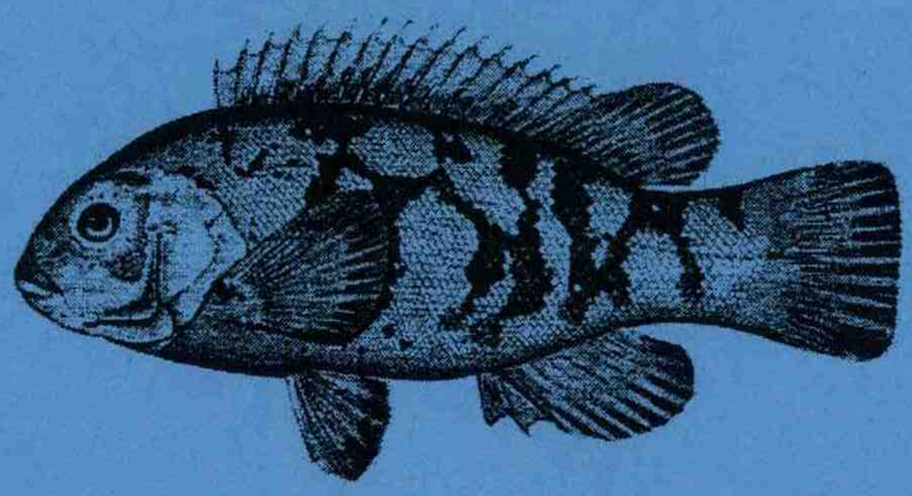
19th MILFORD AQUACULTURE SEMINAR

FEBRUARY 22-24, 1999



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Program Agenda
19th Milford Aquaculture Seminar
February 22-24,1999
Quality Inn Conference Center
New Haven, CT

Monday, February 22, 1999

7:00 - 10:00 pm POSTERS Washington North

P. 1	A comparison of CHROMagar *E. coli,* Millipore Coli-Count Samplers, and the MPN procedure for enumeration of coliforms in bay scallops	Diane Kapareiko NMFS Milford CT
P. 2	Methodology for the generation of polymorphic molecular tags in the bay scallop, *Argopecten irradians*	Maronda Brown UCONN Storrs CT
P. 3	Growth and survival of juvenile bay scallops from genetic lines at different densities and depths: Collaborative study between the NMFS and Bridgeport Aquaculture School	Joseph Choromanski NMFS Milford CT
P. 4	Investigation of genetic variation in populations of *Scapharca broughtonii* and *Tegillarca granosa.*	Ziniu Yu Ocean University Qingdao China
P. 5	Aquatic animal health and UCONN aquaculture program: New faculty and opportunities	Richard French UCONN Storrs CT
P. 6	The inverted propeller-beanie--a new way to mix large microalgal tanks	Mark Dixon NMFS Milford CT
P. 7	Australian/Tasmanian oyster culture	Harriette Phelps Univ. of DC Washington DC
P. 8	Utilization of semipurified diets by tautog, *Tautoga onitis*	Laurel Ramseyer NMFS Milford CT

P. 9	Feeding studies on juvenile tautog, two experiments: Weaning juvenile tautog to an artificial diet and effects of feeding frequency on growth of juvenile tautog	Steve Yankocy URI Kingston RI
P. 10	The effects of stocking density of larval tautog	Lindsay Lydon URI Kingston RI
P. 11	Effects of photoperiod on survival, growth and pigmentation of summer flounder (*Paralichthys dentatus*) larvae in laboratory culture	Marina Huber URI Kingston RI
P. 12	Post-metamorphic growth of summer flounder in laboratory culture: Do early-settling larvae grow faster than late settlers?	Tessa Simlick URI Kingston RI

<u>Tuesday, February 23, 1999</u>		Washington South
8:50 a.m.	INTRODUCTION	Walter Blogoslawski
9:00 a.m. P. 13	*Vibrio parahaemolyticus* and other shellfish diseases of public health significance: A review	Richard French UCONN Storrs CT
9:20 a.m. P. 14	*Vibrio parahaemolyticus* - a new problem for the shellfish industry in the northeast	David Relyea F.M. Flower, Inc. Oyster Bay NY
9:40 a.m. P. 15	*Vibrio parahaemolyticus* - a new challenge for state shellfish control agencies	William Hastback NYDEC E. Setauket NY
9:55 a.m. P. 16	A comparison of anticlumping solutions used for initial recovery of hemocytes from the bay scallop, *Argopecten irradians*	Steven Pitchford NMFS Milford CT
10:05 a.m.	COFFEE BREAK - POSTERS	Washington North
10:20 a.m. P. 17	The presence of *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (DERMO) in *Crassostrea virginica* along the Connecticut and northern Long Island shoreline in 1998 - An extensive survey	John Karolus State Conn. Aqua. Div. Milford CT
10:40 a.m. P. 18	Disease-resistant oysters, *Crassostrea virginica*, in Long Island Sound	Inke Sunila State Conn. Aqua. Div. Milford CT
11:00 a.m. P. 19	Histopathological survey of the quahog, *Mercenaria mercenaria*, along the Connecticut coastline	Joseph DeCrescenzo State Conn. Aqua. Div. Milford CT
11:20 a.m. P. 20	The effect of density on growth of *Argopecten irradians* in Long Island Sound: In partnership with NMFS scientists	Sherry Lonergan Bpt. Reg. Aqua. School Bridgeport CT
12:00 NOON	LUNCHEON	Washington South
1:30 p.m. P. 21	An overview of aquaculture research in Atlantic Canada	Shawn Robinson Fisheries & Oceans St. Andrews NB Canada

2:15 p.m. P. 23	NOAA fisheries and aquaculture	Edwin Rhodes NMFS Washington DC
2:40 p.m. P. 24	Wampanoag shellfish aquaculture	David Grunden Island Aquaculture Oak Bluffs MA
2:55 p.m. P. 25	Developments in the private aquaculture industry on Martha's Vineyard	Richard Karney MVSG Oak Bluffs MA
3:15 p.m.	SODA BREAK - POSTERS	Washington North
3:30 p.m. P. 26	Control of eutrophication by bivalves: Filtration of particulates and removal of nitrogen through harvest of rapidly growing stocks	Michael Rice URI Kingston RI
3:50 p.m. P. 27	Feeding rations and regimes for post-set oysters, *Crassostrea virginica,* fed cultured microalgae in a land-based nursery	Gary Wikfors NMFS Milford CT
4:15 p.m. P. 28	Fertilization rates and procedures using commercial "f/2" nutrient mixes to grow T-ISO (*Isochrysis sp.*) and PLY429 *Tetraselmis chui*	Barry Smith NMFS Milford CT
4:30 p.m. P. 29	Reflections on biofilter selection for shellfish culture	James Widman NMFS Milford CT
4:50 p.m. P. 30	Experimental testing of field techniques for farming the softshell clam (*Mya arenaria*)	Kenneth LaValley Spinney Creek Eliot ME
5:15 p.m. P. 31	The economics of sea scallop grow-out: Aquaculture at an offshore site	Porter Hoagland WHOI Woods Hole MA
6:00 p.m.	DINNER	Washington South
7:00 p.m.	*V. parahaemolyticus* ROUNDTABLE DISCUSSION	Washington South

<u>Wednesday, February 24, 1999</u>		Washington South
9:00 a.m.	INTRODUCTION	Walter Blogoslawski
9:10 a.m. P. 33	A tour of upwellers on Cape Cod	Dale Leavitt SE MASS Aqua. Center Buzzards Bay MA
9:25 a.m. P. 34	Growth characteristics in triploid Pacific oysters - A new dimension	Brenda Landau Haskin Shellfish Res. Port Norris NJ
9:50 a.m. P. 35	Superior growth as a general feature of triploid shellfish: Evidence and possible causes	Ximing Guo Haskin Shellfish Res. Port Norris NJ
10:15 a.m.	COFFEE BREAK - POSTER REMOVAL	Washington North
10:30 a.m. P. 36	A social and economic evaluation of an oyster mariculture training program for Long Island commercial fishermen	Steven Lang CUNY Jamaica NY
10:55 a.m. P. 37	The transition from commercial fishing to oyster culture: Results of a NMFS Fishing Industry Grants project	Richard Langan UNH Durham NH
11:20 a.m. P. 38	Progress in bioeconomic evaluation of the Milford Laboratory scallop nursery recirculating system	Gisele Magnusson Env. and Nat. Res. URI Kingston RI
11:40 a.m. P. 39	Recent streamlining of the aquaculture regulatory process	Michael Ludwig NMFS Milford CT
12:00 NOON	LUNCHEON	Washington South
1:30 p.m. P. 40	Early induction of spawning of a captive tautog broodstock by light and photoperiod manipulation	Grace Klein-MacPhee URI Kingston RI
2:00 p.m. P. 41	Summer flounder culture in the Northeast: Update on recent research and industry status	Gregg Rivara Cornell Coop Ext. Southold NY

2:30 p.m. P. 42	The potential for bivalve aquaculture in Maryland's coastal bays	Mark Homer MD-DNR Annapolis MD
3:00 p.m. P. 43	Updating the plans for sea scallop aquaculture in Massachusetts	Harlyn Halvorson UMASS Boston MA
3:30 p.m. P. 44	The need for aquaculture in the world today	Robert Link Liquid Life Tech. Islandia NY
4:00 p.m.	Fruit Break and Concluding Remarks	Walter Blogoslawski

A COMPARISON OF CHROMOMAGAR *E. COLI*, MILLIPORE COLI-COUNT SAMPLERS, AND THE MPN PROCEDURE FOR ENUMERATION OF COLIFORMS IN BAY SCALLOPS. **Diane Kapareiko** and **Richard A. Robohm**, USDOC, NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT 06460

Little information exists on whether bay scallops are capable of harboring microorganisms of human health significance. To assure a safe product resulting from our bay scallop aquaculture development activities, we are interested in surveying bay scallops for the presence of fecal coliforms (human health indicator organisms). The recommended procedure for coliform detection, the MPN procedure, requires a relatively large expenditure of time, labor and materials. Two recently-developed products, CHROMagar E. coli™ , and Millipore Coli-Count Samplers™, appear to be simpler to apply for detection of coliform bacteria.

CHROMagar E. coli, a chromogenic plate medium, expedites the identification of Escherichia coli on the basis of contrasting colony colors. Millipore Coli-Count Samplers combine a grid-marked, 0.45 um Millipore membrane filter over a nutrient pad, which facilitates growth. Microorganisms present in the sample being tested affix to the filter pad and are cultured within its plastic case. Both products contain a chromogenic substance which reacts with genus or species-specific enzymes to produce a blue colony color for fecal coliforms. Other gram-negative bacteria remain colorless.

We tested both of these products for their accuracy in enumerating in comparison with the traditional MPN method. Aliquots of bay scallop homogenate were "seeded" in blender jars with three individual doses of a pure culture of *E. coli*; this consisted of a low dose (mean colony count = 1.8667×10^2/ml), a medium dose (mean colony count = 1.8667×10^4/ml), and a high dose (mean colony count = 1.8667×10^5/ml). A fourth aliquot of scallop homogenate was not seeded in order to provide colony count information on possible pre-existing levels of E. coli. The number of organisms recovered from each dose was enumerated using the MPN procedure, CHROMagar E. coli and Millipore Coli-Count Samplers simultaneously; the experiment was repeated for a total of three trials. Individual counts were expressed as the ratio of the number of *E. coli* recovered (minus the background count of) divided by the dose administered(colonies/ml).

Ratios resulting from CHROMagar E. coli and Millipore Coli-Count Sampler counts for each dose were normally distributed. One-way ANOVA testing indicated no significant differences between the means of these ratios for each technique at the $p = 0.05$ level of significance ($p = 0.3808$ for low dose, $p = 0.9368$ for medium dose, $p = 0.1450$ for high dose). Further results and conclusions, as well as graphics depicting the comparison of these two products to the results using the MPN procedure will be presented in the poster.

