

WATERLINES

NEWSLETTER OF THE WESTERN REGIONAL AQUACULTURE CENTER - WINTER 2005

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Focus on WRAC Research

Ken Chew, Outgoing WRAC Director, School of Aquatic & Fishery Sciences, University of Washington

Contents

Focus on WRAC Research	1
WRAC Researchers Watch Grass Grow	2
Understanding Finfish Immune Function	4
Sturgeon Aquaculture: The Future for Caviar Production	6
Optimizing Quality and Shelf-Life of Sturgeon Caviar	8
Crossbreeding Pacific Oysters for High Yield	10
Sillet Salmon Barbecue Recipe	11
Reducing Phosphorus Discharge from Aquaculture Systems	12
Ken Chew Appointed to Fish and Wildlife Commission	13
Recirculation Aquaculture Systems	14
US Trout Farmers Association Celebrates 50th Anniversary	16
Graham Young, New WRAC Director	17
Farming of Geoduck Clams in Washington Becomes Reality	18
NAA News	20
Publications	21
Awards	21
Calendar	22
Extension Contacts	23

In this issue of *Waterlines*, we are pleased to highlight seven WRAC-supported research projects.

All WRAC research projects are initiated after review of the priority needs of the aquaculture industry by the Industry Advisory Council and subsequent review and input by the Research and Extension Subcommittees of the Technical Committee. The breadth and scope of these studies demonstrate the diverse research needed to assist the aquaculture industry.

In the eelgrass project, researchers are studying the impact that shellfish aquaculture has on native eelgrass—a critical habitat for several endangered and federally managed fish species (pages 2–3).

In another study, researchers are examining finfish immune function in order to help control and prevent disease in aquaculture production (pages 4–5).

The recently completed study on sturgeon broodstock development (pages 6–7) helped produce successful spawning and culture techniques for white sturgeon, which have since been applied for green sturgeon culture as well. This project helped to get sturgeon aquaculture started on the West Coast.

The sturgeon broodstock study also “spawned” another project, in which researchers are focusing on enhancing product quality and processing methods for caviar (pages 8–9). This study is

very timely: overfishing of Caspian Sea sturgeon has resulted in a drop in production despite an overall high market demand for caviar products.

In another ongoing project, researchers have been exploring an alternative approach to genetic improvement of oyster stocks (crossbreeding) and have shown that hybrid Pacific oysters have dramatically higher yield and superior metabolic performance than their inbred parents at all life stages (pages 10–11).

The phosphorus discharge reduction project addresses the industry’s need to reduce this effluent from high-density, flow-through aquacultural facilities (pages 12–13).

The recirculation aquaculture study has been working on fine solids removal and improved nitrification efficiency, off-flavor removal systems, and development of extension literature for best management practices for meeting the new EPA effluent regulations (pages 14–15).

We invite you to read about these projects in more detail in the following pages.

New WRAC Director

On November 1, 2004, Dr. Graham Young became WRAC’s new executive director (story on page 17).



Funding provided by the US Department of Agriculture, Cooperative State Research, Education & Extension Service

Vol. 13, No. 2

fish.washington.edu/wrac

WRAC Researchers Watch Grass Grow

Jennifer Resnick, Department of Biology, University of Washington, and Bill Dewey, Taylor Shellfish Farms

Eelgrass provides critical habitat for endangered salmonid species

Just like your lawn, eelgrass growth accelerates in summer, but its rapid growth leaves land-based grass in the dust. Unlike your lawn, eelgrass is protected by federal and state regulations.

Eelgrass provides critical habitat for endangered salmonid species and is essential habitat for a number of other federally managed fish species. As such, the National Marine Fisheries Service (NMFS) must be consulted when any federally funded or permitted activity may adversely impact eelgrass.

The species of foremost interest in this region is native eelgrass (*Zostera marina*), which provides a variety of ecosystem services, including structure for small fish and invertebrates, primary production, and sediment stabilization. Worldwide, eelgrass is in terrible shape, lost largely to coastal development and water pollution. Concern has spilled over to aquaculture activities, especially if they occur

in the low intertidal and shallow subtidal zones that are wet enough and get enough sunlight for eelgrass to survive (about -4 to +1 feet relative to mean lower low water in the Pacific Northwest).

The US Army Corps of Engineers (USACE) issues permits for a variety of shellfish culture-related activities. These permits trigger consultation with NMFS. Whether shellfish seeding and other culture activities should be allowed or even potentially encouraged in submerged aquatic vegetation (eelgrass) is an area that the Pacific Coast Shellfish Growers Association has been discussing with the USACE and NMFS in recent years.

Shellfish aquaculture may disturb eelgrass directly, but it also has potential indirect effects through modifying water and sediment properties. For instance, shellfish may filter sufficient particles from the water to improve light conditions for eelgrass. Their feces and pseudofeces may add nutrients to sediment



Researchers setting up experimental study plots on eelgrass beds

Alan Trimble

that can then be taken up through eelgrass roots.

Lacking a clear understanding of shellfish culture impacts (both positive and negative) on eelgrass, the shellfish industry approached WRAC about funding this research. The potential indirect effects of shellfish on eelgrass are currently under study in Willapa Bay and Puget Sound, Washington—funded by WRAC and industry partners from 2003 to 2007.

Many shellfish growers have a difficult time appreciating eelgrass, and not just because its protection seems a threat to the industry. They report that eelgrass grows so densely in summer that shellfish become stunted and equipment tangles in long blades of grass.

The problems are particularly acute on oyster beds where a single crop is grown for two or three years. In some cases, beds that were formerly devoid of vegetation became covered by eelgrass after shellfish were planted. These reports indicate a facilitative effect of shellfish on eelgrass, or at least rapid recovery after disturbance.

Shellfish–eelgrass interactions

Research on shellfish–eelgrass interactions involves a combination of observations over large time and space scales, plus manipulative experiments to test mechanisms of interaction. The context for the research is set by seasonal samples of eelgrass density, biomass, growth rate, and phenology (flowering, branching, germination).

Samples are collected almost monthly from seven locations in Willapa Bay and three in south Puget Sound. This sampling shows strong seasonal patterns in the life cycle of eelgrass and confirms observations by growers that most interference from eelgrass occurs during summer.

In late summer and fall, many eelgrass shoots differentiate to become long, round-stemmed flowering shoots, and all flowering shoots subsequently die. Consequently, winter densities of eelgrass are much reduced, and

the remaining individuals are smaller and grow slower. Beginning in February, as the days lengthen, shoots go through a burst of branching that results in higher density. Seeds germinate primarily in March to May, further increasing density. Plants become larger and grow faster, with individual blades extending 5 cm (2 in) per day in Willapa Bay. Peak biomass occurs in July and August.

A major difference in eelgrass exists between Willapa Bay and Puget Sound. In Willapa, plants reach lengths of nearly 2 m (6 ft) at densities of about 100 per square meter. Plants in south Puget Sound are smaller and denser, just 30 cm in length but at densities of thousands of shoots per square meter. Strong regional differences between Puget Sound and Willapa Bay (let alone between the East and West coasts) may make it difficult to develop a “one size fits all” management policy.

Large-scale experiments

Aquaculture beds are essentially large-scale experiments, perfect spots to survey sediment and eelgrass density and growth to see how they respond to change. Preliminary analyses suggest that reduced densities of eelgrass are often found on oyster beds, but eelgrass grows similarly on and off beds. Nutrient levels are high in sediments throughout the study areas.

Highest densities of newly germinated eelgrass were found on beds harvested a year ago, and by two years post-harvest, eelgrass densities approached background levels. These surveys have confirmed yet another grower observation, that eelgrass reaches high densities on oyster beds after a few years. However, the results will likely surprise many eelgrass experts, because *Zostera marina* in other locations has short-distance seed dispersal and low rates of successful sexual reproduction.

