto oyster described below. Local shellfish growers will continue to benefit from immediate transfer of relevant research findings that these new capabilities foster, instead of depending on data from outside the region.

TASMANIAN KUMAMOTO-TYPE OYSTER

Kenneth K. Chew, UW School of Fisheries

William Hershberger, UW School of Fisheries

Ralph Elston, Battelle Marine Research Laboratory

The Kumamoto-type oyster is revered for its shape and flavor, and it commands top prices in the fresh and half-shell markets. If propagated widely, this variety could give an economic lift to the oyster industry on the U.S. West Coast. Unfortunately, the parent stocks in Japan have been decimated by overharvesting and pollution, and existing West Coast stocks are sparse and inbred, making them unsuitable for supporting expanded production here. There are healthy and abundant stocks of Kumamoto-type oysters on the Australian island of Tasmania, however. Samples of these stocks will be brought to the Northwest and observed for possible diseases in the existing quarantine facility of Dr. Ralph Elston, then transferred to UW.

Researchers have built an approved quarantine facility at the UW Experimental Shellfish Hatchery at Manchester, trained a graduate student in the techniques of electrophoresis to perform genetic

comparisons among oyster stocks, and obtained an import permit from the Washington Department of Fisheries. The first Tasmanian oysters are scheduled to arrive during fall 1991. If disease-free, the samples will then be analyzed for genetic characteristics and ultimately supplied to West Coast growers who would cultivate it for eager consumers.

GUIDE TO MANILA CLAM CULTURE IN WASHINGTON

Kenneth K. Chew, UW School of Fisheries

Patricia Peyton, Washington Sea Grant Program

Doug Thompson, Washington Department of Fisheries

The Manila clam arrived by chance to Northwest waters in the 1930s and 1940s aboard shipments of Pacific oysters from Japan. Although it is not native to the area, the species has many attributes that make it an excellent choice for intertidal culture in Puget Sound. Statewide production increased from 500,000 pounds in 1970 to 4.2 million pounds in 1989. Washington is now the largest U.S. Manila clam producer and exporter, yet production still lags behind market demand.

As a result, demand also has exceeded supply for Washington Sea Grant's popular but out-of-print Manila clam growers guide. The guide has been thoroughly revised, and the new edition incorporates research advances from the past decade. It also includes several findings from Washington Department of Fisheries (WDF) studies supported by this project.

1. The three main Manila clam culture methods (in-ground bags, predator exclusion netting, and substrate modification) have been analyzed for cost effectiveness. The guide compares five-year cash flows for each method, a useful economic exercise for potential clam growers who must make similar projections.

2. In-ground bag culture, first used in France and only recently introduced in Washington, has proven effective in areas of heavy predation and also permits growers to extend present culture areas to lower tidal levels.

3. Adding gravel to the bottom to enhance natural "seed" sets increased the yield of marginal Manila clam beds from 3 to 1,492 pounds per acre on a test bed on Hood Canal. Adding crushed oyster shell to the gravel, however, appeared to inhibit rather than stimulate growth of juvenile Manila clams. Many growers have already adopted these practices to enhancing yields, and WDF is continuing studies on modified substrates.

With explanations of culture techniques and inclusion of up-to-date research, the new edition of the Manila clam guide will help increase yield and cost-effectiveness for this booming segment of the shellfish industry.

SURVIVAL AND SHELL STUDIES OF JUVENILE GEODUCKS IN A SAND NURSERY

J. Harold Beattie, Washington Department of Fisheries

Sandra Downing and Kenneth K. Chew, UW School of Fisheries

The geoduck *(Panope abrupta)* is the most valuable clam resource in Washington, with an annual landed value of $8 million and an estimated sustainable yield of 5 million pounds. The Washington Departments of Fisheries and Natural Resources are conducting a program to double natural production. Geoduck larvae are raised in a hatchery at WDF's Point Whitney Shellfish Laboratory on Hood Canal and transferred to a nursery as juveniles. They are kept there until they grow enough to be "seeded" into Puget Sound to boost production from commercial beds. Until now, however, the survival rate of juveniles seeded on natural beds has been disappointingly low, averaging less than 1 percent.