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METHODOLOGY FOR THE GENERATION OF POLYMORPHIC MOLECULAR TAGS IN THE BAY SCALLOP, *Argopecten irradians*. **Jeff Southworth, Maronda Brown** and **Linda Strausbaugh**, Department of Molecular & Cellular Biology, University of Connecticut, Storrs, CT 06269; **Sheila Stiles**, USDOC, NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT 06460

Several promising species for aquaculture lack genetic and morphological markers. Consequently, there is a critical need for the development of physical and genetic tags for monitoring and identifying brood stocks. We are examining methods to differentiate bay scallop populations (*Argopecten irradians*) at the genotypic level using Type I and Type II markers. We have chosen to investigate the potential of a Polymerase Chain Reaction (PCR), and Random Amplification of Polymorphic DNA (RAPD) [similar to DNA Fingerprinting (DAF)] or Arbitrarily Primed PCR {AP-PCR } techniques.

We have examined levels of polymorphism within and among 5 populations of bay scallops collected from the United States northeast coast. Approximately twenty PCR primers were analyzed for their effectiveness at revealing polymorphisms among individuals and populations of this marine organism. A significant amount of time was spent optimizing the primers and the PCR conditions to obtain clearer, more consistent results. We have determined that there is a high degree of polymorphism at the level of individual organism genotype. In addition, RAPD analysis is reliable and reproducible, as well as extremely sensitive. In a complementary approach we have selected coding regions that might provide species and/or strain-specific markers as well as promoters for genetic engineering applications. Additional investigations include the design of core histone gene primers from both *Drosophila melanogaster* and *Strongylocentrotus purpuratus* to screen a genomic library of *Argopecten irradians*. Development of molecular tags can provide a screen for genetic diversity, ultimately circumventing inbreeding depression.

GROWTH AND SURVIVAL OF JUVENILE BAY SCALLOPS FROM GENETIC LINES AT DIFFERENT DENSITIES AND DEPTHS: COLLABORATIVE STUDY BETWEEN THE NATIONAL MARINE FISHERIES SERVICE AND THE BRIDGEPORT AQUACULTURE SCHOOL. **Joseph Choromanski, Sheila Stiles, Christopher Cooper**, and **Eric Bedan**, USDOC, NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT 06460; **Sherry Lonergan** and **Paul Trupp**, Bridgeport Regional Vocational Aquaculture School, 60 St. Stephens Road, Bridgeport, CT 06605

Hatchery-reared juvenile scallops were being field-tested to evaluate growth and survival of genetic lines of bay scallops (*Argopecten irradians*) in western Long Island Sound. Students and staff from the Bridgeport Regional Vocational Aquaculture School cooperated with scientists at the Milford National Marine Fisheries Service Laboratory in these collaborative grow-out studies. In May 1998, Milford scientists provided a total of five-thousand scallops from different genetic lines for the students to use in their project. The lines used were large- and small-selected. The scallops were counted, measured, and their total volume determined. They then were divided into groups containing varying numbers of scallops to determine effects of density. Chinese lantern nets and Japanese lantern and pearl nets were deployed off Bridgeport/Fairfield near Penfield Reef in Long Island Sound. Nets were suspended from a floating longline to a depth of approximately three meters. A second set of scallops was counted and measured, then placed in lantern nets anchored to the bottom (ten meters at high tide) and buoyed up into the water column to a height of two meters, to serve as comparisons for nets suspended from longlines.

Counts and measurements were made approximately midway through the experiment. Nets were heavily fouled with seaweed and tunicates. However, overall survival was high. Growth was not exceptional, which was presumed attributable to rather heavy current and wave action. A severe storm, which occurred in the area in July, loosened an anchor mooring and resulted in the loss of some of the nets. A videotape and visual inspection was made by NMFS divers to assess conditions and damage which had been caused by the storm. The final phase of this particular experiment ended in November when the nets were retrieved and evaluated. One longline net from the comparative depth study was lost, while both bottom nets survived intact. Initial observations showed slightly better growth from the bottom nets, while survival was comparable.

This longline project was a unique opportunity for several reasons. While the final results of this first year may be preliminary, invaluable logistical experience in longline aquaculture was attained for the staff of the lab and the school; this will be used in planning future projects. The mutually beneficial experiment provided both valuable assistance for the NMFS scientists, and a learning experience for the students to become familiar with tools and protocols used in measuring the scallops in particular, as well as "hands-on" exposure to aquaculture in general.

INVESTIGATION OF GENETIC VARIATION IN POPULATIONS OF *Scapharca broughtonii* AND *Tegillarca granosa*. **Ziniu Yu**, College of Fisheries, Ocean University of Qingdao, 5 Yushan Road, Qingdao 266003 P. R. China

Scapharca broughtonii and *Tegillarca granosa* are two blood cockle species of economical importance along coastal waters of China. In recent years, however, they have suffered heavy mortalities, and their wild stocks and genetic diversity have been threatened to some extent due to over-fishing and changes of ecological environment. The allozyme variation in four populations of *S. broughtonii* and three populations of *T. granosa* were investigated using horizontal starch gel electrophoresis.

The mean heterozygosity (Ho) were 0.123(0.038 for Dalian (DL), 0.105(0.023 for Qingdao (QD), 0.091(0.031 for Korea Pusan (KP) and 0.087(0.024 for Qinghuangdao (QH) populations of *S. broughtonii*, and 0.097(0.034 for Wenzhou, (WN), 0.068(0.026 for Qingdao (QN) and 0.062(0.031 for Rongcheng (RN) populations of *T. granosa*. The mean effective number of alleles were 1.415(0.150 for QD, 1.398(0.102 for DL, 1.253(0.084 for KP and 1.230(0.046 for QH populations of *S. broughtonii*, and 1.409(0.275 for RN, 1.407(0.192 for WN and 1.301 (0.142 for QN populations of *T. granosa)*. For *S. broughtonii*, the highest genetic similarity was between DL and QH populations, and the next highest was between DL and QD populations. There was obvious genetic differentiation and a barrier of gene flow between those three populations and the KP population. Morphological measurement also showed differences between the three Chinese populations and the KP population. It is possible that the KP population of *S. broughtonii* is in the process of subspecies formation where apparent genetic differentiation has occurred. Similarly, for *T. granosa*, there was a relatively close relation between QN and RN populations, and there was genetic divergence to some extent between QN, RN and WN populations. In addition, general heterozygote deficiency evidently existed at most polymorphic loci in populations of two species. The heterozygote deficiency index (D) ranged from 0.535 to 0.423 in *S. broughtonii*, and 0.303 to 0.396 in *T. granosa*. The reasons for heterozygote deficiency are discussed.

AQUATIC ANIMAL HEALTH AND UCONN AQUACULTURE PROGRAM: NEW FACULTY AND OPPORTUNITIES. Richard A. French, Salvatore Frasca, Jr., Sylvain De Guise, and **Herbert J. Van Kruiningen,** University of Connecticut, Department of Pathobiology, Northeastern Research Center for Wildlife Diseases, 61 North Eagleville Road, Storrs, CT 06269

The State of Connecticut has made a substantial investment in aquaculture industries and teaching aquaculture science. In April 1989, the Connecticut State Board of Education approved a request by the Bridgeport Board of Education to create a Regional Vocational Aquaculture School. The state appropriated 7.5 million dollars for the construction of the first of these schools, the Bridgeport Regional Vocational Aquaculture School. In 1994, the State Board of Education established the Sound School Regional Vocational Aquaculture Center in New Haven. Both institutions provide high school students with specialized laboratories and classrooms that complement a marine science-related curriculum. Facilities at these centers include pathology laboratories, aquaculture tanks to grow finfish and shellfish, indoor boat shops, marine engine laboratories, and computer-assisted drafting laboratories.

The University of Connecticut has made a commitment to develop an undergraduate teaching program in aquaculture science, which is embodied in the formulation of a multidisciplinary aquaculture minor, including courses from the College of Agriculture and Natural Resources and the College of Liberal Arts and Science. The contribution of the Department of Pathobiology to this multidisciplinary aquaculture minor will be didactic and active teaching in the field of aquatic animal health (e.g. preventive medicine, disease recognition and treatment, mechanisms of disease, health surveillance). To this end, the University has hired three new veterinary research faculty in the Department of Pathobiology; Dr. Sylvain De Guise, Dr. Salvatore Frasca, and Dr. Richard French, and added an undergraduate course entitled, "Systemic Finfish and Shellfish Pathology and Microbiology," to be offered in Spring Semester 2000.

The aquaculture science program is affiliated with regional aquaria, fisheries, and professionals (Mystic Aquarium, The Maritime Aquarium, The Connecticut Department of Agriculture, Bureau of Aquaculture and Laboratory, and private industry), providing active instruction and cooperative training opportunities to students. In addition, a state-of-the-art Marine Science and Technology Center facility is under construction at the University of Connecticut Avery Point Campus, which will offer unique educational prospects to undergraduate and graduate students. The Connecticut Veterinary Diagnostic Laboratory, which provides autopsy service for state and private concerns, will expand and support the accession of numerous aquatic animal cases directed toward a primary teaching, diagnostics and research initiative. The Department of Pathobiology offers a Bachelor of Science undergraduate degree, and Master of Science and Doctor of Philosophy graduate degrees. Graduate students in Pathobiology may specialize in Pathology, Microbiology, Virology, Immunology, Clinical Chemistry, Avian and Aquatic Animal Pathology, and Wildlife Diseases. Regarding aquatic animal health, ongoing research includes studies of marine mammals, marine and freshwater finfish, and shellfish. Interested students should contact the University of Connecticut, Department of Pathobiology, 61 North Eagleville Road, Storrs, CT 06269, 860-486-3736 or visit our web site at http://www.lib.uconn.edu/CANR/patho/index.html

THE INVERTED PROPELLER-BEANIE...A NEW WAY TO MIX LARGE MICROALGAL TANKS. **Mark S. Dixon, Barry C. Smith,** and **Gary H. Wikfors,** USDOC, NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT 06460

Large-scale open microalgal cultures can be viewed as bioreactors; they are defined as "stirred reactors" by chemical engineers. Energy must be supplied to the system, nutrients added at a rate equal to their use, wastes removed as they are generated, and cells must be exposed to the reactive surface (the culture/air interface). The Greenhouse for Research on Algal Mass Production Systems (GRAMPS) at the National Marine Fisheries Service Laboratory in Milford, Connecticut houses two 20,000 liter oval (5.5m x 3m x 1.2m) fiberglass tanks used for the production of large volumes of microalgae to feed post-set shellfish in a land-based nursery. Three stirring methods were considered for GRAMPS production tanks: 1) air mixing, 2) manual stirring with paddles, 3) mechanical stirring with a motorized device. Air mixing was rejected based upon previous experience showing that bubbles in dense, open microalgal suspensions encourage bacterial growth. The benefit of constant mixing by mechanical means needed to be established before investment in equipment and its operation could be justified. Paddle-wheel mixers have been used in other large-scale microalgal production systems, but all are custom made and too expensive for routine application. In many industrial processes, tanks of reactants are stirred by a foil on a shaft, driven by a motor - essentially an inverted propeller beanie.

The recent addition of a propeller style mechanical mixer to one of the large tanks provided an opportunity for comparison with previous tank cultures which required regular manual mixing via a muscle-powered paddle. The reality of occasional hand mixing is a poorly-mixed culture which can only be maintained at relatively shallow depths. Reduced culture volumes, settling cells, and unequal exposure of cells to light all reduce the productivity of a culture. By contrast, a tank culture which is mixed continually allows all cells to be on the lighted, reactive surface on a calculated regular interval controlled by varying the speed of the propeller, thereby providing all cells access to light for photosynthesis and the culture/air interface for gas exchange many times during the day.