When scientists do experiments, they generally select smaller plots than most shellfish growers do. Experiments provide direct tests of potential interactions by elucidating cause and effect, in this case by “tweaking”

Aquaculture beds are essentially large-scale experiments, perfect spots to survey sediment, eelgrass density, and eelgrass growth to see how they respond to change

continued on page 5

Understanding Finfish Immune Function

Vaughn Ostland, Kent SeaTech Corporation, and James Winton, Northwest Biological Science Center

It is estimated that disease costs US finfish aquaculture up to \$200 million annually

While aquaculture is the fastest growing sector of the US agriculture industry, infectious disease continues to impede its growth and expansion. It is estimated that disease costs US finfish aquaculture up to \$200 million annually. In addition to the direct loss of valuable animals, disease also increases overall production costs in the form of poor growth and feed conversion and the need for repeated medication.

Traditional approaches to managing or treating fish diseases typically involve intervention after the onset of infection. Currently, however, there are only a few approved antibiotics and chemicals to help treat some of the bacterial, protozoan, or fungal diseases that affect finfish aquaculture. None of the viral diseases affecting finfish have effective therapeutic agents.

Vaccination represents a promising alternative to reduce our dependence on antibiotics, as well as to help prevent many

of the economically devastating diseases that afflict warm- and cool-water finfish species cultured in the western United States.

Initially, there was rapid progress in the commercial development of killed vaccines against a few of the gram-negative bacterial pathogens. However, it soon became apparent that this early success would not continue and there are currently no effective vaccines to prevent most of the important diseases affecting commercially reared finfish in the western United States. Until we have a better understanding of how the finfish immune system responds to an infection or can be appropriately stimulated by vaccination, infectious disease will continue to impede the future growth and expansion of aquaculture in the United States.

The recently developed WRAC project on immunology has assembled a group of experienced academic and industry scientists to study the immune function of hybrid striped bass and rainbow trout, two of the most economically significant finfish species reared in the western United States. While focusing on these two species, the project's findings will be directly applicable to all warm- and cool-water finfish species reared throughout the country.

With research just underway, an initial goal is to develop key reagents and assays that will serve to quantify the immune response of the representative species. Using these newly developed tools, the group can then test how the immune system responds during an infection or following immunization with novel vaccine antigens. Such assays could be adopted by various aquaculture companies or other fish health workers to monitor immune function during the onset of infection or during treatment and to evaluate immune status after vaccination.



Courtesy of Scott LaPatra

Box Canyon facility of Clear Springs Food, Inc. along the Snake River in Idaho

Eelgrass

continued from page 3

Another goal is to assist in the development of large-scale methods of vaccine delivery and examine whether these delivery strategies do indeed stimulate the appropriate components of the immune system, thus ensuring that existing and novel vaccines can be delivered in an effective manner.

The researchers also intend to study the effects of different biological and environmental factors common to aquaculture, such as life stage, stocking density, water temperature, and water quality on the immune function of both species. This information would help aquaculture managers devise alternate management strategies to minimize the stress of intensive culture, ultimately leading to improved fish health and disease prevention.

A better understanding of how the fish immune system responds to infection could help shape the direction and approach for future disease management. The ability to accurately measure finfish immune functions will provide methods to understand the effects of fish culture practices and environmental stressors and help us determine how resistance to disease is affected by the physical and biological factors common in intensive culture environments.

In addition, this approach will aid in broodstock development, perhaps with the identification of stocks that have enhanced immune function, enabling them to respond rapidly to infection and immunization, as well as displaying inherent resistance to important pathogens affecting aquaculture species.

Understanding finfish immune function will also play a key role in vaccine development, improve the efficacy of existing vaccination strategies, and allow the development of new vaccine delivery technologies that will be designed to target specific components of the finfish immune system. This approach to finfish health will help lead US aquaculture far into the 21st century. ■

the shellfish in the system to see how eelgrass responds. Instead of shellfish beds covering acres of tideflat, researchers set up hundreds of plots that were 1–2 m (3–6 ft) on a side.

Factors manipulated in the crossed design included the presence or absence of eelgrass, shellfish, extra nutrients in the sediment, and shell structure. Parallel experiments were set up in Puget Sound with geoducks and in Willapa Bay with oysters this summer, to be tracked over the next two years. Measurements will be taken on recovery and growth of eelgrass. Industry cooperation was essential to setting up these experiments.

Graduate student Lorena Wischart at Oregon State University is collecting and sorting literally tens of thousands of eelgrass seeds, which look like very small dark rice grains. These seeds will be used in an experiment to find out why seedling densities vary across aquaculture types. By placing equal numbers of seeds in different habitats, Lorena controls for the arrival of seeds and determines what proportion landing in an area actually germinate. The results will shed light on whether the high seedling densities in one-year-old dredged beds are due to seed dispersal, seed germination, or seedling survival.

The eye-opening results of the work so far concern the resilience of eelgrass, particularly its ability to recover rapidly from a short-term perturbation. It seems much less sensitive to variation in sediment and water quality, at least over the range of conditions that the plant regularly experiences in these study sites. However, with many field experiments just initiated and two more field seasons ahead, it's clear that WRAC researchers will spend many more hours watching eelgrass grow. The long-term objective is to understand multiple impacts of aquaculture and shellfish and provide scientific data that can inform better management.

The research team includes three universities—the University of Washington, Oregon State University, and Columbia University—and the Washington Department of Fish & Wildlife. WRAC funds support several graduate students, undergraduate research assistants, and research technicians. Faculty members and several high school students have volunteered their time. Industry matching funds have allowed the purchase of equipment to monitor water properties around shellfish beds. ■

Sturgeon Aquaculture: The Future for Caviar Production

Joel P. Van Eenennaam and Serge I. Doroshov, Department of Animal Science, University of California, Davis

More than ten years ago, the Western Region aquaculture industry undertook a challenging project on domestication and culture of white sturgeon. In this short period of time, relative to the longevity of sturgeon, the industry made significant progress in culture, especially in California and Idaho. The most notable aspect is the sustained production of caviar during the past three years.

The interdisciplinary WRAC Sturgeon Broodstock Development Project (1993–2003), conducted in direct collaboration with industry, was successful in establishing domesticated sturgeon broodstocks and improving their management and reproduction.

Sturgeon farms have achieved independence from wild broodstock and use effective methods to produce their own seedstock each year. Most recently, the Idaho sturgeon industry has had two years of highly successful spawning of the indigenous Snake River sturgeon stock and is fully capable of producing endemic seedstock to fill the needs of their commercial industry.

Maturation and management

Today, farmed white sturgeon grow and mature three times faster than their wild counterparts. Broodstock maturation rates and reproductive performance were enhanced by optimization of thermal and feeding regimes, development of reproductive diagnostics, and improved hormonal spawning induction procedures.

Management recommendations from the epidemiologic studies have been directly applied by sturgeon growers, and survival of juveniles, previously impacted by viral disease, has improved. Farms now routinely make decisions on the risk factors contributing to disease outbreaks, and the bottom line is that viruses are not affecting meat and caviar production levels at this time.

Sturgeon farms

There are currently three major sturgeon farms in California (Stolt Sea Farm, The Fishery, and Tsar Nicoulai Caviar) and four in Idaho (ARK Fisheries, Blind Canyon Aquaranch, Clear Springs Foods, and Fish Breeders of Idaho) that have successfully cultured and bred sturgeon. There are also a few smaller growers that focus on meat production, using larvae from another farm.

As a direct result of this project's research and outreach, and the long-term collaboration with colleagues at Malaspina University-College, there is also one recently established commercial white sturgeon farm in British Columbia, Canada (Target Marine Products).

Green sturgeon

Interestingly, the techniques developed during this project for white sturgeon have been applied and successfully modified to fit the spawning and culture requirements of another West Coast species, green sturgeon, studied at the University of California, Davis during the past four years.

Green sturgeon have some unique characteristics that can be valuable for commercial production, such as very large eggs (4.3 mm in diameter vs. 3.5 mm in white sturgeon), and robust easy-to-rear larvae. One-year-old green sturgeon reared in well water (19° C) have attained body sizes averaging 2–3 kg. Although two of the California farms have green sturgeon listed on their aquaculture permits, the future of green sturgeon aquaculture is uncertain, as recently, this species has been petitioned to be listed as endangered.

Sustained production

The Western Region white sturgeon industry is now able to replace products from the severely depleted worldwide commercial fishery with the sustained production of meat and caviar. During the last three years, the estimated annual production levels have been about 1,000 metric tons (MT) of food fish and 5.0–6.5 MT of caviar. Approximately 2,000 individual females have been processed annually for caviar, and the average yield per fish has been about 3 kg of final product (canned caviar).