Recent Canadian research had showed that juvenile geoducks feed on the bottom with their "foot," rather than filtering water as larvae and adults do. In an experimental nursery, these investigators verified that juveniles given food on the nursery bottom survived well, whereas those given only algae in the water fared poorly. Using coarser sand on the nursery bottom also improved survival. Survival is still variable, however, probably because of fluctuations in the amount and quality of natural food supplies.

In a related study, this project conducted microscopic studies of geoduck shells in the nursery to determine growth conditions that foster healthy shell growth. Thinning and breakage of the shells is observed in the nursery and is suspected of killing many clams at a later stage after the seed are planted in Puget Sound.

This improved understanding of causes and mechanisms of geoduck survival will enhance the state's ability to sustain the highest yields from its submerged lands.

REMOTE SETTING AND NURSERY CULTURE FOR SHELLFISH GROWERS

Workshop, February 19, 1991, Olympia, Washington

Terry Y. Nosho, Washington Sea Grant Program

Twenty-five years ago the establishment of the first oyster hatcheries on the West Coast represented a major breakthrough for the shellfish industry, for it meant that oyster growers would no longer have to depend on foreign and erratic wild sources for their seed.

The advent of remote setting and nursery culture of oysters and other bivalves has again propelled the industry a great step forward. Seed producers and growers no longer have to ship seed on heavy cultch to the growout site; now just the tiny larvae—millions of them wrapped in wet gauze and occupying a space no bigger than a baseball—can make the journey, saving shipping and maintenance costs. As a result, the setting and nursery activities that once took place at a centralized hatchery are now dispersed about the countryside and are conducted by individual growers rather than hatchery operators.

In February 1991, the Washington Sea Grant Program organized a one-day federally funded workshop to bring together shellfish growers and scientists to discuss remote setting and nursery procedures prior to growout of the shellfish. The record of this workshop, published and distributed by Sea Grant, provides a useful reference work for growers, researchers, and students, and should help advance shellfish culture in the Pacific Northwest. State funding made it possible to follow up and amplify the workshop findings and to publish the record. Due to demand from industry, an additional workshop will be held in 1992, with others following.

water quality education

Michael Spranger, Terry Y. Nosho, Steve Harbell, James Bolger, Paula Cullenberg, Washington Sea Grant Marine Advisory Services

At the same time as the Washington State Shellfish Studies described above were under way, Washington Sea Grant's Marine Advisory Services was conducting related educational activities in the areas of water quality and shellfish enhancement under a separate legislative mandate.

Around Puget Sound, as in other populated areas, water quality is deteriorating because of failing septic systems, livestock in or near streams, stormwater runoff, erosion resulting from poor land practices, and improper application of lawn care and other products. Thoughtless boating practices such as pumping sewage and bilge water overboard, spilling fuel, and discarding trash also degrade the marine environment.

The Washington State Legislature, recognizing that education is a cost-effective method for improving water quality, established a water quality education demonstration project in 1990 under SB 6326. The legislature called upon the University of Washington Sea Grant Program and the Washington State University Cooperative Extension Service to develop this model project for a four-county area in the Olympic Peninsula, with the objective of improving and preserving the water quality of Puget Sound. It was responding to public hearings and public involvement working groups, which recommended the Sea Grant and Cooperative Extension models as the most effective ways of educating and assisting the public. One hundred thousand dollars was appropriated to each university for the initial one-year program.

The program was extended for the 1991-1993 biennium as part of the 1991 Puget Sound Water Quality Authority Management Plan, with appropriations to Sea Grant for two marine water quality field agents and Cooperative Extension for three freshwater quality field agents. The agents are assigned to implement educational components of the 1991 Puget Sound Water Quality Authority Management Plan. They work together to provide information and technical assistance to shellfish growers, shoreline home owners, fishermen, Native Americans,

county officials, school children, and the general public.