A culture of *Tetraselmis chui* (PLY429) has been maintained in the mechanically-mixed tank for the past 6 months using semi-continuous management. The mechanically-mixed tank was operated at a maximum depth of 1.1 meters or approximately 18,000 liters. Maximum operation depths for the hand-mixed tanks were less than 0.4 meters or approximately 6,000 liters. Cell densities in the mechanically-mixed tank often exceed 1×10^6 cells/ml, while hand-mixed tanks average approximately 1×10^5 cells/ml. Mechanically-mixed tanks are much longer lived than hand-mixed tanks under a semi-continuous harvest strategy; 6 months versus 6 weeks.

Higher productivity, greater culture volumes, a superior algal product, long lived cultures, and reduced maintenance are all benefits of mechanically-mixed, large-scale microalgal cultures. Economic analysis and evaluation of performance of the mixer as it is integrated into the overall automation of GRAMPS are planned for later this year.

AUSTRALIAN/TASMANIAN OYSTER CULTURE. Harriette L. Phelps, University of the District of Columbia, Biology Department, 4200 Connecticut Ave., N.W., Washington, DC 20008

In Australia, the two main cultured oyster species are the Sydney Rock Oyster (*Saccostrea commercialis*) and the Japanese Oyster (*Crassostrea gigas*). The Sydney Rock Oyster is presently cultured mostly in a few estuaries near Sydney and although the Japanese Oyster is found in some of those estuaries, the oyster farmers consider *C. gigas* highly detrimental because of competition for space from its earlier settlement pattern and faster growth.

The majority of commercial oysters are *C. gigas* spawned and grown in Southern Australia and the island of Tasmania. Tasmania is lightly settled and has numerous shallow estuaries with clean water mostly on the east coast and used for aquaculture. Presently, the oyster farmers send seed oysters for spawning to the oyster hatchery at Bicheno. The seed oysters are conditioned, spawned together, and the larvae raised in large tanks with some cultured algae addition. The oyster larvae set and transform on finely ground scallop shell added to the tanks. The young cultchless spat are returned to the farmers and reared in upwellers until transferred to bags set on trays in the shallow estuaries. The oysters are transferred to larger mesh bags until ready for sale at two years, at which time they are marketed mostly in coastal Australian cities as the live-shell product.

I saw several varieties of *C. gigas* being raised at one facility I toured: black, golden, striped-shell, etc. What I found interesting was that the central Bicheno hatchery made no attempt (unless requested) to separate the spawning oyster stocks, yet said they could tell which estuary where an oyster was raised in by its shape or other physical characteristics. Sometimes it was impossible to tell live *S. commercialis* from *C. gigas* except by the inner shell teeth of the Rock Oyster. However, the flavor was quite different.

UTILIZATION OF SEMIPURIFIED DIETS BY TAUTOG, *Tautoga onitis*. Laurel J. Ramseyer, National Academy of Sciences, USDOC, NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT 06460

Experiments were conducted to determine if standard experimental semipurified diets would support growth in the stomachless fish, the tautog, *(Tautoga onitis.)* Semipurified diets contained 50% protein and either 7% or 12% lipid on a dry matter basis. A commercial salmonid feed containing 54% protein and 15% lipid on a dry matter basis was used as a reference feed. Semipurified diets were either as-is (intrinsic pH 5.5-5.8) or with pH adjusted during preparation to ~7.6. Experiments were conducted with 6-12 g tautog at 20°C for 28-31 d.

Tautog were fed the reference and the 7% lipid semipurified diets at rates providing 10, 12 or 14 g protein/kg body weight/d. Fish fed the semipurified diets required at least 14 g protein/kg body weight/d for weight gain, whereas fish fed the reference feed gained weight at all three feeding rates. Fish fed the pH 7.6 diet gained weight faster than fish fed the pH 5.5 diet. However, when dietary lipid was increased to 12%, weight gain of fish fed the lower pH diet was not significantly different from weight gain of fish fed the pH 7.6 diet or the reference feed. The pH of digesta was 8.7-9.1 throughout the gut regardless of dietary treatment. The results indicated that the alkalinization of digesta in tautog is an energy-dependent process. Therefore, experimental diets used to determine the nutritional requirements of tautog should be alkalinized.

FEEDING STUDIES ON JUVENILE TAUTOG, TWO EXPERIMENTS: WEANING JUVENILE TAUTOG TO AN ARTIFICIAL DIET AND EFFECTS OF FEEDING FREQUENCY ON GROWTH OF JUVENILE TAUTOG. **Steve Yankocy, Grace Klein-MacPhee** and **Aimee Keller**, University of Rhode Island, Graduate School of Oceanography, Narragansett Bay Campus, Narragansett RI 02882-1197

Focus was placed on reducing costs and labor by enhancing growth through selection of a good commercial diet for juveniles and determining the best feeding schedule. Two feeding experiments were conducted on juvenile tautog with the goal of finding an optimum feeding regime. The first experiment dealt with the type of food which would be consumed by the fish. The experiment utilized two types of food: Kyowa™ brand dry food and live brine shrimp . Three different feeding regimes were used. One group was fed Kyowa, one live brine shrimp and the third a combination of brine shrimp and Kyowa. There were three replicates of each treatment. The fish were weighed and measured prior to the experiment with each tank receiving an equal weight of fish. The experiment lasted two weeks. The fish fed the Kyowa diet were larger than those fed brine shrimp or a combination of both , however the results were not statistically significant. Based on the cost of brine shrimp cysts and the extra effort to hatch and enrich them, the kyowa diet was more economical.

The second experiment dealt with feeding frequencies. Feeding schedule has been shown to influence growth patterns or food conversion rates significantly in a number of species. Three groups were set up all of which would receive the same amount of Kyowa brand dry food on different feeding schedules. One group received two feedings a day, the second four feedings a day and the third six feedings a day. The fish were weighed and measured at the start, and there were three replicates of each treatment. Feedings were done by hand and with the help of mechanical feeders. Fish fed four and six times a day were significantly larger than fish fed twice a day, but were not significantly different from each other.

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THE EFFECTS OF STOCKING DENSITY OF LARVAL TAUTOG. Lindsay Lydon and **Grace Klein-MacPhee**, University of Rhode Island, Graduate School of Oceanography, Narragansett Bay Campus, Narragansett RI 02882-1197

A preliminary study was conducted on larval tautog to determine if two different 15 gallon tank shapes, conical and rectangular, affected tautog survival. The two tank shapes did not have an effect on fish survival. However stocking density influenced larval growth in the four tanks.

Tautog eggs were collected from broodstock that spawned 7/29/98 and 7/30/98.After 8 hours of incubation, 10 mls of eggs were added to each of the four tanks. Green alga, *Tetraselmis suecica* was added daily to each tank for the first 19 days. Survival was good in all tanks except for one conical which had 100% mortality by day 5. Additional larvae were added from the tank with the highest larval density.

Larvae were fed a combination of dry and live food, rotifers, artemia and Kyowa™ diet. The tanks initially set up as semistatic systems were transferred to flow-through systems after larvae were 19 days old.

After 14 weeks, there was a statistically significant difference in size between fish groups. Fish growth was best in the tank with an initial stocking density of 2.8 fish/liter for about 148 fish. These fish had a mean length of 36 mm and mean weight of .90 grams compared to 29.28 mm and .50 grams for the tank with the highest larval density of 848 fish at a stocking density of 15 fish/liter. More work needs to be done to determine optimum stocking density for growth and survival.

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EFFECTS OF PHOTOPERIOD ON SURVIVAL, GROWTH AND PIGMENTATION OF SUMMER FLOUNDER (*Paralichthys dentatus*) *LARVAE IN LABORATORY CULTURE*

Marina Huber, Eric Moore, Neil Marcaccio, Robin Katersky and **David Bengtson**,
Department of Fisheries, Animal and Veterinary Science, University of Rhode Island, Kingston, RI 02881

Summer flounder represents a promising species for commercial aquaculture in the northeastern United States. In order to optimize production, the effects of various environmental parameters on biological production parameters must be studied. We investigated the effects of photoperiod on three parameters important to hatchery production: survival, growth and abnormal pigmentation. The last parameter involves incomplete pigmentation of the eyed side, including minor non-pigmented blotches to complete albinism. Flounder larvae were reared in replicate 75-L aquaria under three light regimes, 24L:0D (constant light), 16L:8D (summer conditions), 8L:4D:8L:4D (abnormal conditions to trick the fish into physiologically living two "days" in one). No significant differences in survival or growth were detected in the larvae through metamorphosis; however, after metamorphosis, fish reared in constant light had significantly lower levels of abnormal pigmentation. The experiment was repeated with an additional treatment, 8L:16D (winter conditions); no significant differences in pigmentation were observed among treatments, but fish in the 8:4:8:4 treatment grew significantly more.

POST-METAMORPHIC GROWTH OF SUMMER FLOUNDER IN LABORATORY CULTURE: DO EARLY-SETTLING LARVAE GROW FASTER THAN LATE SETTLERS? **Tessa L. Simlick, Robin S. Katersky, Neil Marcaccio**, and **David A. Bengtson**, Department of Fisheries, Animal and Veterinary Science, University of Rhode Island, Kingston, RI 02881

Laboratory-reared summer flounder larvae begin to settle to a benthic existence 30 to 35 days after hatching but settlement can continue for about a 30-day period, because completion of metamorphosis among individuals does not occur simultaneously. We perform weekly gradings (i.e., removal of settled flounder) until all fish have settled in order to prevent cannibalism and stress, because newly settled juveniles tend to be larger than swimming larvae. Although we know there is a strong correlation between larval growth and time of settlement (fastest growers settle first), no data exist on post-settlement growth variability. We wanted to know whether fast-growing larvae become fast-growing juveniles or whether slow-growing larvae can 'catch up' in growth rate. Experiments were designed and conducted at the Narragansett Bay Campus Research Facility to explore these inquiries. Settled fish were graded from the larval tank at 32 days after hatch (DAH) (Grade 1), 39 DAH (Grade 2), and 46 DAH (Grade 3). Graded fish were randomly placed in three replicate 75-L aquaria per grade, at a density of 30 fish per aquarium. Flounder were fed *Artemia* for 30 days after removal from the larval tank and were then weaned onto a commercial diet. All fish were measured by Image Analysis at bi-weekly intervals until the fish were 95 DAH. No significant differences in post-settlement growth rate were seen among the three grades. In the final set of measurements, the fish exhibited an increase in size variation within replicates and cannibalistic attacks were again causing mortality. Future experiments will continue to investigate specific growth rate variation in all stages of juvenile growth.

***Vibrio parahaemolyticus* AND OTHER SHELLFISH DISEASES OF PUBLIC HEALTH SIGNIFICANCE: A REVIEW.** **Richard A. French**, University of Connecticut, Department of Pathobiology, Northeastern Research Center for Wildlife Diseases, 61 North Eagleville Road, Storrs, CT 06269

The incidence of foodborne illness associated with consumption of contaminated seafood products has recently triggered media attention that has helped to increase public awareness of issues related to food safety. This media coverage has also generated a number of misconceptions regarding the safety of eating seafood. Microorganisms and other toxic substances commonly ingested by shellfish may accumulate within animal tissues and be passively transmitted to humans when they consume the tainted seafood products. Though generally relatively harmless to the affected shellfish, these microorganisms and chemicals are often pathogenic or toxic to humans. Pathogens of public health significance associated with contaminated seafood include causative agents of hepatitis and gastroenteritis, biotoxins (paralytic shellfish poisoning) and toxic industrial chemicals (heavy metals, polycyclic aromatic hydrocarbons, and chlorinated hydrocarbons). One important microbial pathogen of marine species, including crabs, shrimp, lobster, and oysters is *Vibrio parahaemolyticus*. Recent foodborne disease outbreaks associated with consumption of oysters in the Pacific Northwest (1997), Galveston Bay, Texas (1998) and Oyster Bay, New York (1998), have heightened awareness of *V. parahaemolyticus*. This *Vibrio* species is a halophilic bacterium that is part of the normal flora of estuarine and other coastal areas worldwide. Human illness associated with *V. parahaemolyticus* is characterized by a self-limiting, mild to moderate gastroenteritis occurring within 4-96 hours after consumption of raw or improperly cooked, and/or stored fish and shellfish. Several halophilic *Vibrio* species associated with mollusks are reported to cause gastroenteritis in humans. Disease is strain-specific within *Vibrio* species and correlated with production of various toxins, including enterotoxins, cytotoxins, and hemolysins. In addition to surveillance efforts designed to identify the pathogenic strains of *V. parahaemolyticus*, epidemiologic and pathogenesis studies are currently underway. Such research will help determine the geographic distribution of *V. parahaemolyticus* and provide a better understanding of the mechanisms of the disease process. Diagnostic methods for the detection of *V. parahaemolyticus* and species typing continue to improve. A review of shellfish-associated foodborne diseases and current efforts to improve food safety in the United States will be addressed.