The rapid decline in caviar supplies from wild stocks and the increasing harvest restrictions, particularly in the Caspian Sea, will continue to create an incentive for production of caviar from farmed sturgeon. Given that the United States has historically imported over 50 tons of caviar annually, and the fact that restrictions on international trade of sturgeon caviar (CITES) are tightening, the US sturgeon industry will almost certainly be a major source of caviar in the future. However, the continued expansion and sustainability of new sturgeon farms will ultimately



Juan Medrano

*above: Spawning sturgeon at UC Davis. l to r: Javier Linares, Jean-Benoit Muguet, Serge Doroshov, Christa Woodle
at right: Serge Doroshov (right) receives an award for his outstanding contribution to the growth and development of aquaculture in the United States. He played a significant role in starting sturgeon culture in the Western Region. The award is presented by Meryl Broussard on behalf of CSREES, USDA.*



Ken Chreu

depend on government regulations, production costs, market demands, and price.

A new approach

The offshoot of WRAC’s Sturgeon Broodstock Development Project is a new WRAC project on caviar processing and food technology (see pages 8–9), which is expected to improve production and quality of caviar from farmed sturgeon.

Although WRAC’s Sturgeon Broodstock Development Project has been completed successfully, there are other continuing research projects that are important for sturgeon aquaculture, including breeding plans for selection of desirable traits, sex identification and monosex production, gamete cryopreservation, disease detection and prevention, and development of optimal feeds for growout, broodstock, and caviar production. ■

Optimizing Quality and Shelf-Life of Sturgeon Caviar

Barbara Rasco, Department of Food Science, Washington State University

Most sturgeon caviar (about 90%) comes from the Caspian Sea. However, each year, thousands of pounds of finished product are often rejected by buyers for quality defects. Furthermore, overfishing of Caspian Sea sturgeon has resulted in import bans and restrictions internationally as a means of saving the fishery. There has been a drop in production despite an overall high world market demand for caviar products, a situation that US aquaculture can reverse.

Commercial aquaculture of white sturgeon in California and the inland Pacific Northwest provides a unique opportunity to supply caviar from farmed fish to meet market demands. However, there are product-quality issues specific for caviar, some possibly unique to cultured sturgeon produced in these regions, that still need to be addressed.

As other nations bring farmed sturgeon products to market, it will be necessary to understand how the US product differs and how quality attributes of the US product can be exploited to create a market advantage. At the same time, the international demand for high-quality caviar and roe products is growing, presenting an opportunity for fish culturists to enter a new area—US producers should be ready to meet the increasing demand.

White sturgeon (*Acipenser transmontanus*) is the most prominent sturgeon on the North American continent and has been successfully cultured for meat and caviar production for several years. Because of the freshness of eggs obtained from farmed sturgeon, caviar of consistently high quality can be obtained.

Challenges and objectives

One challenge for the industry is to modify husbandry practices to produce a good yield of caviar from mature eggs. Other problems are associated with storage stability, flavor, and texture.

Over the past three years, Dr. Barbara Rasco and her research team at Washington State University have addressed a number of scientific and technical issues associated with quality assessment and ways to improve product quality, processing technologies, and product safety. Having solid technical information for sturgeon caviar could improve domestic markets and reduce technical barriers to trade that affect entry and growth in export markets.

Our specific project objectives have been to:

1. Characterize the sensory attributes of caviar and determine what factors influence product flavor, texture, color, and other sensory attributes.
2. Determine how to optimize quality factors through diet modification, rearing conditions, and timing of harvest.
3. Evaluate thermal and non-thermal processing methods to improve the shelf-life of caviar; evaluate microwave and refrigeration/freezing processes for pasteurization.
4. Evaluate freezing methods to improve the shelf-life of caviar, and evaluate enzyme pretreatment, cryogenic, and partial freezing processes for preservation.

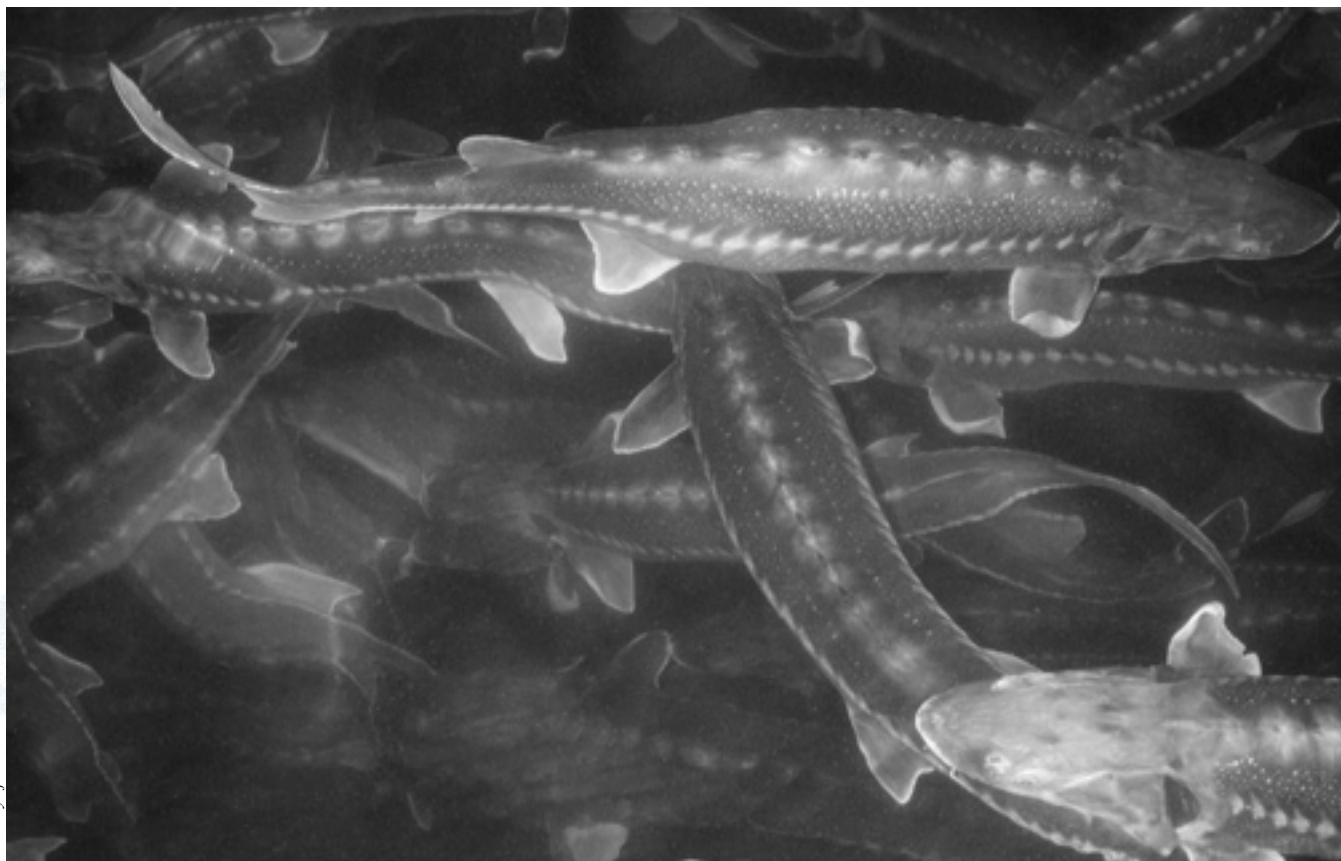
Collaborative research developments

During this project, Dr. David Reid at the University of California, Davis, developed freezing and frozen storage technologies to improve the shelf-life of caviar products. Dr. Rasco and her team developed microwave and radiofrequency thermal processing techniques, which reduce heat damage to pasteurized products. Her group also developed methods for reducing the heating requirements through combined treatments with the antimicrobial agent nisin, which improves the effectiveness of thermal processing treatments.