The field agents consult closely with local governments and community groups in each county to develop a defined set of priorities to meet site-specific local needs. The agents also meet periodically to coordinate efforts throughout the region. They disseminate water quality information through a variety of means, including one-on-one contacts, workshops, and publications. They also serve as facilitators to link federal, state, and local resources and expertise to deal with local water quality problems. Among many, many other activities, the field agents as a group have:

- sponsored on-going stormwater stencil projects with 4-H, scouts, and other youth groups;
- developed "Waterwatch," a volunteer citizen water quality monitoring program for selected streams;
- instituted a pilot project with local bankers and realtors to promote an alternative "Welcome Wagon" package that provides basic water quality and stewardship information;
- worked with numerous school teachers to provide them with the latest educational curricula and audiovisual materials on water quality that can be incorporated in classrooms.

Sea Grant agents Paula Cullenberg and James Bolger also worked together, with the cooperation of state and local agency personnel, to conduct the regional workshops and to produce *Shellfish in Your Front Yard*, an easy-to-read guide encouraging waterfront property owners to help maintain clean water and grow oysters or clams for their own use. The Sea Grant agents built upon the ongoing efforts of coastal field agent Steve Harbell and aquaculture specialist Terry Nosho, who in 1989 and 1990 held shellfish workshops throughout the Puget Sound region attended by more than 700 shoreline property owners. In connection with these workshops, Nosho wrote a technical manual, *Small-Scale Oyster Farming for Pleasure and Profit*, that was published by Washington Sea Grant.

By combining the resources of two major state universities, the water quality education program extends the research capability that is necessary to resolve regional and local water quality issues. Field agents can access state-of-the-art research and expertise from these universities, as well as throughout the United States, through the National Sea Grant and Land Grant Programs. And because the agents' sole mission is education and problem solving rather than regulation, they are viewed in the community as credible and nonadversarial sources of information, making it easier to promote cooperation among diverse groups attempting to resolve local water quality problems.

This regional water quality educational project is but a first step in an ambitious plan for the Puget Sound region. Under the 1991 Puget Sound Water Quality Management Plan, it is envisioned that by 1996 there will be a water quality specialist in each Puget Sound county and an additional six water quality specialists to work directly with the Native American tribes around the Sound.

available publications

The following Washington Sea Grant publications on shellfish are available for purchase from the sources listed. Please write Washington Sea Grant Communications Office, 3716 Brooklyn Avenue NE, Seattle, WA 98105, for a catalog describing these and other Sea Grant publications and including ordering information.

Publications funded by the Washington State Shellfish Studies are identified by an asterisk.

Allen, Standish K., Jr., Sandra L. Downing, and Kenneth K. Chew. 1989. *Hatchery manual for producing triploid oysters.* Published by Washington Sea Grant Program; distributed by University of Washington Press (Seattle). ISBN 0-295-77031-7. 27 pages. Paperback: $8.00
Companion video [1/2" VHS] and manual. ISBN 0-295-77034-1. $250.00
Companion video [Umatic] and manual. ISBN 0-295-77035-X. $250.00
An illustrated step-by-step approach to triploid oyster production from conditioning the broodstock through methods for verifying the technique's success.

Bill, Alexander H., and Terry Y. Nosho. 1988. *Aquaculture in Washington State.* Washington Sea Grant Marine Advisory Services [Seattle]. WSG-AS 88-05. 6 pages.

Cheney, Daniel P. and Thomas F. Mumford, Jr. 1987. *Shellfish and seaweed harvests of Puget Sound.* Published by Washington Sea Grant Program; distributed by University of Washington Press (Seattle). ISBN 0-295-95990-8. 164 pages. Paperback: $8.95
An in-depth discussion of the commercial shellfish industry of Puget Sound and the region's increasingly important seaweed resources.

Chew, Kenneth K. and Louisa Nishitani. 1989. *Gathering safe shellfish in Washington: Avoiding paralytic shellfish poisoning.* Washington Sea Grant Marine Advisory Services [Seattle]. WSG-AS 89-07. 8 pages. [Out of print, revision due in 1992]
Precautions for recognizing and preventing paralytic shellfish poisoning.