Vibrio parahaemolyticus - **A NEW PROBLEM FOR THE SHELLFISH INDUSTRY IN THE NORTHEAST.** **David R. Relyea,** Frank M. Flower and Sons Inc., P.O. Box 88, Oyster Bay, NY 11771

During the time period between 8/10/98 and 8/29/98 eight cases of gastroenteritis occurred and were eventually reported to the New York State Department of Environmental Conservation (NYSDEC). The illnesses occurred in Nassau and Suffolk counties in New York (6) and (2) cases were from New Jersey. Stool samples from patients indicated that the illnesses were caused by a naturally occurring marine bacterium, *Vibrio parahaemolyticus*. Tagging information seemed to indicate that the source of the bacteria was oysters and clams from area NS2 which includes Oyster Bay and Cold Spring Harbor. However, most patients had also eaten other seafoods (crabs, shrimp, etc.) that are known to be sources of *Vibrio parahaemolyticus*. Health Department officials claimed that the only food common to all patients was shellfish from NS2. New York State Department of Health (NYSDOH) and USFDA notified NYSDEC that NS2 had to be closed and NS2 was closed to shellfishing on 9/10/98.

Due to confusion and insufficient Federal guidelines the area was not able to be reopened until 10/22/98. During that time Frank M. Flower and Sons with 40 employees and about 50 individual baymen had no source of income. This presentation gives the industry perspective of this perplexing problem.

Vibrio parahaemolyticus - A NEW CHALLENGE FOR STATE SHELLFISH CONTROL AGENCIES.

William Hastback, New York State Department of Environmental Conservation, 203 North Belle Mead Road, Suite 1, East Setauket, New York 11733

In late August 1998, the New York State Department of Environmental Conservation (NYSDEC) shellfish sanitation program was advised by the New York State Department of Health (NYSDOH) of a series of five (5) individual illnesses in shellfish consumers. Laboratory analyses of patient samples indicated that the illnesses were caused by the naturally occurring marine bacterium - *Vibrio parahaemolyticus*. (VP).

The initial information available indicated that the shellfish implicated in the illnesses had been harvested from the area designated as NS-2, including Oyster Bay and Cold Spring Harbors, in northwestern Nassau County. On September 8, we learned that two individuals in New Jersey had become ill after consuming oysters from the same area. On September 9, the NYSDOH advised NYSDEC of their determination of a statistical association between the consumption of shellfish and the illnesses. On September 10, the NYSDEC Bureau of Marine Resources designated Oyster Bay and Cold Spring Harbors as uncertified for the harvest of shellfish on an emergency basis. The closure was in effect through October 22, a period of six weeks. The decision to reopen was based on declining water temperatures and the results of DNA probe examinations of oyster samples conducted by two FDA laboratories.

In the interim, the federal Centers for Disease Control identified the 03:K6 strain of VP isolated from patient samples. That strain of VP had been identified as the cause of a oyster-related illness outbreak that affected approximately 450 people in several states during June. Galveston Bay, Texas was the source of the oysters in that outbreak. The 03:K6 strain has also been responsible for large seafood related illness outbreaks in southeast Asia, from India to Japan.

A COMPARISON OF ANTICLUMPING SOLUTIONS USED FOR INITIAL RECOVERY OF HEMOCYTES FROM THE BAY SCALLOP (*Argopecten irradians*). **Steven Pitchford** and **Richard Robohm**, USDOC, NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT 06460

Efforts to study the immune capabilities of bay scallop hemocytes *in vitro* were hampered by excessive clumping of cells upon withdrawal of hemolymph from adductor muscles. To resolve this problem, seven solutions used by others to prevent clumping of blood cells *in vitro* (five used in other invertebrate species and two in human medicine) were modified by adjusting osmolality and pH to match that of scallop blood and examined for their ability to prevent scallop cell aggregation.

In brief, the protocol consisted of withdrawing hemolymph from scallop adductor muscles, dispensing it into each of the anticoagulant solutions in multi-chambered, glass, microscope slides and allowing the hemocytes to attach. This was followed by cell fixation. The number of single attached cells, small clumps (2-4 cells), and large clumps (> 4 cells) were counted in at least 15 fields for each of the anticoagulants. In addition, observations were made on the appearance and relative degree of attachment of the hemocytes to the substrate.

Results were collected using weighted values from three experiments; each experiment used hemolymph from three scallops – each exposed to all seven solutions. Dunnett's test for pairwise multiple comparisons showed that a modified solution, Adema's solution, previously used to prevent clumping in cells of a freshwater snail, was statistically superior to all but one of the other solutions. Three solutions developed by others for use with various molluscs were very poor in their ability to prevent clumping of scallop cells. Use of the best solution will be essential in many of our subsequent studies of bay scallop immunity.

THE PRESENCE OF *Haplosporidium nelsoni* (MSX) AND *Perkinsus marinus* (DERMO) IN *Crassostrea virginica* ALONG THE CONNECTICUT AND NORTHERN LONG ISLAND SHORELINE IN 1998 - AN EXTENSIVE SURVEY. **John Karolus, Inke Sunila, Stacey Spear, Joe DeCrescenzo** and **John Volk,** Connecticut Department of Agriculture, Bureau of Aquaculture, P. O. Box 97, Milford, CT 06460

Previous data generated by this laboratory determined a widespread prevalence of *Perkinsus marinus* (Dermo) starting in 1996 and *Haplosporidium nelsoni* (MSX) starting in August, 1997 in the *Crassostrea virginica* (eastern oyster) population along the Connecticut coast. An extensive survey was conducted in 1998 to include the entire coast line of Connecticut and the northern shore of Long Island.

Samples of 30 oysters each were collected at selected sites representing both leased oyster growing areas, seed areas and locations of special interest. For the diagnosis of MSX, oyster tissue was preserved in Davidson's fixative with 20 $^{o}/_{oo}$ artificial seawater. Paraffin-sections were stained with hematoxylin - eosin and Ziehl's acid fast stain for detecting spores. For the diagnosis of Dermo, anal rectal tissue were cultured in Ray's Fluid Thioglycollate Medium.

Haplosporidium nelsoni was found at epizootic levels at few sites along the Connecticut shoreline in 1998. Ninety one percent of the Connecticut samples were found positive for MSX. Prevalence varied from 3 to 77%. Adult oysters at three locations were found to contain sporulating MSX during the autumn. Forty-four percent of the New York samples were positive. The prevalence range was 3 to 37%.

For Connecticut sampling sites, the results for *Perkinsus marinus* in 1998 indicated no significant difference from the intensity of infection between the shallow waters (eight feet or less) and the deeper water samples. *Perkinsus marinus* was found in 100% of the Connecticut samples. In addition, there was no significant difference between the intensity of infection for 1997 versus 1998. In New York, sixty-nine percent of the samples were positive for Dermo. However, the Dermo intensity of infection was not significantly different from that found in Connecticut during 1998.

MSX results for 1998 indicated most of the CT shoreline was experiencing a post-epizootic period. It appeared that Dermo had established an enzootic prevalence in Long island Sound.

DISEASE-RESISTANT OYSTERS, *Crassostrea virginica,* IN LONG ISLAND SOUND. **Inke Sunila, John Volk** and **John Karolus**, State of Connecticut, Department of Agriculture, Bureau of Aquaculture, P.O. Box 97, Milford, CT 06460; **Terry Backer**, Long Island Soundkeeper Fund, Inc., P.O. Box 4058, East Norwalk, CT 06855; **Stan Czyzyk**, Bluepoints Co., Inc., Atlantic Avenue, P.O. Box 8, West Sayville, NY 11796; **Ed Lang**, P.O. Box 314, Clinton, CT 06413; **Matt Mroczka**, Cedar Island Marina Research Laboratory, P.O. Box 181, Clinton, CT 06413; **Karen Rivara**, AEROS Cultured Oyster Company, 41 Heathcote Court, Shirley, NY 11967

Under heavy infection pressure, oysters develop resistance to parasitic diseases such as MSX (*Haplosporidium nelsoni*). Resistant oysters still get infected, but their mortality rate is lower than that of susceptible oysters. Genetic resistance can be developed against other economically important oyster diseases such as Dermo-disease (*Perkinsus marinus*) or JOD (Juvenile Oyster Disease).

A MSX-epizootic, associated with high mortalities in some areas, raged in Long Island Sound (LIS) starting in 1997. Hatchery-raised, highly susceptible seed experienced 99% mortality. Connecticut's commercial oyster companies were advised to increase the prevalence of resistant oysters in two different ways: 1. Establishing brood stock sanctuaries in heavily infected sites to permit survivors to produce resistant seed. This could be done by not harvesting part of the infected lot (10% area) for a period of three years. 2. Selecting disease-resistant strains when using hatchery-raised seed.

The prevalence of potentially MSX-resistant oysters, based on histological characteristics, in the field increased eightfold from 1997 to 1998 on previously exposed sites. A cooperative program was initiated with production hatcheries to produce a commercially available, disease-resistant oyster seed especially bred for Long Island Sound conditions. Present management strategies respect traditional oyster culture methods, which include deployment of hatchery-raised seed concurrently with natural set. This gave rise to the need of developing a hatchery stock with a spawning cycle compatible with wild oysters. Spawning time is an inherited characteristic, which is maintained upon transplantation. The new oyster strain would have the characteristics for spawning time, growth, temperature and salinity tolerance and hardiness of the parent population in LIS. In addition, it would have been selected for disease resistance. Brood stock was created from survivors of 90% mortality (83% MSX prevalence, 100% Dermo prevalence) from Clinton, Connecticut. A commercially available, local seed was used as a control. "Clinton" strains have been tested since the spring 1998 in an infected location for growth, mortality and infection rates. During the first season, "Clinton" had a 16% higher growth rate than the control. Both strains acquired MSX and Dermo infection. "Clinton" experienced a 1% mortality, control 11%. The first generation "Clinton" showed superior survival and growth characteristics. This seed has been deployed in commercial scale at several sites in LIS. Grow-out facilities have been established to grow hatchery-raised seed prior to dispersing it to the field. Brood stocks are exposed in different locations to other oyster diseases such as Dermo, JOD and SSO (Seaside Organism or related species).

HISTOPATHOLOGICAL SURVEY OF THE QUAHOG, *Mercenaria mercenaria*, ALONG THE CONNECTICUT COASTLINE. **Joseph DeCrescenzo, Inke Sunila, John Karolus** and **John Volk**. State of Connecticut, Department of Agriculture, Bureau of Aquaculture, P.O. Box 97, Milford, CT 06460

A histopathological survey was conducted along the Connecticut coast line on the hard clam, *Mercenaria mercenaria*. Quahog Parasite Unknown (QPX), an economically important parasite, *phylum Labyrinthumorpha*, has been found off the coast of Massachusetts. The purpose of this survey was to detect QPX or other conditions which might possess a threat to Connecticut's hard clam harvest.

Eleven different locations were sampled along the Connecticut coast line. Samples of 30 clams each were taken from either commercial fisherman or harvested from wild clam beds. A gross pathologic examination was then conducted before they were processed for histopathologic examination. The clams were shucked and placed into a Davidson's fixative. Sections were then stained in hematoxylin-eosin.