Dr. JX Guinard (UC Davis) devised a reliable sensory lexicon for caviar and can differentiate product by source, feed regimes, and processing conditions, using well-characterized flavor, aroma, color, and texture attributes specifically developed for caviar. Some of the most interesting results have been with textural properties. Correlations have been found between egg size and skin thickness, dissolvability, breakability, and firmness.

Guinard and Reid have been working closely to develop ways to monitor texture by comparing rheological and sensory measurements, and it appears it is possible to correlate results from a back extrusion rheological (texture measurement) method with results from a sensory panel.

Drs. Yi-cheng Su and Michael Morrissey at Oregon State University have been working on improving product texture by crosslinking membrane proteins in the “shell” of a sturgeon egg with transglutaminase to make the egg stronger so that it can survive freezing and thermal processing.



Courtesy of B. Rasco

Studies on the effect of a high antioxidant diet on caviar quality were conducted by Dr. Rick Barrows at the US Fish and Wildlife Service and Peter Struffenegger at Stolt Sea Farms. Samples from the diet trial have been evaluated and indicate that sensory characteristics of caviar from fish fed a diet high in vitamin E are not significantly different from the control—with the possible exception of firmness and breakability for samples held five weeks.

The samples from fish fed the diet high in antioxidants were slightly firmer and took more pressure to break in the mouth. They also had a higher overall firmness by the back extrusion test. Evaluation of caviar quality following longer-term storage will help to determine if there is a beneficial effect of diet supplementation.

Our collaborative work indicates that a number of strategies are possible for maintaining caviar quality by altering the diet of the fish by the incorporation of anti-

oxidants, and by improving freezing and thermal processing treatments. Employing combined treatments can reduce the growth of *Listeria monocytogenes*, a food pathogen of great importance in ready-to-eat aquatic foods. Reducing membrane fragility through the use of transglutaminase treatment may not be possible, and further work is necessary on other possible treatments.

Caviar can be characterized using the sensory lexicon developed at UC Davis for color, aroma, flavor, and texture attributes. Sensory textural attributes can be correlated with rheological measurements using the back extrusion test developed earlier during this project.

This WRAC-sponsored research has had a positive impact on the industry by providing advice on processing and storage technologies that may extend shelf life and maintain product quality and safety. Investigators have been working with individual aquaculture facilities on strategies to maintain product quality and produce caviar effectively and safely. ■

Crossbreeding Pacific Oysters for High Yield

Dennis Hedgecock, Department of Biological Sciences, University of Southern California, and Joth Davis, Taylor Shellfish Farms

Oysters have been farmed along the West Coast of the United States for 150 years

Oysters have been farmed along the West Coast of the United States for 150 years. Annual production of the Pacific oyster, *Crassostrea gigas*, which was introduced to the West Coast from Japan in the 1920s, averages approximately 5,000 metric tons of shucked meats with a dockside value of more than \$35 million per year—nearly 60% of the total value of West Coast marine aquaculture.

Success in farming the Pacific oyster is attributable to its natural resistance to diseases that have decimated American and European oyster fisheries, and to the development of reliable sources of seed from commercial hatcheries.

Though demand for farmed Pacific oysters in the United States and Asia far exceeds supply, the West Coast oyster industry faces mounting constraints from urbanization of estuarine environments. Improvements in yield are required to maintain or enhance production. One certain way to improve the

yield of farmed oysters is by breeding, which the Pacific Coast Shellfish Growers Association identifies as a top priority.

Selective breeding of high-yielding, high-health stocks was begun with US Department of Agriculture funding, in 1996, by the Molluscan Broodstock Program (MBP) based at Oregon State University's Hatfield Marine Science Center in Newport, Oregon. Higher yields from selected seed, compared to industry or naturally produced seed, have been recorded.

An ongoing WRAC project has explored an alternative approach to genetic improvement—crossbreeding—and shown that hybrid Pacific oysters have dramatically higher yield and superior metabolic performance than their inbred parents at all life stages. This striking hybrid vigor suggests that crossbreeding, in addition to traditional selection as practiced by the MBP, could improve yield dramatically and quickly.

For example, crossbreeding has increased corn yield in the United States nearly fivefold since the Civil War and about 60% of this improvement is genetic (Crow 1998). Corn breeders achieve these gains by annually testing millions of hybrid progeny, produced by crosses among thousands of inbred lines, to select elite lines for crossbreeding. Unfortunately, the oyster industry lacks the capacity and technology for testing inbred lines on this scale.

The goals of this WRAC project have been to provide basic technology and methods for making and testing inbred lines and to work with industry to apply these methods on a commercial scale.

These goals are beginning to be achieved. This project helped to alleviate two roadblocks to commercial crossbreeding programs: the absence of mechanisms for transferring selected



Jonathan Davis

WRAC investigator Dennis Hedgecock (left) deploying a group of hybrid oysters for yield-evaluation with Chris Pratt of Taylor Resources, Inc.

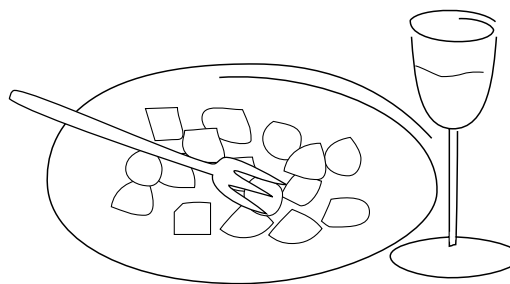
stocks and breeding concepts to commercial hatcheries, and the inefficiency of field-testing the cross-performance of inbred lines.

The outreach portion of this project defined commercially acceptable measures of yield, obtained baseline data on industry yield, and developed commercial protocols for testing improved seed produced by the WRAC project.

As a result of their experiences with commercial yield trials, Taylor Shellfish Farms has implemented a cradle-to-grave, hatchery-to-market tracking system for evaluating production of hybrid stocks. This system allows yield to be measured at large scales of production, enabling the detection of statistically significant differences despite the inherently large variation of such an integrative measure of performance as yield.

A hybrid cross that was identified by WRAC testing experiments was put into commercial production this year. Approximately 100,000 seeds were put out for testing and harvested in 2004. The hybrids compared favorably to the control oysters in size and condition.

The research portion of the project developed protocols to improve the efficiency with which superior hybrid combinations can be identified, by testing for growth potential at the earliest possible life stages. Yield can be predicted at the early seed stages, which allows many more hybrid combinations among inbred lines to be tested than could ever be done when rearing to harvest size by conventional methods. Research to predict yield even earlier focused on underlying physiological, molecular, and genetic mechanisms of growth, rather than on yield itself. This work has identified candidate genes, whose expression could be monitored as indicators of hybrid growth potential. ■



Skillet salmon barbecue

Ken Chew

- 2 tablespoons lemon pepper
- 1 tablespoon granulated dry garlic (looks like powder)
- 1 teaspoon black pepper
- 1 tablespoon dry onion flakes
- 1½ pounds salmon filet (cut into 2 inch sections/pieces)
- Olive or canola oil (enough to cover a very thin layer in frying pan)

With no heat, put all the seasoning (spread evenly over the oil) into a 10–12 inch frying pan.

Now turn on medium heat. Using the spatula, swirl the oil in the pan (while holding the frying pan handle to assist in the swirling). The garlic will turn brown quickly, so be prepared. The onion flakes will turn brown after the garlic. Together, they will provide a nice golden brown color. Caution!! This will turn black quickly, so remove the heat when golden brown. **TURN OFF HEAT NOW!**

Now, still with no heat, place the sections (pieces) of fish with flesh side down in the pan. Be certain the golden brown ingredients are spread evenly before placing the salmon sections. After all the fish pieces are in the pan, turn heat back on to medium. Allow 3–4 minutes, and with the spatula, turn the fish pieces to the skin side. If no skin, turn over anyway. The golden brown mixture is now cooked onto the flesh side. Cover with lid and turn to low/simmer heat until cooked.

If pieces are about one inch thick, it takes about 15 minutes to cook through.

This is sort of like slow cooked/steamed in oil and salmon juice, and yet retains the nice brown color and taste of barbecue salmon. Using spatula, remove the fish to serving plate. The extra oil/juice in the pan should be scraped on top of the salmon pieces. Garnish with greenery and lemon slices to serve. ENJOY.