Cullenberg, Paula and Jim Bolger. 1991. *Shellfish in your front yard: Healthy food from healthy waters.* Washington Sea Grant Marine Advisory Program (Seattle). WSG-AS 91-10. 14 pages. $2.50
Designed for shoreline owners interested in raising shellfish on their beaches. Introduces a variety of methods available and stresses the importance of clean water in producing shellfish that are safe to eat.

*__Elston, Ralph A.__ 1990. *Mollusc diseases: Guide for the shellfish farmer.* Washington Sea Grant Program; distributed by University of Washington Press (Seattle). ISBN 0-295-97001-4. 73 pages. Paperback: $9.95
An illustrated guide to specific mollusc diseases, the guide is organized by species and by major diseases to which each species is vulnerable. Each disease is described in its historical and geographical context, with details on mortality rates, environmental factors, seasonality, diagnosis, and preventive measures.

*__Mumford, Thomas F., Jr., Patricia Peyton, James R. Sayce, and Steve Harbell, editors.__ 1991. *Spartina workshop record.* November 14-15, 1990, Seattle WA. Washington Sea Grant Program (Seattle). WSG-WO 91-01. 73 pages. Paperback: $9.95
Summaries of workshop discussions on methods for *Spartina* control in shellfish-growing areas, policy aspects, impacts of this cordgrass in coastal areas around the world, and regional strategies for combatting *Spartina* invasions. Extensive 370-entry bibliography.

__Nosho, Terry.__ 1989. *Small-scale oyster farming for pleasure and profit.* Washington Sea Grant Marine Advisory Services (Seattle). WSG-AS 89-01. 12 pages. Advisory bulletin: $1.25
An introduction to oyster farming considerations, growing methods, and legal aspects.

*__Nosho, Terry Y. and Kenneth K. Chew, editors.__ 1991. *Remote setting and nursery culture for shellfish growers: Record of a workshop.* February 19, 1991, Olympia, WA. Washington Sea Grant Program (Seattle) WSG-WO 91-02, ISBN 0-934539-15-4. 68 pages. Paperback: $9.95
Summaries of workshop presentations by commercial growers and scientists. A useful reference for other growers, researchers, and students.

__Schink, Timothy D., Katherine A. McGraw, and Kenneth K. Chew.__ 1983. *Pacific Coast clam fisheries: A survey.* Washington Sea Grant Program (Seattle). WSG 83-01. 72 pages. Paperback: $4.50
Examines commercial operations for littleneck, razor, Manila, butter, horse, geoduck, and soft-shell clams in Washington, Alaska, Oregon, and California. Covers historical developments, availability of stocks, water quality, disease, harvesting methods, transportation, processing and marketing, and environmental issues.

__Skidmore, Douglas and Kenneth K. Chew.__ 1985. *Mussel aquaculture in Puget Sound.* Washington Sea Grant Program (Seattle). WSG 85-04. 57 pages. Paperback: $5.00
Summarizes ten years of mussel research at the University of Washington. Methods of seed collection, times and locations of peak settlement of mussel larvae in Puget Sound, and possibilities of using hatcheries to provide seed are described.

biblio-graphy

Following is a bibliography of publications that have resulted from Washington Sea Grant research and Marine Advisory projects over the last 21 years. They encompass the entire spectrum of shellfish and related activities: activities from intricate explorations of the internal workings of the genes to writing guides for consumers and hobby growers; species from common oysters and clams to exotic abalones and octopi; and benefits from preventing human illness to converting crabshell waste to a valuable agricultural and medicinal product. They are further evidence of the magnitude and quality of Washington Sea Grant's effort over its short life span, and its powerful effects on advances in shellfish culture and research.

Many of these publications are out of print, but most of the journal articles, technical reports, and student theses may be found in the University of Washington or other scientific libraries. All Sea Grant publications may be borrowed from the National Sea Grant Repository at the Pell Library, University of Rhode Island, Narragansett, RI 02882, (401) 792-6114.

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