Samples were diagnosed for infectious agents such as viruses, Chlamydia, bacteria, fungi or any protozoan or metazoan parasite. Histopathological lesions were classified as inflammations, degenerative process, cell or tissue death, or proliferative responses. The results showed no signs of the commercially important parasite QPX. However, some infectious and non-infectious agents were found in the examination. The following conditions appeared at low prevalences: *Chlamydiales*, ceroidosis, ciliates in the gill region, sloughing of the epithelium in the digestive diverticula, hemorrhage in the intestine and stomach, and mucus around the foot.

In conclusion, no economically important parasites were present in the samples. Recent mortalities in oyster beds due to infection with MSX have shifted more harvesting pressure toward hard clams. This study, based on the low prevalences of histopathological conditions and active gametogenesis in the gonads, predicts a positive future for Connecticut's clamming industry.

THE EFFECT OF DENSITY ON GROWTH OF *Argopecten irradians* IN LONG ISLAND SOUND: IN PARTNERSHIP WITH NATIONAL MARINE FISHERIES SERVICE SCIENTISTS. **John J. Curtis, Sherry W. Lonergan, Thomas McGann,** and **Paul J. Trupp**, Bridgeport Regional Vocational Aquaculture School, 60 Saint Stephens Road, Bridgeport CT 06605

Being consistent with its philosophy of infusing meaningful activities into the instruction at the Bridgeport Regional Vocational Aquaculture School, an invitation was accepted to have students work with National Marine Fisheries Service scientists of the Milford, Connecticut laboratory on a project to study "the effect of density on growth of *Argopecten irradians* in Long Island Sound." The initial study was recently concluded in part, in December 1998 with the harvest of the targeted crop.

The school's role was clearly defined with educational goals and objectives established at the onset of the project for the involved students. The species, *Argopecten irradians*, is one familiar to the students at the Aquaculture School since its introduction in a 1994 - 96 international collaboration with the People's Republic of China. In that project the students and staff of our school learned not only the biology of the bay scallop but also the methods of spawning, grow-out and harvesting. In addition, procedures for statistical analysis of the collected scientific data were included for follow-up studies.

Students from the school's Intensive program were introduced to the project by NMFS scientists in the spring of 1998. They began work on design, construction and deployment of a long-line at the school's farm in Long Island Sound. The project began with NMFS scientists, students and staff transporting juvenile bay scallops, reared at the Milford Laboratory, to our test location. Scallops were sorted into test groups, measured and transferred to various style culture nets and attached to the long line. In the fall, students and scientists collected data on the growth rate (shell height and width) of the scallops which were then transferred to nets of a larger mesh size and returned to the water. The final phase of this project had two objectives. The first was to gather growth data on one group of test scallops and the second was to implement a separate long-line for another group of scallops for research on the effects of over-wintering.

The educational objectives of this project were many and varied. By immersing students in real-life scientific study, they were presented the procedures necessary to assist in the design and implementation of a high-level research project from beginning to end. Discussion of scientific methods, proper research techniques, data collection and analysis augmented the standard curriculum of science and technology. This project has offered our students opportunities to develop the skills of problem-solving in a meaningful activity that have already translated into higher academic performance and a better scientific understanding.

From an educational perspective, much has been learned to date and much more can be extracted from this project through continuation. The difficulties encountered in the initial attempt will be addressed through earlier phases of conditioning, spawning and placement at the farm site. The problems to gear presented by natural conditions are being addressed in the CAD classroom with students redesigning lantern nets and researching better methods of deployment. The students and staff of the Bridgeport Aquaculture School look optimistically to our continued involvement and the accomplishment of the prime goal of the project: to develop better methods to grow bay scallops which can be competitively sold in the market place.

AN OVERVIEW OF AQUACULTURE RESEARCH IN ATLANTIC CANADA. Shawn M.C. Robinson, Dept. Fisheries and Oceans, Biological Station, St. Andrews, New Brunswick, Canada, E0G 2X0

The aquaculture industry in Canada is in a growth phase. Since 1986, shellfish culture has grown in production volume at an annual rate of 10% and finfish culture has grown at an annual rate of 28%. This rapid growth in the industry has fueled a push in research to support the development of existing species in culture as well as to bring new species on-line. There is also active research on factors that affect the industry such as disease and environmental interactions.

In Atlantic Canada, the lead federal agency for aquaculture research is the Dept. of Fisheries and Oceans. Its role is to provide scientific knowledge for the sustainable development of aquaculture including the development of an economically competitive and environmentally sustainable industry. The research laboratories are located at the Biological Station in St. Andrews, New Brunswick, the Gulf Fisheries Centre in Moncton, New Brunswick, the Bedford Institute of Oceanography in Dartmouth, Nova Scotia and the Northwest Atlantic Fisheries Centre in St. John's, Newfoundland. However, there are other major research organizations in Atlantic Canada as well such as: 1) provincial aquaculture agencies in Newfoundland, Nova Scotia, Prince Edward Island, New Brunswick and Quebec 2) the National Research Council – Institute for Marine Biosciences in Halifax Nova Scotia 3) the universities (UNB, Moncton, UPEI-AVC, NSAC, Acadia, Dalhousie, Laval, Quebec and Memorial) 4) the Canadian Centre for Fisheries Innovation and 5) the industry itself including the provincial aquaculture associations. The majority of the research is done in collaboration with industry partners.

Research on finfish has been strongly emphasized to date. Atlantic salmon is the most commercialized species so far and much of the early developmental work has been done. Research on this species is ongoing in the Bay of Fundy and Newfoundland and is concentrating on broodstock (new strains, transgenics), fish health (record of performance, husbandry practices, therapeutants), nutrition (area and species specific diets), grow-out technology and environmental linkages (freshwater discharge, waste management). There are also a number of new finfish species that are being studied such as: halibut, haddock, winter flounder, striped bass, steelhead and American eels. These studies are going on primarily in Newfoundland, Nova Scotia and New Brunswick. The scope of research on these new species falls into four categories: 1) Broodstock/seedstock (environmental influences on maturation, influence of diets, prediction of maturation, capture techniques) 2) Fish health (identification and life histories of diseases and parasites, baseline data on normal fish) 3) Nutrition (nutritional requirements, culture techniques for native plankton, micro-encapsulated larval diets, larval feeding behaviour) and 4) Grow-out (early rearing techniques, tank and grow-out designs, refinement of automatic feeding techniques, *in situ* estimation of fish size in cages).

Shellfish research is active in all provinces. The industry is presently mostly located in Newfoundland, the Atlantic coast of Nova Scotia and the Gulf of St. Lawrence although it is starting to grow in the Bay of Fundy. In general there are four research areas being targeted: 1) Broodstock/seedstock (hatchery development, natural spat collection) 2) Shellfish health (identification of diseases and parasites, diagnostic tools and treatments) 3) Grow-out (optimize

rearing of juveniles, seeding densities, predator control, roe enhancement) 4) Environment (environmental effects on growth and survival, site selection, carrying capacity, effects of winter ice). Species being studied are: blue mussels, sea scallops, American oysters, European oysters, hard-shell clams, soft-shell clams and sea urchins. There is also some work being done on bio-fouling species such as tunicates.

There is a small program on algal research. Programs are underway on the dynamics of phytoplankton blooms and some shellfish sites are being monitored for toxic algal effects. Grow-out trials are being done on some macro-algal species such as dulse (*Palmaria palmata*), nori (*Porphyra* spp.) and kelp (*Laminaria longicruris*).

As the marine culture industry develops, there is an increasing research effort being directed toward the linkages between the commercial culture of various species and the environment. Oceanographic modeling techniques are being developed for area management strategies, site assessment and remediation techniques are being studied, and practical methods for monitoring by the industry are being developed.

Past research has contributed substantially to the development of the Atlantic Provinces aquaculture industry and there is strong support from industry for work in the future. The major research impediment to-date has been securing reliable long-term research funds.

NOAA FISHERIES AND AQUACULTURE. **Edwin Rhodes**, USDOC, NOAA, National Marine Fisheries Service, 1315 East-West Highway, Silver Spring, MD 20910

Aquaculture has played a significant role in NOAA Fisheries and its predecessor agencies since their origins in the 19th century. The continuing efforts by the agency in its 127 year history contributed some of the key science in the field of aquaculture, including research that contributed to the commercial development of salmon, shrimp and shellfish culture.

Since the 1980's , agency priorities in the area of fisheries management, coupled with budget limitations, have restricted the participation of NOAA Fisheries in aquaculture. Recently, aquaculture has reemerged as an important consideration as NOAA Fisheries plans for the new century. This planning and policy development stage is critical because it is through this process that agency priorities are set and budgets are driven. The NOAA Fisheries strategic plan has as one of its objectives to "promote the development of robust and environmentally sound aquaculture" and outlines specific goals in the areas of technology development, siting, permitting and financial assistance. Partly based on this plan, the Northeast and Northwest Centers of NOAA Fisheries have reorganized to include aquaculture divisions, and new aquaculture industry financing programs are being developed.

At the NOAA level, NOAA Fisheries, the National Ocean Service and the Office of Oceanic and Atmospheric Research have collaborated to put a new aquaculture policy in place that recognizes the significant role that environmentally sound aquaculture will play in meeting future demand for seafood, as well as the potential to contribute to wild stocks through enhancement. The NOAA policy also foresees a major aquaculture effort for the production of non-food products such as bait, aquaria species, chemicals and pharmaceuticals.

Finally, an active task force is developing a Commerce-wide policy for aquaculture, and its formulating plans to facilitate aquaculture permitting in the U.S. exclusive economic zone. This policy and planning activity has helped to generate a new interest in aquaculture in the Department and the recognition of the potential for aquaculture speaks to an optimistic future.

WAMPANOAG SHELLFISH AQUACULTURE. **David W. Grunden**, Wampanoag Aquaculture Director, Island Aquaculture, Oak Bluffs, MA 02557

The Wampanoag Tribe of Gay Head Aquinnah is a Federally Acknowledged Native American Tribe located on Martha's Vineyard Island. Their tribal offices are in the town of Aquinnah, MA. They have observed the decline of the local shellfishery in the town and have two goals for their aquaculture enterprise. The first, of course, is to make a profit. The second is to return a percentage of the yield from the hatchery back to the wild and to protect their cultural heritage of depending on the local shellfish as a food. They also hope that it will allow the fishery to recover so that many of their tribal members can continue to fish commercially within the local ponds. In working to achieve this second goal the tribe has a Memorandum of Understanding with the Town to assist their shellfish department with any of its propagation and predator control programs. This has evolved into assisting the Town's shellfish department in developing a comprehensive plan to manage the shellstock.

A report on the early development of the Native American Wampanoag Tribe of Gay Head Aquinnah's commercial shellfish aquaculture enterprise will be presented. It will include an introduction to where the project is located, what has been done to date and the expected developments for 1999.

A hatchery is planned as well as grow-out of the seed to both field plant and market sizes. Additionally the Tribe is working with the local Town to develop a comprehensive shellfish management plan.

DEVELOPMENTS IN THE PRIVATE AQUACULTURE INDUSTRY ON MARTHA'S VINEYARD. **Richard C. Karney**, Martha's Vineyard Shellfish Group, Inc., Box 1552, Oak Bluffs, MA 02557; and **John C. Blake**, Sweet Neck Farm, Box 1468, Edgartown, MA 02539

The progress of private aquaculture ventures spawned by two National Marine Fisheries Service (NMFS) Fishing Industry Grants (FIG) is reported. Five growers have successfully taken thousands of 2 mm oyster seed to a 3 inch legal size in about three years. The single oysters grown in cages off-the-bottom are well shaped, deeply cupped and as good or better quality than most cocktail oysters seen in raw bars. The growers consistently received fifty to sixty-five cents apiece for their oysters. Despite the loss of up to 25 percent of the three year old oysters due to Seaside Organism (SSO, *Haplosporidium costale*) in the spring of 1998, production of market size oysters per grower for the past year ranged between 800-11,000 oysters with an average of about 3,000 oysters per grower.