Reducing Phosphorus Discharge from Aquaculture Systems

Shulin Chen, Washington State University, and Gary Fornshell, University of Idaho

The problem

Nutrient and solids control is a key issue in the management of effluent from high-density flow-through aquaculture systems. Water-quality-based environmental regulations such as total maximum daily loads (TMDL) focus on nutrients, especially phosphorus.

In the Thousand Springs area of Idaho, the year-round optimum temperature and quality of the water resource has led to the development of highly productive, flow-through raceway production facilities, which contribute significantly to the regional economy. Although the effluent is characterized by very low concentrations, the combined effluent of these operations has resulted in a nutrient mass discharge that has been linked to eutrophication in the Middle Snake River. The Environmental Protection Agency has approved a TMDL to limit discharge of phosphorus from aquaculture operations.

These high-flow, low-concentration aquacultural effluents present a technological and economic treatment challenge. Capital and operation costs of typical wastewater treatment processes for nutrient control can be prohibitive because of the large volumes of discharge generated from even small flow-through aquaculture operations. Any applicable treatment technology must be consistent with the requirement for discharging into the Middle Snake River and the current practice of land application of waste solids.

The aquaculture industry needs low-cost, yet more effective management practices in order to comply with environmental regulations *and* maintain economic competitiveness.

WRAC research project

A WRAC-sponsored project team was assembled to address research needs for reducing phosphorus. The working group includes Dr. Shulin Chen (working group chair), Washington State University (WSU); Dr. Kevin Fitzsimmons, University of Arizona (Arizona); Drs. Ronald Hardy and Greg Moller and Mr. Gary Fornshell, University of Idaho (Idaho); Dr. Rick Barrows,

US Department of Agriculture–Agricultural Research Service (USDA–ARS); and Dr. Raul Piedrahita, University of California, Davis (UC Davis). Other support is provided by Technical Advisor Dr. John Colt and the Industry Advisory Committee.

The goal of this project is to reduce the discharge of all species of phosphorus from high-density, flow-through aquacultural facilities by investigating the fate of phosphorus and solids between the point of particle introduction into the water and the point of removal.

Specific objectives include the following:

1. determine the fate of particles in raceways, including transport and breakdown.
2. investigate the rate of excretion of dissolved phosphorus from fish and the rate of release from fecal particles in raceways.
3. design and evaluate scrap iron granule reactors for removing dissolved phosphorus.
4. improve fecal pellet stability and minimize phosphorus loss through feed manipulation.
5. develop best management practices featuring excretion reduction and efficient removal of both particulate and dissolved phosphorus.
6. evaluate the best management practices in commercial settings.

Research results

To date, almost all the project objectives have been achieved. For example, the particle fate and transport research (WSU) showed that the efficiency of particle transport by water velocity and the solids removal efficiency at the quiescent zone are limited by the design of the system. The measured mean raceway water velocity was 0.05 m/s, a value well below the 0.1–0.4 m/s range recommended for prevention of waste solids settlement.

The quiescent zones provide adequate hydraulic retention time only for removing large particles. Based on the measured results of mean particulate and dissolved concentrations of phosphorus in the effluent (0.04 mg/L and 0.06 mg/L, respectively), it is estimated that removal of

These high-flow, low-concentration aquacultural effluents present a technological and economic treatment challenge

particles greater than 100 μm is necessary in order to achieve a 20% reduction of total phosphorus. Such a reduction is very difficult within the quiescent zones alone.

The phosphorus production research (Arizona) showed that phosphorus release from feces occurs more rapidly in the first hour than after that time.

The reactor study (Idaho) resulted in a moving bed reactor that can effectively remove dissolved phosphorus from the offline settling basin, but at too great an expense.

The feed study results (Idaho and USDA-ARS) showed that manipulation of fish feeds will increase fecal density and improve recovery of solids in the quiescent zone of raceways.

To address transport limitations and allow particles to be moved as quickly as possible to the quiescent zone where the solids can be removed and discharged to the offline settling basin, Dr. Chen's team at WSU invented a moving baffle.

The moving baffle was carried on a carriage system that moved along the length of the raceway. The upper edge of the baffle was hinged to the upstream member of the carriage, spanning the channel width, while the lower edge rotated into the channel and was fixed against the carriage in the operating position.

As the water is forced to flow through the gap between the lower edge of the baffle and the bottom of the raceway, water velocity increases. In addition, the baffle itself moves due to the hydraulic pressure built up at the back side of the baffle. In the non-operating position, the baffle is rotated out of the water and fastened to the carriage in a horizontal fashion.

Test results showed that average particle transport efficiencies increased from 15% to 75%. A baffle design procedure for a range of facility and waste characteristics was also developed. A mathematical model was developed by the UC Davis team for evaluating different options by describing the particle transport process and hydraulic improvements.

The information and the practices results from this project will be helpful for raceway effluent management after further testing. ■

Ken Chew Appointed to Fish and Wildlife Commission

Longlines, Pacific Coast Shellfish Growers Association Newsletter

January/February, 2005

Dr. Ken Chew has been appointed by Washington's outgoing Governor Gary Locke to a seat on the influential Fish and Wildlife Commission for a term that goes through the end of 2010.

Dr. Chew, certainly one of the West Coast's most pivotal figures in the past few decades, has mentored legions of shellfish industry movers and shakers. He recently retired from his posts as associate dean of the University of Washington's College of Ocean and Fishery Sciences, and director of the Western Regional Aquaculture Center.

Dr. Chew's expertise covers a wide spectrum, including global aquaculture, shellfish biology and culture, paralytic shellfish poisoning, and the ecology of benthic intertidal and subtidal invertebrate communities.

He has served as science advisor to numerous foreign countries, and as a member of the first US Aquaculture delegation to the People's Republic of China in 1980.



Gerald Chew

Ken enjoying one of his favorite pastimes with his son Curtis and grandson Bradford.

Recirculation Aquaculture Systems

Raul H. Piedrahita, University of California, Davis, Kevin Fitzsimmons, University of Arizona, and Shulin Chen, Washington State University

Researchers working on the WRAC-sponsored recirculation aquaculture project have been studying some of problems the industry is facing. The objectives of the project are to: (1) formulate design information specific to the needs of species cultured in the Western Region, (2) study off-flavor removal systems that are appropriate for recirculation systems, and (3) develop extension literature related to reuse and recirculation systems, focusing on best management practices (BMP) for meeting the new Environmental Protection Agency (EPA) effluent regulations.

System design

Researchers have studied system design and operation, such as fine solids removal and improved nitrification efficiency, especially at low ammonia concentration and low temperature.

Nitrification rates as a function of substrate concentration (total ammonia nitrogen (TAN) and organic carbon) have been measured for three types of biofilters (floating bead, submerged biocube, and fluidized) at 10°, 15°, and 20° C and at organic carbon to nitrogen (C/N) ratios of 0, 0.5, and 2.

Highlights of the study results follow:

1. The nitrification rate of all three types of biofilters increased linearly with TAN concentration up to 6 mg/L for all C/N ratios.
2. Organic carbon inhibited nitrification performance for all three biofilter types. As the C/N changed from 0 to 0.5, nitrification rates decreased dramatically, and as C/N changed from 0.5 to 2, the nitrification rate of the floating bead filter continued to decrease while the nitrification decrease was insignificant for the fluidized and submerged biocube filters.
3. When C/N=0, the floating bead filter had an areal nitrification rate of 12% and 50% higher than that of the fluidized filter and submerged biocube filter, respectively, but the difference among them became less significant with increasing organic carbon.

Researchers conclude that biofilters using media with a high specific surface area are particularly advantageous as they will have higher volumetric nitrification rates and can be more compact.

As a result of this work, a new three-phase filter, combining nitrification and fine solids removal, is being

developed. This biofilter should have advantages such as high nitrification rate, absence of clogging problems, improved mass transfer and oxygenation, and reduced maintenance and pumping needs.

Off-flavor removal

Off-flavor in recirculation systems may be caused by the presence of geosmin and 2-methylisoborneol (MIB), compounds that are produced by cyano-bacteria or actinomycetes. Saturation concentration of geosmin and MIB were determined to be under 10 nanograms (ng)/L.