Over a half million new seed oysters were cultured by twelve growers in 1998. Growth and survival has been excellent. Growers who have been conscientious about thinning and cleaning the seed, report that 2 mm seed set out in July was averaging 2 inches in September. Seed cultured in a tidal upwelling nursery grew to 2 inches (from 2 mm) in eight weeks! Some of these oysters reached 3 inches by December.

Island cultured shellfish were promoted under a $4,000 grant from the Southeastern Massachusetts Aquaculture Center (SEMAC). The grant provided for the development of a logo, printing of promotional materials, and introducing the new cultured seafood products to Island chefs, retailers, and the general public.

Under a grant from the Massachusetts Department of Food and Agriculture, Jack Blake, an Edgartown grower, constructed and operated a floating hatchery/nursery prototype. The first two attempts at larval culture of quahogs failed. During the first attempt, fertilized eggs introduced to the flow through the larval culture system escaped when a drain screen dislodged. A second attempt was made to culture quahog larvae. This time the larvae were cultured in a closed system tank where water was changed every other day and cultured phytoplankton was fed daily. This culture succumbed to a *Vibrio* infection traced to source water which was drawn from a prefilter reservoir contaminated with oyster feces from an adjacent nursery culture system. In a third attempt, two million two-week-old oyster larvae introduced into the system were successfully grown in a closed system mode. Within a week, the veligers progressed to eyed larvae and were set on microcultch in the system. This culture attempt has resulted in over 110,000 of 2-5 mm oyster seed. Results from these early trials are promising and the innovative hatchery is scheduled to be run again next year.

CONTROL OF EUTROPHICATION BY BIVALVES: FILTRATION OF PARTICULATES AND REMOVAL OF NITROGEN THROUGH HARVEST OF RAPIDLY GROWING STOCKS. **Michael A. Rice,** Department of Fisheries, Animal and Veterinary Science, University of Rhode Island, Kingston, RI 02881

Filter feeding by populations of bivalves has been suggested as a means of reducing eutrophication in coastal estuaries by exerting control of phytoplankton populations in the water column. In some estuaries programs have been established for the purpose of improving water quality and, frequently, large populations of mature shellfish that reside behind pollution closure lines in estuaries represent a large filter feeding biomass. The rate of filter feeding by bivalves is size dependent and allometrically related to shell dimensions, so the largest and oldest individuals filter the greatest volumes of water. In most areas closed to shellfishing, bivalve populations are composed of mostly older adults. These large animals are slow growing, have a low rate of new tissue production in relation to standing crop biomass, and have a neutral nitrogen balance (organic-N assimilated = NH_3-N excreted). These large adults increase sedimentation through filter feeding, but since they are neither harvested nor growing rapidly, they do not directly remove much nitrogen from the estuary. Although it is possible that increased sedimentation can lead to greater denitrification rates in the sediments. The only way filter feeding can directly remove nitrogen from the environment is through tissue growth. The dry weight of the soft tissues of most bivalves is typically around 60% protein, so for each kilogram of shucked shellfish meats harvested there are about 17 grams of organic nitrogen removed from the estuary. Nutrient removal from estuaries can be maximized through management of shellfisheries for maximum biomass production and harvest, and the development of aquaculture projects in which rapidly growing shellfish are harvested regularly.

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FEEDING RATIONS AND REGIMES FOR POST-SET OYSTERS, *Crassostrea virginica*, FED CULTURED MICROALGAE IN A LAND-BASED NURSERY. **Gary H. Wikfors, Jennifer H. Alix, Mark S. Dixon**, and **Barry C. Smith**, USDOC, NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT 06460

Filter-feeding bivalves, such as the eastern oyster, have evolved feeding behaviors that respond to changes in both quantity and quality of suspended particles. In near-shore waters, particle loadings are highly variable and beyond the control of the shellfish farmer relying upon natural primary production to feed his or her seed oysters. The risks associated with "raw water" nursery culture of oysters (poor nutrition; exposure to pollutants, disease, and predators; vandalism), and seasonal limitations, eventually will exceed the costs of controlled, land-based nursery culture; as this occurs, information needs about oyster feeding will shift from describing responses to varying environmental conditions to providing feeds in a way that optimizes their use by the spat. Feeding standards developed for animal agriculture that list daily nutritional input, in biochemical terms, and growth obtained on these specific diets, represent a useful model for aquacultured animals. For filter feeders, however, the "daily allowance" concept is complicated somewhat by the behavioral responses to particle loadings mentioned above.

To begin the process of identifying practical feeding rations and regimes for post-set oysters, we conducted an experiment in which daily rations were varied (1, 2, 5, or 10% of oyster live weight in dry matter of feed) and each ration was provided in 2, 4, or 16 feedings each day; a 50:50 mix of two high-lipid *Tetraselmis* strains, PLY429 and PLAT-P, was used for all experimental treatments. Oyster growth was determined weekly -- in terms of live weight, volume displacement, and shell size -- and at the end of the seven-week experiment in terms of dry weight. Feed conversion efficiency was calculated from change in oyster dry weights and the sum of algal dry weight feed provided during the experiment.

Oysters (65 mg live weight initially) grew progressively faster on 1, 2, and 5% rations, regardless of regime, but there was no significant increase in growth when the ration was increased to 10%. Oysters grew fastest when fed most often, but the statistical significance of this effect was dependent upon ration, e.g., at the highest ration, effect of regime was not significant. Feed conversion efficiency was inversely related to growth, and was in the range of 2-20% from high to low rations. Results of this experiment indicate that the optimal feeding ration for oysters on a qualitatively suitable diet will lie within the range of 2-5% of live weight in dry matter per day, and that providing the daily ration in multiple daily feedings becomes more important at lower rations. These findings confirm results obtained previously with bay scallops, *Argopecten irradians*, in that maximal growth is obtained on daily rations between 2 and 5% and multiple daily feedings improve growth. Oysters, however, with a maximal conversion efficiency of less than 20% appear to be less efficient at converting feed to growth than scallops which can achieve a conversion efficiency of 24% with identical nutritional input.

FERTILIZATION RATES AND PROCEDURES USING COMMERCIAL "F/2" NUTRIENT MIXES TO GROW T-ISO (*Isochrysis sp.*) AND PLY429 (*Tetraselmis chui*). **Barry C. Smith, Sara Barcia, Jennifer H. Alix,** and **Gary H. Wikfors**, USDOC, NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT 06460

Two developments intended to make microalgal feed culture more convenient have collided. First, pre-mixed concentrated nutrient products, formulated according to Guillard's "f/2" recipe, are entering wide use; these products are sold in two solutions that are kept separate to avoid chemical complex formation until used to make culture media. The second development is the use of automated methods of adding nutrients to culture water, e.g., metering pumps and venturi eductors. The two-part nutrient mixes will require duplicate apparatus for their automated dispensing, increasing technical complication, chances for malfunction, and cost. A simple solution (pun intended) to this dilemma would be a dilution with water of the combined two-part product that would remain stable. Several dilutions of combined f/2 concentrates were observed over two weeks for visible precipitates. Then, culture media were prepared with the concentrate dilutions, and their ability to support growth of T-ISO and PLY429 was compared to freshly-prepared f/2 of two brands. In a nested Analysis of Variance design, four concentrate dilutions (Part A:Part B:water, 50:50:0, 40:40:20, 30:30:40, 20:20:60) were used to prepare four final nutrient media (f/4, f/2, f, 2f) each. Algal division rates were calculated from optical density readings of triplicate test-tube cultures, and final population densities were determined by microscope cell-counts.

All nutrient dilutions precipitated but were re-dissolved easily. For *Tetraselmis chui*, PLY429, nutrient pre-dilution and final concentration had significant effects upon division rate and final population. Maximal division rates were higher when nutrient solutions were pre-diluted, and significantly higher in the 2f media as compared with lower enrichments. Final cell densities tended to be higher when nutrients were not pre-diluted, especially at lower fertilization rates. Predictably, higher fertilization rates led to higher final cell yields, but a nitrogen budget analysis showed nearly half of the added nitrate was not taken up by PLY429 at the 2f enrichment. For *Isochrysis* sp., T-ISO, division rate was highest in the most pre-diluted nutrients and lowest at the highest fertilization rate. Cell yield of T-ISO tended to be higher in nutrient mixes less pre-diluted and was significantly lower in the f/4 enrichment compared with higher fertilization rates. Nitrogen budget analysis of T-ISO cultures showed that nitrate remained unassimilated at all concentrations above the f/4 enrichment.

Indications from these experiments are: 1) enrichments above the "f" level for PLY429 and above "f/4" for T-ISO result in wasted nutrients, suggesting that some other nutrient (perhaps vitamins) limited T-ISO in these experiments; 2) pre-dilution of two-part commercial algal fertilizers increases maximal division rate, but not final cell yield, suggesting that chemical complexation is reversed during algal growth, making nutrients available to algae over time. Pre-dilution of combined two-part algal fertilizer products can affect performance of cultures; the decision to pre-dilute will depend upon whether cultures are being optimized for rate or yield.

REFLECTIONS ON BIOFILTER SELECTION FOR SHELLFISH CULTURE.

James C. Widman Jr., USDOC, NOAA, National Marine Fisheries Service, Northeast Fisheries Science Center, Milford Laboratory, Milford, CT 06460

Selecting biofilters for shellfish recirculating systems can be a perplexing process. Many of the biofilters used in finfish recirculating systems have numerous disadvantages when the requirements of shellfish culture are considered. One of the main requirements is live phytoplankton as a food source. Many commercially available biofiltration systems are capable of trapping and removing phytoplankton-size particles. Finfish systems, on the other hand, are designed to remove fecal material and unused food from the water stream. Many of them also use high flow rates essential to many finfish species but usually detrimental to shellfish. These systems must be modified before being considered for shellfish recirculating systems.

Bead filters are effective at removing and trapping phytoplankton size particles and sand-bed filters have similar drawbacks. Protein skimmers/foam fractionators not only remove organics, but also phytoplankton-size particles. Numerous drum filters capable of removing fish wastes do not appear to be appropriate for the fragile waste products of shellfish; some mesh sizes also remove phytoplankton. Many of these systems are still undergoing modifications and may eventually evolve into effective shellfish biofilters in the future.

There are systems that appear to satisfy the requirements of shellfish culture today. Many of these systems act as contact filters, basically providing large surface areas for nitrifying bacteria to grow. Rotating biological contact filters (RBC's) , Aquacube, moving bed biofilters, and submerged panels are examples of this technology.

Trickle filters and fluidized sand bed filters may be effective, but may be subject to fouling, or damage to the phytoplankton. Caution must be exercised when biofilter specifications mention the removal of solids. Pads, mats, foams and types of trickle filter media can become fouled with both waste material and phytoplankton, making them less efficient at nitrogen removal.

EXPERIMENTAL TESTING OF FIELD TECHNIQUES FOR FARMING THE SOFT-SHELL CLAM, (*Mya arenaria*). **Kenneth J. La Valley, Thomas L. Howell, Riley Y. Morse**, Spinney Creek Shellfish, Inc., Eliot, ME 03903; **Brian Beal**, and **Bertrand Dubois**, University of Maine, Machias, ME 04654

The purpose of this USDA/SBIR Phase I research project was to determine the feasibility of commercially farming the soft-shell clam, *Mya arenaria*. To accomplish this objective the research proposed to: 1) Produce a high volume of high quality hatchery-reared seed; 2) Optimize Floating Up-weller techniques for soft-shell clam culture; 3) Investigate the added benefits of conditioning seed beds by harrowing; and 4) Investigate several seed planting/grow-out techniques.