Laboratory and on-farm tests of degassing, using a packed column, were carried out following a preliminary investigation of potential removal methods. The results of the tests indicate that significant reductions in geosmin and MIB concentrations in water may be achieved in a packed column when operated with a substantial ventilation rate. The information obtained can be used to estimate the necessary column height to achieve a given effluent concentration, or to estimate the mass of geosmin and MIB removed per-unit-time at a given flow rate and for a given influent concentration.

New EPA guidelines

On August 23, 2004, the EPA formally published the new guidelines for regulating aquaculture effluents. They cover private and public facilities that produce, hold, or maintain more than 100,000 pounds of aquatic animals during a year and that release effluents to US waters more than 30 days per year. This applies to flow-through systems, recirculating systems, and cage farms.

The most encouraging aspect of the new guidelines is that EPA has considered the public comments expressed when the preliminary regulations were released last year. The numerical limits that formed the basis of the preliminary regulations were dropped in favor of a Best Management Practices (BMP) scenario, letting producers devise and implement the scheme that will best allow an individual operation to meet the reduced effluent goals expressed in the guidelines.

In other words, each farm will be responsible for developing its own implementation plan, based on a published set of BMPs. The producer will keep a set of documents (BMP plan) that record how they are implementing a suite of practices to reduce solids discharges, eliminate chemical and pesticide spills and releases, and

report any releases of chemicals, pesticides, or excessive amounts of uneaten feed or animal wastes.

The individual BMP plan will also document how farm staff have been trained to implement the plan. The plan will also include documentation of number and weight of animals produced, amount of feed used, list of drugs and pesticides used, and frequency and maintenance of production and waste reduction equipment and facilities. The majority of these are records that well-operated farms maintain anyway, so the additional burden on farmers should be reasonable.

These criteria apply to virtually all commercial operations in the US West. Of interest to producers is the caveat that discharges to waters of farms that dispose of waste onto field crops so that there is no run-off to US water would be exempt. Farms that discharge for fewer than 30 days in an entire year would also be exempt. This might apply to very closed recirculating systems that release effluents less than once every two weeks.

WRAC programs to assist producers

WRAC has several research and extension programs designed to assist Western Region producers to meet these new guidelines, for both flow-through and recirculation systems. WRAC has supported research into reducing solid waste in effluents, reducing phosphorus discharges, improving filter design and operation (described on page 14), and detailing the benefits of aquaculture effluent use for field crop irrigation.

Some specific findings that will best assist producers to develop and implement their BMP Plans are as follows:

- Mechanical screen filters were ineffective for use on the main flow of raceway operations, but were effective to reduce solids discharges from the off-line settling basins.
- The standard rotating drum filter design was superior to the standard belt filter design.
- Models were developed and are available for use by producers to better design settling basins to achieve the maximum solid deposition given the available water volume, solids characteristics, and land area.
- Studies verified that rapid removal and deposition of feces and uneaten feed reduces the release of suspended solids, that phosphorus rapidly leached out of fecal pellets, and that rapid removal from the main

water flow was imperative to reduce total phosphorus and suspended solids loads.

- Biofilter studies in cool water determined that the C/N ratio of the effluent was critical to the efficiency of the biofiltration and that increased carbon content in the effluent stream reduced efficacy to a certain level after which higher carbon did not further degrade the process.
- Relatively low-cost gas stripping could be used to reduce geosmin and MIB levels about 75%, thereby reducing the opportunity for these off-flavor compounds to reduce the quality of edible fish.
- Use of aquaculture effluents on field crops was shown to provide economic and fertilization benefits to farmers, without causing any operational problems to cotton, barley, olive, and hydroponic vegetable farms.
- Details on research and applications, and additional information on BMPs for aquaculture, are available at http://ag.arizona.edu/azaqua/extension/BMPs/Final_EPA.html. ■



Courtesy of S. Chen

Laboratory set up for the packed column experiments.

US Trout Farmers Association Celebrates 50th Anniversary

Gary Fornshell, University of Idaho, Twin Falls County Extension

The US Trout Farmers Association (USTFA), the oldest aquaculture trade association in the United States, celebrated its 50th anniversary in Twin Falls, Idaho, on September 16–18. One hundred sixty-three participants from across the nation and as far away as Tasmania attended the conference and trade show.

Established in Denver, Colorado in 1954, the association's mission is to:

1. promote and advertise US trout and recreational trout fishing.
2. protect the interests of US trout farmers.
3. disseminate information to its members.

The three-day agenda was filled with fun, nostalgia, and useful information. Twenty speakers contributed to the program that included a mixture of national updates on current topics, such as the recently signed

Environmental Protection Agency (EPA) national rule on aquaculture effluents and the federal effort to develop a National Aquatic Animal Health Plan, and research programs in trout genetics and nutrition.

In addition, speakers addressed organic aquaculture, crop insurance, biosecurity, non-traditional markets for recreational trout, and verification of recommended practices for trout production. USTFA plans to post the Powerpoint presentations on its website in the near future (www.usdfa.org).

Of course, there was also lots of fun! Troutlodge, Inc., held its 60th birthday bash dinner Thursday night, which included the Blues Brothers Rock N' Soul Revue. Quite a few trout folks managed to get out on the dance floor to strut their stuff.

Friday night, USTFA hosted the awards banquet. Rebecca Cooper and Ken Cline of Cline Trout Farms, Inc., received the most prestigious award offered by USTFA, the Clark and Mimi White Award for distinguished lifelong service and dedication to the US trout industry.

In addition, an old tradition was revived: the Ugly Trout Farmer Award. Bob Blankenship of North Carolina, who was once arrested for being ugly in public, presided over the ceremony along with his apprentice, Jerry Zinn of Idaho. This year's Ugly Trout Farmer Award deservedly went to Charley Conklin, II of Big Brown Fish Hatchery, Inc.

A Special Award was given to Mary Lee, Executive Administrator of USTFA, for her dedicated service to the industry and USTFA.

The conference and trade show concluded Saturday with a tour of the Magic Valley and a fish fry.

The following sponsors contributed to the success of the anniversary celebration: Aqua Health, Ltd.; Clear Springs Foods, Inc.; Fresh-Flo Corporation; Hagerman Fish Culture Experiment Station; Idaho Aquaculture Association; Magic Valley Heli-Arc, Mfg.; Nelson & Sons, Inc.; Rangen, Inc.; The Hartford Live-stock Insurance; and Troutlodge, Inc. ■



Courtesy of B. Cooper and K. Cline

Rebecca Cooper and Ken Cline received the Clark and Mimi White Award for distinguished lifelong service and dedication to the US trout industry, the most prestigious award offered by the US Trout Farmers Association

Graham Young, New WRAC Director

Ken Chew, Professor Emeritus, School of Aquatic and Fishery Sciences, University of Washington

Dr. Graham Young's research contributions have led to a better understanding of fish reproductive physiology

On November 1, 2004, Dr. Graham Young came on board as executive director of the Western Region Aquaculture Center (WRAC) program. He replaces Dr. Ken Chew, who served as director through most of the years since WRAC was established in 1987. (Dr. William Hershberger—now director at the National Cool and Cold Water Center for Aquaculture in West Virginia—was director for two years in 1996–98 when Dr. Chew was interim director of the University of Washington [UW] School of Fisheries.)

Dr. Young received his BSc in 1975 and PhD in 1980 (Zoology) from the University of Sheffield in England. He did post-doctoral work in Japan and the US and then served as a visiting research professor at several academic/research institutions.

From 1989–2002, Dr. Young was a faculty member in the Department of Zoology at the University of Otago, New Zealand. In 2002, he moved to the United States and joined the faculty of the Department of Biological Sciences and Center for Reproductive Biology at the University of Idaho.

Dr. Young has conducted research in developmental, stress, and reproductive physiology and endocrinology of teleost fishes, particularly of salmonids but also of eels and marine species, at levels ranging from molecular to organismal. His contributions have led to a better understanding of fish physiology, which is relevant to problem solving in the finfish industry, and an important component of the UW School of Aquatic & Fishery Sciences' teaching program.