To optimize hatchery production, larval stocking densities of 10K, 20K, 40K, and 100K larvae/gallon were evaluated for survival and maturity to settlement. Pediveliger metamorphosis occurred predictably from days 18 to 21 at 22^{0}C. Highest larval survival was observed at stocking densities between 20K and 30K larvae/gallon.

The Floating Upweller System (FLUPSY) design exceeded our expectations, delivering 189 ℓ/min. of upwelled water flow through each silo. The FLUPSY produced 20-22 mm animals in 2.5 months with near 100% survival. This reduced the grow-out time by up to three seasons compared to natural stocks. Soft-shell clams were stocked at high densities in upweller silos without a compromise in growth or survival, which reinforced the commercial application of the FLUPSY design. A design capacity of 100K (10 mm) seed clams per silo was determined, for a total capacity of 1 million (10 mm) seed clams per ten silo Floating Upweller System.

August field experiments were conducted at two sites in Kennebunkport, and one site in Portland, Maine to determine the added benefits of conditioning seed beds by harrowing. Soft bags similar to those used in the Florida quahog fishery were considered as a potential grow-out technique. Survival was a problem at all three sites. Netting, especially in the harrowed treatments at the Portland site, provided the best survival, and soft bags were found to be inappropriate, except, possibly in the softest muds.

Recognizing the potential and regional importance of soft shell clam farming, Spinney Creek Shellfish (SCS) has begun to address the administrative framework necessary for fostering this new commercial activity. SCS has drafted proposals for enhancing the existing framework along with the Maine Department of Marine Resources so that the best possible revised structure is in place at the point in time that this activity comes to full commercial potential.

In conclusion, the specific objectives were met, establishing this species as a candidate for commercial farming. The FLUPSY rapidly produced plantable seed clams with minimal maintenance, favoring scaling to commercial capacity. The bottleneck for this species was grow-out. Future research will include determining optimal planting size and sediment type, tidal height, tidal stage, and time of year for enhanced survival and growth.

THE ECONOMICS OF SEA SCALLOP GROW-OUT: AQUACULTURE AT AN OFFSHORE SITE. **Porter Hoagland, Hauke L. Kite-Powell** and **Di Jin**,
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The extent to which offshore sea scallop aquaculture is a commercially viable business depends upon both the costs of growing scallops relative to wild harvest operations and conditions in the relevant product market.

Here we report on the development of a discounted cash flow model of the grow-out of sea scallops at an offshore farm, such as that represented by the Westport Fishing Corporation's sea scallop experiment off the coast of Martha's Vineyard, Massachusetts. We examine the economic viability of four alternative approaches to scallop farming: seabed seeding and three variations on cage culture: lantern cages; bottom cage trawls; and bottom cage clusters. For each alternative, we estimate capital and operating costs and revenues over a 20 year period. We assume a two-year cycle from collection of juveniles to harvest, and scale the farming operation in every case to produce 100 thousand pounds of scallop meat per two-year cycle (that is, every other year).

Under baseline assumptions, the only alternative that is profitable is seabed seeding. A 100 thousand lbs/cycle seabed seeding operation requires less than $400 thousand in start-up capital and pays back the initial investment in four years. It requires a lease area of about 150 acres and requires the use of a large scallop vessel about 3 months out of the year, on average. The cage operations are not profitable because the higher survival rate and growth are not enough to justify the added cost of buying, maintaining, deploying, and harvesting the cages and associated moorings. Although they require smaller lease areas, the cage operations demand between $1-2 million in startup funding. Of the three alternatives, bottom cage trawls come closest to break even because gear costs are relatively modest.

There are several sources of uncertainty in the model, including the ex-vessel price for sea scallops. In order to help manage this uncertainty, we have estimated a model of supply and demand for New England sea scallops using monthly data during the period 1985-93. The model is a linear representation of both supply and demand for "average size" sea scallops, implying a market equilibrium over the 1985-93 period of $5.42 per pound.

It is useful to think of the production of scallops from an offshore farm as an inventory problem. At an offshore site, seed scallops grow over a period of about two years to a size that may command a premium over the average size scallop. We have developed a simple algorithm to help the farmer take advantage of historical monthly variability in sea scallop demand. If this variability persists, we find that when farm output is small relative to the market, the farmer should act as a price taker, harvesting and marketing his product only in January. As potential output increases, however, the time profile of output shifts. Output of up to 150 thousand pounds should be produced in January and November. When output reaches 200 thousand pounds, there should be some level of production in every month except July.

It is costly to monitor sea scallop mortality at an offshore site. Because of uncertainty about mortality, the time profile of production is suggestive of a strategy for harvesting the aquaculture product. It may be sensible to sample the product through partial harvesting, say, in October. This sample will give the farmer an estimate of mortality. If mortality is low, then a production profile that places product on the market in every month might be followed. If mortality is high, then production should be adjusted accordingly, and product would be placed on the market in November or January. Note also that the production profile can be readjusted during the year as market conditions become revealed and as uncertainty about the quality of the farmed product is reduced.

This research has been supported with funds from the Westport Fishing Corporation and the National Sea Grant College Program.

A TOUR OF UPWELLERS ON CAPE COD. Dale F. Leavitt, Patricia L. Gohring, and **William P. Burt,** Southeastern Massachusetts Aquaculture Center, c/o Hurley Library - Mass. Maritime Academy, 101 Academy Drive, Buzzards Bay, MA 02532

The use of upwelling culture systems for nursery grow-out of commercially important bivalve mollusks has become an important component of community and private shellfish aquaculture on Cape Cod. The nursery phase of bivalve culture is frequently a limiting step for bivalve seed production due to limitations in space and food availability in commercial hatcheries. A concerted effort has been made on Cape Cod to increase shellfish seed production by expanding the region's capability to raise seed through the nursery phase. During September, the Southeastern Massachusetts Aquaculture Center (SEMAC) conducted a tour of ten different upweller systems to investigate the design and operation of a variety of approaches to upwelling. The technical information compiled from these systems will be presented along with a pictorial display of various approaches to upweller design.

GROWTH CHARACTERISTICS IN TRIPLOID PACIFIC OYSTERS - A NEW DIMENSION. **Brenda Landau** and **Ximing Guo**, Rutgers University, Haskin Shellfish Research Laboratory, 6959 Miller Avenue, Port Norris, NJ 08349

Standard practice has been to measure length and whole weight of randomly sampled oysters as a means of documenting performance. During routine random sampling earlier, the observation was made that the height or thickness of triploid oysters compared to their diploid controls was noticeably larger. To test this hypothesis, an allometric study was done to compare four measurements, length, width, thickness, and whole weight of triploid oysters to those of their diploid controls for two different year classes, 1994 and 1995. The triploids were produced from a previous study by diploid x tetraploid matings. It has been previously documented that triploid oysters grow faster than diploids and that polyploid gigantism may, in part, account for the larger overall size, though thickness measurements were not used. A comparison of means shows triploids to be 17.0%, 19.7%, 42.8%, and 93.2% larger than their diploid counterparts for length, width, thickness, and whole weight, respectively, for the '94 year class; and, 5.1%, 12.2%, 25.2%, and 46.3% larger for the '95 year class. An analysis of variance for the general linear model in which group (triploid vs. diploid) and replicate (k=2) are main factors shows the group effect to be significant (p=0.000 to 0.002) in both year classes for each of the four measurements. Results of this study show that thickness, rather than length and width, is the primary dimension for the increased growth in triploid oysters. Consequently, triploid oysters are more deeply cupped than diploids. This study used only two replicates, so a follow-up study with more replicates is needed to confirm these results.

SUPERIOR GROWTH AS A GENERAL FEATURE OF TRIPLOID SHELLFISH: EVIDENCE AND POSSIBLE CAUSES. **Ximing Guo,** Rutgers University, Haskin Shellfish Research Laboratory, 6959 Miller Avenue, Port Norris, NJ 08349, USA

Triploids are organisms with three sets of chromosomes instead of the two sets found in normal diploids. Aquacultural interest in triploid shellfish so far has primarily focused on their sterility. The presence of an extra set of chromosomes poses a problem for meiosis and leads to complete or partial sterility in triploids. Because excessive gonadal development negatively affects meat quality of diploid molluscs, sterile triploids provide a high quality product that can be marketed year round. Triploid Pacific oyster is now widely used for aquaculture production. However, another important benefit of triploid molluscs, superior growth, has been largely overlooked by early studies and aquaculturists. During the past decade, triploids have been studied in over 20 species of molluscs. A review of recent data indicates that superior growth may be a general feature of triploid molluscs. Triploids exhibit significantly higher growth rate than diploids in almost all species studied so far. Triploids grow faster than diploids by 12-30% in *Crassostrea virginica*, 25-51% in *Crassostrea gigas*, 42-52% in *Crassostrea dalienwhanensis*, 72% in *Mulinia lateralis*, 27-58% in *Pinctada martensii*, 36% in *Argopecten irradians*, 32-59% in *Chlamys nobilis*, and 81% in *Chlamys farreri*. The adductor muscle of triploid scallops is larger than that of diploids, by 73% in *A. irradians*, 96% in *C. farreri*, and 167% in *Argopecten ventricosus*. The expression of the triploid advantage in growth may be influenced by genetic and environmental factors. Triploids may not show superior growth in food-limiting environments. Several hypotheses have been proposed to account for the superior growth in triploids. One hypothesis attributes the superior growth to increased heterozygosity in triploids. A positive correlation between heterozygosity and growth rate has been found in diploid molluscs. Triploids are theoretically more heterozygous than diploids. The heterozygosity hypothesis is supported by the observation that triploids produced from blocking polar body I and diploid x tetraploid mating, which are more heterozygous, grow faster than triploids produced from blocking polar body II. Another hypothesis views that sterility in triploids distributes more energy to growth rather than sexual reproduction. The energy relocation hypothesis cannot explain growth difference expressed before sexual maturation. Finally, it has also been suggested that triploid cells are larger than diploid cells and may contribute to an overall increase in body size. All these factors may contribute somewhat to the overall growth of triploids. Regardless of causes, triploid molluscs may benefit aquaculture by offering greatly improved growth. The challenge is that commercial production of triploids is technically difficult in most species. Commercial use of triploids may ultimately depend on the development of tetraploids, which can produce 100% pure triploids simply by mating with normal diploids. Tetraploids have been successfully developed for triploid production in the Pacific oyster, and success in other species may soon follow.

A SOCIAL AND ECONOMIC EVALUATION OF AN OYSTER MARICULTURE TRAINING PROGRAM FOR LONG ISLAND COMMERCIAL FISHERMEN. Steven Lang, York College, The City University of New York, 94-20 Guy Brewer Blvd., Jamaica, N.Y. 11451

Despite a long history of shellfish mariculture, numerous public shellfish enhancement programs, and large tracts of available and potentially productive underwater land, New York's mariculture industry remains stagnant. For the most part, the constraints on shellfish mariculture are social, political and economic rather than environmental or technological. By far, one of the major obstacles hindering the development of mariculture has been the antagonistic attitude of commercial fishermen who have a long history of being opposed to the private use of public underwater land. The history of shellfishing in Long Island has been filled with struggles and conflicts between small-scale commercial fishermen who harvest wild shellfish from the public resources and shellfish farmers who cultivate shellfish and are dependent upon a system of exclusive property rights.

At the present time, amidst a steady decline in the natural stocks and shrinking opportunities caused by several factors, some fishermen are beginning to reconsider their negative attitude towards mariculture. While a few fishermen place great hope in mariculture's potential to create new opportunities, most are skeptical. For the potential of mariculture to be realized, attitudes will have to change so that it is viewed as a legitimate marine activity by members of the commercial fishing community.

In 1995, through the East End Institute, funds were made available from New York State to establish an oyster mariculture training program for Long Island commercial fishermen to learn simple off-bottom culture techniques. In 1996, additional funds from the Fishing Industry Grants Program of the National Marine Fisheries Service were made available. Approximately 40 fisherman were given seed, culture gear, and informal training in oyster culture with the hope of them starting mariculture "cottage industries" that would supplement their incomes.