His previous research with an applied focus included studies on the parr-smolt transformation and the optimum time for transfer of smolt to seawater, assessing the aquaculture potential of several fish species in New Zealand, and methods for inducing or accelerating reproductive maturation in freshwater eels and salmonids.

His current research interests include egg recruitment and quality, and the mechanisms controlling the timing of puberty of fish. His



Penny Swanson

Dr. Graham Young's appointment is for 50% as Director of WRAC and 50% as Professor in the School of Aquatic & Fishery Sciences, University of Washington.

laboratory is undertaking USDA-funded research directed at understanding the relationship between growth and reproduction, and the mechanisms that determine fecundity.

At the School, he is developing a new core course in aquatic animal physiology. One goal of the new course is for students to develop an understanding of how knowledge of the physiology of aquatic animals forms the basis for addressing many problems in the cultivation of aquatic animals for commercial or conservation purposes.

Dr. Young will provide a close linkage between academia and the aquaculture industry so that research within the Western Region can be directed towards problem solving. He states, "I look forward to strengthening the interface between science funding agencies, researchers, and industry, and promoting the mission of WRAC."

Dr. Young can be reached by phone at 206-543-4291, and by email at GrahamY@u.washington.edu. ■

Farming of Geoduck Clams in Washington Becomes A Reality

Ken Chew, Professor Emeritus, School of Aquatic and Fishery Sciences, University of Washington

In the past three decades, culture of the giant geoduck clam (*Panopea abrupta*) has become a success, with positive economic outcomes.

Early emphasis was on getting hatchery seed for enhancement purposes and augmenting declining stocks for recreational digging on intertidal beaches. Responsibility for producing the seed clams for planting was given to the Point Whitney Hatchery at the Washington State Department of Fisheries and Wildlife (WDFW) Shellfish Laboratory at Hood Canal. Funding support was in part from the Washington State Department of Natural Resources (WDNR).

John H. Beattie, Point Whitney Hatchery manager at the time, said it was a real challenge to produce the seed without heavy mortalities. But slowly, techniques were developed and refined. By the late 1980s, the work was phased out due to lack of funding and because it was recognized that private commercial hatcheries were expanding their operations and research in these areas.

The geoduck market

In his article “Cashing in on geoducks,” (Aug. 21, 2004), *Seattle Post-Intelligence* reporter Colin McDonald noted that “in less than two decades, the wholesale price and market for geoducks has soared—from 50 cents a pound and fodder for Ivar’s famous clam chowder to a \$10-a-pound (wholesale live weight) delicacy flown to Asia.”

The potential market for geoducks was recognized about 20 years ago when Asian countries demonstrated great interest in this giant clam as a food delicacy. At that time, harvest was mainly from wild stocks.

Wild geoducks are found on the West Coast in harvestable quantities in Puget Sound, British Columbia, and southeast Alaska. They come from underwater tracts, which are measured out with estimated crop size. Harvest rights are auctioned off, with the winner paying a “stumpage fee.” WDNR collects nearly \$7 million a year auctioning off harvesting rights, making geoducks the agency’s most valuable fishery. Wild harvests are limited to a narrow band of tidal heights between –5 and –21 meters. They are harvested by commercial divers using water jets to fluidize the substrate surrounding the clams, which facilitates their removal.

WDNR was the principle manager of the geoduck resource until 1995, when the Puget Sound Tribes

became co-managers—a result of the Rafeedie federal court decision, which gave Tribes the rights to 50% of the wild shellfish resource in Puget Sound.

The WDNR/Puget Sound Tribes have set a 4.6-million-pound annual quota for wild harvest, with half designated for tribal harvest. This quota will apparently not be increased until a better understanding of the geoducks’ recovery rate is reached or more geoduck beds are certified as non-polluted by the Washington State Health Department.

Two major producers of seed in Washington are Taylor Shellfish Company Hatchery and Lummi Tribal Hatchery. Two of the largest producers of cultured or farm-reared 1½–2 pound geoducks are Taylor United and Seattle Shellfish. There are several other smaller farms in operation, which will add to farm production in the coming years.

Bill Taylor of Taylor Shellfish Company, located in southern Puget Sound, said that it takes about 5+ years for geoducks to reach 1½+ pounds when planted as seed in the lower intertidal zone. He said initially these clams were not easy to cultivate. They hadn’t been grown in commercial quantities before, only on an experimental basis. According to Taylor, for several years, the company was spending \$750,000 a year for geoduck operations, knowing that others had tried without success.

For Taylor’s company, the money was well spent. The first harvest in 2002 and subsequent crops have proven successful. Taylor noted that there are about 90 acres of privately owned tidelands being used for geoduck farming, and more permit requests are in the pipeline. In addition, his company has been able to negotiate with some private beachowners to use their tidelands to culture geoducks. When harvest is made, the beachowner receives a percentage on the total harvest wholesale value.

Recent research

Regulatory agencies are concerned about the impacts of geoduck stocks moving undetected from one bay to the next through outplanting of hatchery-produced seed. This concern has led to studies funded through Washington Sea Grant to develop a basic understanding of the genetic makeup of geoduck populations—especially to detect if there are major genetic differences in stocks in various bays and inlets throughout the Puget Sound area and British Columbia.

Brent Vadopalas, a researcher at the School of Aquatic and Fishery Sciences (SAFS) at the University of Washington (UW), has been conducting genetic and population studies of geoducks for five years. According to him, identification of genetic variability and stock structure in wild geoduck populations is a prerequisite for monitoring genetic change to wild populations.

He and Paul Bentzen (presently at Dalhousie University, Nova Scotia) from the UW and Jim Shaklee and Larry LeClair of WDFW examined population differentiation among collections from sites in the Strait of Juan de Fuca–Georgia Strait–Puget Sound complex. They analyzed 1,645 specimens from 17 locations, which revealed a pattern of apparent genetic homogeneity with statistically significant differences interspersed among a minority of collections. Vadopalas said, “The neutral genetic differences detected within Puget Sound do not appear related to reproductive isolation or lack of gene flow, but more work is needed to address whether adaptive differences exist.”

Vadopalas noted that he and Jonathan Davis, a researcher at the Taylor Shellfish Research Hatchery have developed triploid (sterile) induction techniques for geoducks with a 95% success rate. They are investigating whether triploidy confers sterility and/or a growth advantage. Growing sterile geoduck to market size and harvest would minimize the concern that wild and cultivated stocks would cross in the natural environment.

Several researchers have been studying the age and growth of geoducks. José “Lobo” Orensanz (researcher, presently in Argentina), while still at SAFS, conducted analyses of geoduck age frequencies that showed declining recruitment through the 1970s and early 1980s. Based on WDFW recovery plots, Orensanz found that Puget Sound geoduck populations fall into two general groupings of recovery trends—fast and slow.

SAFS graduate student Juan Valero is building on this work, using large sets of contemporary age-frequency data. He is working to model the population dynamics of geoducks. It appears he has found a regional correlation between sea surface temperatures and recruitment, and a reversal of the declining trend through the 1970s, suggesting that geoduck recruitment appears episodic, and is currently on the upswing.

This was in alignment with earlier work by another graduate student, Are Strom. He refined reliable age

estimation for geoduck clams and described their shell growth and sea temperature as correlated, similar to tree rings. Graduate student support for geoduck research at SAFS comes from the William H. Pierre, Sr., the Roy Jensen, and the Claire L. and Evelyn S. Egtvedt fellowships .

Vadopalas said that the atomic bomb tests in the 1950s and 1960s produced a dramatic increase in atmospheric radiocarbon (^{14}C) that was then reflected circum-globally in dissolved inorganic carbon (DIC) in marine waters, and incorporated as calcium carbonate in the shells of bivalves.

This increase provides a precise marker for age verification in species with longevity that span the bomb period. To verify that growth lines in the shell are deposited annually, he and Chris Weidman of Woods Hole Oceanographic Institute microsampled thin sections of shell and used accelerated mass spectrometry to compare ^{14}C levels in geoducks with putative birth years spanning the atomic bomb testing period, and found evidence that growth rings in geoduck clams are deposited annually throughout their life history, and that age estimates based on growth ring counts are valid.