A major objective of the oyster mariculture training program was to encourage small-scale mariculture by changing attitudes on the part of fishermen who have traditionally been opposed to it. The operating logic of the training program was to create opportunities for a few fishermen to become successful so that other fishermen would become interested and pursue mariculture on their own. At the heart of the oyster mariculture training program is the notion that top-down development and management schemes initiated from distant external authorities are counterproductive and will not change negatives attitudes on the part of fishermen. Change has to emerge from within the fishing community and must be facilitated in non-threatening ways which encourage active participation on the part of fishermen. The long and difficult process of institutionalizing mariculture as a way of life has to be based on some type of co-management arrangement between fishermen and government agencies. Development schemes have to incorporate attitudes and concerns of fishermen and include them in project designs and management arrangements. If developed rationally and in ways that are socially acceptable, mariculture could help to preserve traditional fishermen and enable them to follow the water in their customary ways.

For the most part, the oyster mariculture training program has been successful. This paper will explore some of the reasons for that success as well as implications for the future of small-scale mariculture in the region.

THE TRANSITION FROM COMMERCIAL FISHING TO OYSTER CULTURE: RESULTS OF A NMFS FISHING INDUSTRY GRANTS PROJECT. Richard Langan, Jackson Estuarine Laboratory, University of New Hampshire, 85 Adams Point Rd., Durham, NH 03824

With support from the NOAA National Marine Fisheries Service Fishing Industry Grants Program, three New Hampshire commercial fishermen participated in a comprehensive oyster culture training program designed to give them an opportunity to evaluate shellfish culture as a part time alternative to wild harvest fisheries. The fishermen were provided with guidance and assistance with site selection, permitting, evaluation of oyster culture methodologies, three year classes of oyster seed, and the supplies and equipment needed to continue in aquaculture after project completion.

Culture methodologies included remote setting of hatchery-reared eyed larvae on natural and artificial cultch, suspension nursery culture, and bottom grow-out. Permitting woes, shortages of larvae, extreme weather events, an oil spill, the specter of MSX, and predation of oyster drills and green crabs were balanced by some excellent sets, good growth, and a positive production outlook and provided the fishermen with the opportunity to experience first hand the risks and opportunities of shellfish culture. Of the three fishermen that participated in the project, two will very likely continue with oyster culture.

PROGRESS IN BIOECONOMIC EVALUATION OF THE MILFORD LABORATORY SCALLOP NURSERY RECIRCULATING SYSTEM. **Gisele Magnusson** and **James Anderson,** Environmental and Natural Resource Economics, University of Rhode Island, Kingston, RI 02881

Costs and returns for a land-based recirculation nursery system for bay scallops (*Argopecten irradians*) were calculated and key economic factors affecting the financial viability of the system identified. The system under consideration was developed by the NMFS Milford Laboratory and incorporated a greenhouse for algae production with a re-circulating nursery to test several different filtration systems. A bioeconomic simulation incorporating the stochastic nature of key variables and the dynamic nature of an integrated production system was developed. Rudimentary hatchery and grow-out systems were incorporated to track costs and revenue impacts of various changes to the nursery system. Preliminary results of the model suggest that the average cost of algae from the greenhouse was within the range of published results. However, both the average cost of algae and the growth rate of juvenile scallops will have to change significantly to allow such a system to be financially viable. For the greenhouse system, labor, capital costs and nutrient costs are significant, while to the nursery, algae costs, labor and capital costs were most important. A value for automation systems can be calculated based on the potential savings in labor and nutrient costs, over the base case.

RECENT STREAMLINING OF THE AQUACULTURE REGULATORY PROCESS.

Michael Ludwig, USDOC, NOAA, National Marine Fisheries Service, Habitat Conservation Division, Milford, CT 06460

While aquaculture operations have been permitted and presently occur in the Gulf of Mexico, Atlantic and Pacific waters, initial permitting efforts for a given geographical area, a new culture species or innovative technology can be hampered by a lack of understanding among the applicant, regulators and other involved parties. In addition, the public is often confused by what they perceive as conflicting positions taken by the regulatory agencies. Their confusion often arises from a perception that the agencies are a single entity rather than consortiums of representatives from a variety of programs, each with different (and occasionally conflicting) mandates and responsibilities. The differing expectations of all involved parties about the amount or type of information needed to describe an aquaculture proposal before it is deemed ready for evaluation can result in costly and protracted reviews.

The National Marine Fisheries Service (NMFS) Northeast Region's Habitat Conservation and Protected Resources Divisions has consolidated much of the guidance offered to aquaculturists across the US and Canada. The document was created to establish a standard level of information quality for use in seeking federal authorization of aquaculture projects. The document is intended to be all encompassing and not the minimum required for permit consideration. The all-species package contains guidance from which parties in a regulatory action can select elements for use in application forums. It is our expectation that the document will become the standard for submissions of environmental compatibility and regulatory acceptability in the Northeast and provide a semblance of uniformity for regional evaluation processes. It is our intention that compliance with the entire guidance package would be required only on occasions when the ecological sensitivity of a proposed culturing site or other project details are so complex as to warrant that degree of thoroughness. By seeking out those involved in the regulatory process as early as possible in the development of a proposal and using tools such as pre-applications meetings, an applicant will be able to identify the project assessment requirements to which one will be held. This will greatly facilitate and even expedite a project's evaluation.

However, we recommend that before undertaking any data gathering or committing to any physical site evaluation efforts, the applicant seeks guidance and thoroughly coordinate planning and site evaluation efforts with the appropriate regulatory agencies.

The Guidance package will be described and made available at the meeting.

EARLY INDUCTION OF SPAWNING OF A CAPTIVE TAUTOG BROODSTOCK BY LIGHT AND PHOTOPERIOD MANIPULATION. **Grace Klein-MacPhee** and **Aimee Keller**, University of Rhode Island, Graduate School of Oceanography, Narragansett Bay Campus, Narragansett, RI 02882

Broodstock collected by hook and line from the east passage of Narragansett Bay, RI was maintained in the laboratory in an 8 foot, black fiberglass tank with running seawater, an airstone, and several PVC tubes for shelter. The tank was tented with black plastic, and a fluorescent light set on a timer maintained a photoperiod of 10 hours light and 14 hours dark (approximate ambient photoperiod for winter). Seawater was at ambient temperature and salinity from November 25, 1997 to March 17, 1998. The fish were fed chopped quahogs, live crabs and whole mussels daily throughout December then every other day through March 17. It was a mild winter and water temperatures averaged 7.4°C (range 5.5-9) for November-December and 6°C (range 3.8-7.8) for January - March. During this time the fish were relatively inactive, spending most of the time in their shelters with an occasional sortie around the tanks to feed.

On March 17, the water temperature was raised to 14°C and maintained at an average temperature of 13.4°C (range 10.7-16.6) through March 31. The photoperiod was changed over a period of a week from 10L / 14D to 13L / 11D. On March 31 the fish began to spawn. The first large batch of eggs was collected on April 2 and the progeny from this spawning were raised through juvenile stage. The juveniles are now 10 months old and are healthy and active fish. The broodstock continued to spawn with periodic resting states through November 1998.

Tautog spawn in Narragansett Bay from May through August with a peak in June and July. Ichthyoplankton samples collected in the bay in 1998 contained tautog larvae in June-August.

We successfully succeeded in advancing the spawning date to late March using temperature and photoperiod manipulation, and obtained viable eggs and larvae. We intend to repeat the experiment this year with the addition of a control tank of fish which will be maintained at ambient temperature and photoperiod, and we will begin inducing spawning in February.

SUMMER FLOUNDER CULTURE IN THE NORTHEAST: UPDATE ON RECENT RESEARCH AND INDUSTRY STATUS. **Gregg Rivara,** Cornell Cooperative Extension-Suffolk County, 3690 Cedar Beach Road, Southold, NY 11971; **David A. Bengtson,** Department of Fisheries, Animal and Veterinary Science, University of Rhode Island, Kingston, RI 02881

The Northeastern Regional Aquaculture Center and Sea Grant have been sponsoring research on summer flounder as an emerging aquaculture species in the Northeast. As part of outreach and extension efforts, a workshop is being held for industry just prior to the 19th Milford Aquaculture Seminar. Researchers are presenting their results to industry at that workshop and also describing the future research for which they have received funding. A roundtable discussion involving researchers and industry is also part of the workshop so that industry can describe their research needs. The industry is still small, but is making progress and starting to sell product. A summary of the workshop activities, major research findings and industry status will be provided to the participants at the 19th Milford Aquaculture Seminar.

THE POTENTIAL FOR BIVALVE AQUACULTURE IN MARYLAND'S COASTAL BAYS.
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It has been over a century since the coastal bays of Maryland supported a substantial public oyster fishery, nearly 30 years since hard clam catches peaked and then collapsed, and some 70 years since bay scallops even inhabited this region. Although a successful relay industry on private grounds was established for oysters after natural populations almost disappeared, it essentially ended about 50 years ago. Hard clams currently support only a remnant fishery, while, until this year, bay scallops had not been seen in the wild since the early 1930's.

There have been sporadic, and ultimately unsuccessful, attempts to culture oysters, hard clams, and bay scallops in the Maryland portion of Chincoteague Bay during the past seven decades. Oysters are particularly subjected to a hostile environment, related to environmental changes caused by the stabilization of the Ocean City Inlet in 1933. Three oyster parasites, Dermo, MSX, and SSO are active in the coastal bays, as are two species of highly abundant oyster drills. Any hard substrate placed into Chincoteague Bay is rapidly colonized by a variety of fouling organisms, including serpulid worms, colonial tunicates, hydrozoans, bryozoans, and barnacles. These factors tend to diminish the possibility of successful oyster aquaculture ventures in this region, with the possible exception of a rapid turnaround relay fishery.

Bay scallop culture has only recently been attempted in Maryland, although initial results are not encouraging. Through a Maryland DNR re-introduction project, growth and survivorship data are now available. Preliminary results indicate that growth rates may not be sufficient to produce marketable scallops before their second winter. Given the short life-span of this species and the labor involved in battling fouling organisms, bay scallop culture in Maryland has some serious problems to overcome.

Although Virginia has established a significant hard calm aquaculture industry, including production in Chincoteague Bay, few attempts have been made within Maryland's boundaries. The main impediment to hard clam culture appears to be associated with the permitting process, which includes three state agencies, five federal agencies, public hearings, and, on occasion, an appeals board. This daunting array of agencies, associated regulations, and opposition from waterfront property owners has attracted few individuals to the process. Environmental conditions in the Maryland coastal bays, however, appear to be sufficient to establish at least a modest hard clam aquaculture industry. There are areas outside Federal jurisdiction that provide clean, hard bottom for either planting bags or netting small beds of seed clams. Hatchery-reared clams are readily available from Virginia and there is a suitable, nearby market for hard clams.

UPDATING THE PLANS FOR SEA SCALLOP AQUACULTURE IN MASSACHUSETTS.
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The Sea Scallop Working Group (SSWG) was started five years ago to provide a forum for discussion of interests in aquaculture among various stakeholders. These discussions led to the development of a Blueprint for Sea Scallop Aquaculture in 1995. A SSWG summit meeting was held February 8-9 at the Massachusetts Maritime Academy to evaluate our progress to date on various sea scallop projects and to review the problems encountered. Through the use of breakout groups, the recommendations of the 1995 Blueprint were reexamined , and priorities set for SSWG activities in the coming year. The results of this summit meeting will be reviewed.

THE NEED FOR AQUACULTURE IN THE WORLD TODAY. **Robert Link**, Liquid Life Technologies, Inc., 1727 Veterans Memorial Highway, Islandia, NY 11722

This paper will describe components of the finfish and shellfish aquaculture industries while explaining the challenges and opportunities that exist in those industries. Although the aquaculture industry is growing at a rapid pace, there are some impediments that affect all parts which include: regulations, marketing, and financing. All of these components are necessary for healthy growth and will be discussed in detail.