Expanding geoduck farming in Washington and current research efforts to better understand the life history and genetics of this giant clam suggest that this culture fishery will continue to advance and grow. ■



Ken Chew

Brent Vadopalas preparing to amplify geoduck microsatellite DNA to obtain individual genotypes

naa news

Coastal meetings

Fish Farming News, July–August, 2004

In the span of about six months, directors of the NAA (National Aquaculture Association) met in two locations that define the eastern and westernmost reaches of the US domestic aquaculture industry. In March, the all-volunteer NAA board held its annual meeting in conjunction with the Aquaculture '04 conference and trade show in Honolulu, Hawaii. Then, in August, the board traveled to coastal Maine for the association's mid-year meeting, representing about a 6,000 mile spread between the two sessions.

While in Maine, NAA directors were able to get a first-hand look at a coastal Atlantic salmon farming operation. Erick Swanson of Trumpet Island Aquaculture gave the NAA directors a personal tour of his farm site. The tour was co-guided by Sebastian Belle, executive director of the Maine Aquaculture Association, who used the farm visit to give directors a better sense of many of the issues confronting US salmon farmers.

Rainy, foggy, cool weather that had been the pattern for much of July and August along the downeast coast failed to dampen the spirits of NAA directors who faced a busy work agenda with limited time to take in regional attractions.

A jam-packed business meeting dominated directors' time during the August 20–21 gathering. After running through a review of the NAA's finances and setting a proposed budget for 2005, directors heard committee reports on a variety of topics, including aquatic animal health, environmental issues, bird depredation, and research and development.

NAA President Randy MacMillan of Clear Springs Foods presided. He was surprised at one point with an impromptu presentation by NAA Executive Director Betsy Hart, honoring him for his many months of hard work on the Minor Use Minor Species (MUMS) legislation. The MUMS bill was passed and signed into law in early August.

MacMillan provided the board with both a quick summary of the process, plus a sense of what might lie ahead for the industry in the form of benefits made possible by the MUMS legislation.

Directors also heard industry updates on antibiotic resistance issues, the EPA aquaculture effluent guidelines, country of origin labeling (COOL), and a presentation from Dr. Valerie Rag of USDA /APHIS on the national animal identification program. ■

This past year

Email from NAA, November 17, 2004

This past year, NAA was successful in getting the Minor Use Minor Species (MUMS) legislation passed and signed into law, and navigating through the rule-making process, to minimize the economic impact of the US Environmental Protection Agency Effluent Guidelines.

NAA continues to work with federal agencies, striving to ensure that federal programs actually enhance the prospects of successful domestic aquaculture rather than create obstacles. For example, the NAA is working closely with the US Department of Agriculture's Animal and Plant Health Inspection Service (USDA-APHIS) to ensure the development of a national aquatic animal health management program that assists aquaculture's efforts and meets its needs.

NAA is also working with USDA-APHIS to help determine whether any aquaculture industry sectors could benefit from a national animal identification program (as those being developed for many terrestrial animal industries).

NAA maintains active involvement in programs dealing with offshore aquaculture development, aquatic nuisance and invasive species, and bird depredations.

NAA has also partnered with other groups to better educate US consumers about domestic aquaculture product safety and its environmental stewardship.

NAA continues to organize producer sessions and co-sponsor Aquaculture America conferences. ■

Publications



Online

<http://aquanic.org>

AquaNic.

The Aquaculture Network Information Center is an excellent clearing house of aquaculture information (publications, newsletters, calendar of events, news, and jobs).

<http://was.org>

World Aquaculture Society.

WAS plays an important role in assuring the development of aquaculture by meeting the increased global demand for science based information and technology.

<http://www.aquanet.com>

Aquatic Network—Information Service for the Aquatic World.

Excellent resource. Subject areas include aquaculture, conservation, fisheries, marine science and oceanography, maritime heritage, ocean engineering, and seafood. The Grants and Funding Sources section includes worldwide sources of grants and finding.

<http://www.aquaculturemag.com>

Aquaculture Magazine.

Includes feature articles from the magazine, articles by columnists, Aquaculture Outlook, a back issue list, and a good deal of other information.

<http://www.nsgo.seagrant.org>

National Sea Grant College Program.

The National Sea Grant College Program is a network of roughly 30 constituent programs, funded through the National Oceanographic and Atmospheric Administration of the US Department of Commerce. Collectively and individually, Sea Grant partners fund scientific research, publish educational materials, and assist the aquaculture industry through technology transfer, applied research, and educational programs. In most states, Sea Grant is a close partner of Cooperative Extension, thus bringing the resources of two national programs to bear on industry issues.

<http://www.csrees.usda.gov>

USDA Cooperative Extension. Cooperative Extension is a nationwide educational network, connected through the US Department of Agriculture and Land Grant Universities. Many states have staff members with duties and expertise in aquaculture involved in activities ranging from applied research to workshops, seminars, and technology transfer.

<http://dirs.org/dir-wiki.cfm./Top/Science/Agriculture/Animals>

The world's top animal websites.

The world's top websites listed in the Yahoo, Google, LookSmart, Alexa, About, World's Biggest, TopSites, Encyclopedic and YellowPages directories.

<http://www.lib.utexas.edu/msl/marres.html>

Marine Science Library Resources.

Marine-related websites (aquaculture, fish, oceanography, etc.). A comprehensive bibliography of aquaculture publications.

Awards



Ken Chew

Fred Conte (right) receives award for his outstanding extension and outreach services to the United States and WRAC. The award was presented by Meryl Broussard on behalf of CSREES, USDA.

Calendar



March

13–15 **International Boston Seafood Show**
 Boston, Massachusetts
 phone: 207/842-5500
 fax: 207/842-5503
 email: food@divcom.com
 web: www.bostonseafood.com/

13–16 **IFE 2005, International Food & Drink Exhibition**
 London, UK
 email: ife@freshrm.co.uk
 web: <http://www.ife.co.uk/>

24–26 **2nd National Fisheries Management Conference: Managing Our Nation's Fisheries II —Focus on the Future**
 Washington, DC
 web: www.managingfisheries.org

April

10–14 **National Shellfisheries Association 97th Annual Meeting**
 Philadelphia, PA
 Dee Kreeger or Gary Wikfors
 Academy of Natural Sciences
 1900 Ben Franklin Parkway
 Philadelphia, PA 19103
 phone: 215-299-1184
 fax: 215-299-1079
 email: kreeger@acnatsci.org

14–16 **Agadir Fish Morocco 2005**
 Agadir, Morocco
 web: www.agadirfishmorocco.com/

18–21 **The Fabulous Four**
 Dubai, United Arab Emirates
 web: www.mediaccom.com/

19–20 **Symposium on Invasive Species: Their Ecological Impacts and Alternatives for Control**
 Reno, Nevada
 web: astm.org/cgi-bin/SoftCart.exe/index.shtml?E+mystore

20–26 **15th International Pectinid Workshop**
 Queensland, Australia
 Mike Dredge
 email: flatcalm@ozemail.com.au
 or Peter Duncan
 email: pduncan@usc.edu.au

May

9–13 **World Aquaculture 2005**
 Nusa Dua Beach, Bali, Indonesia
 Conference Manager
 2423 Fallbrook Place, Escondido, CA 92027
 phone: 760-432-4270
 fax: 760-432-4275
 email: worldaqua@aol.com
 web: www.was.org

June

6–8 **East Coast Trout Culture and Management Workshop IV**
 Lock Haven, PA
 Contact: Larry Moahn
 Phone: 540-248-9360
 email: Larry.Mohn@dgif.virginia.gov

7–12 **7th International Marine Biotechnology Conference (IMBC 2005)**
 St. John's, Newfoundland and Labrador, Canada
 web: www.imbc2005.org/

10–12 **5th Mediterranean Conference & exhibition on Fisheries and Aquaculture**
 Athens, Greece
 Contact: Europartners
 phone: +30 210 92 21 254
 email: info@europartners.gr

15–17 **Seafood Russia 2005**
 Moscow, Russia
 email: jon.irwin@informa.co

July

11–14 **29th ANnual larval Fish Conference**
 Barcelona, Spain
 web: www.larvalfishcon.org

August

5–9 **Aquaculture Europe 2005: lessons from the Past to Optimize the Future**
 Trondheim, Norway
 web: www.easonline.org

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