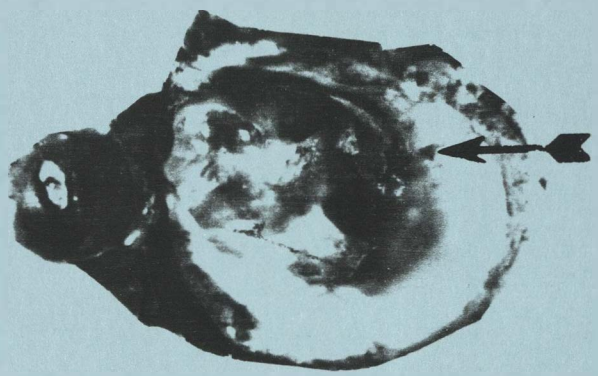
12th ANNUAL SHELLFISH BIOLOGY SEMINAR

FEBRUARY 24-26, 1992



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MILFORD LABORATORY
MILFORD, CONNECTICUT 06460

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Program Agenda

12th Shellfish Biology Seminar
February 24-26, 1992
Milford Howard Johnson's Lodge
Milford, Connecticut 06460

Monday, February 24, 1992

3 - 7:00 p.m.	Annual Meeting of NRAC Extension Workgroup	CHURCHILL ROOM
7 - 10:00 p.m.	**POSTERS AND RECEPTION**	HARBOR ROOM
	Auditing marina utilization by boaters	P. Stanton DeLeuw, Cather & Co. E. Hartford CT
	Effects of Alexandrium tamarense on the New Zealand mussel, Perna canaliculus	S. Shumway Dept. Mar. Res. Boothbay Harbor ME
	Variations in levels of paralytic shellfish toxins among individual surfclams (Spisula solidissima)	A. White NOAA/NMFS Woods Hole MA
	Overwintering survival of triploid and diploid American oysters	G. Shatkin Univ. of Maine Orono ME

Tuesday, February 25, 1992

8:45 a.m.	Historical Perspectives - Shellfish Biology Seminar	W. Blogoslawski Conference Chairman
9:00 a.m.	Unexplained mortalities in juvenile hatchery raised oysters	D. Relyea F.M. Flower & Sons Bayville NY
9:15 a.m.	A study of juvenile oyster mortalities at the F.M. Flower Co. Oyster Hatchery	R. Hillman Battelle Duxbury MA
9:30 a.m.	Unexplained oyster mortalities of hatchery-reared oysters, Crassostrea virginica, in the northeast: A preliminary study	F. Borrero SUNY Stony Brook NY
10:00 a.m.	COFFEE BREAK - POSTERS	CHURCHILL ROOM
10:30 a.m.	Infectious agent, Ulceratus spraguei g.n., sp.n. (Protista incertae sedis), associated with fatal disease in juvenile oysters, Crassostrea virginica, in New York waters	A. Farley NOAA/NMFS Oxford MD

Tuesday, February 25, 1992

11:00 a.m.	A theory on the life-cycle of Haplosporidium nelsoni (MSX)	R. Hillman Battelle Duxbury MA
11:30 a.m.	Monoclonal antibodies recognizing normal hemocytes cross reacts with a sub-population of leukemia cells, suggesting a common origin in Mya arenaria	R. Smolowitz MBL Woods Hole MA
12:00 p.m.	LUNCH	DICKENS ROOM
1:00 p.m.	The Northeastern Regional Aquaculture Center (NRAC): An update	H. Parker USDA Washington DC
1:15 p.m.	Introduction - Genetic improvement of Crassostrea virginica for commercial culture in the Northeast	J. Ewart Delaware Sea Grant Lewes DE
1:20 p.m.	Resistance of oysters to MSX-disease: An overview	S. Ford Rutgers Univ. Port Norris NJ
1:45 p.m.	Growth, survival, and disease levels in MSX-disease resistant and susceptible oysters at four locations in the northeastern United States, 1988-1991	S. Ford Rutgers Univ. Port Norris NJ
2:10 p.m.	Genetics of growth and survival diploid and triploid MSX-disease resistant, susceptible, and hybrid Crassostrea virginica	S. Allen, Jr. in Rutgers Univ. Port Norris NJ
2:40 p.m.	Selection for growth rate in the American oyster	R. Hawes Univ. of Maine Orono ME
3:10 p.m.	BREAK - POSTERS	CHURCHILL ROOM

3:30 p.m. **Panel Discussion on Future Application of Genetics to Commercial Oyster Culture in the Northeast**

S. Ford, Rutgers Univ., Port Norris NJ
S. Allen, Rutgers Univ., Port Norris NJ
P. Gaffney, Univ. of Delaware, Lewes DE
H. Parker, USDA, Washington DC
D. Walsh, Aqua. Res. Corp., Dennis MA
D. Relyea, F.M. Flower & Sons, Oyster Bay NY
W. Canzonier, Maurice River Cove Oyster Found., Port Norris NJ

6:00 p.m. DINNER DICKENS ROOM

Wednesday, February 26, 1992

9:00 a.m.	Are Prorocentrum strains toxic to bivalve mollusks? Evidence from field and laboratory studies	G. Wikfors NOAA/NMFS Milford CT
9:25 a.m.	Phytoplankton pigments accumulated by the Arctic surfclam, Mactromeris polynyma	B. Smith NOAA/NMFS Milford CT
9:45 a.m.	COFFEE BREAK - POSTERS	CHURCHILL ROOM
10:00 a.m.	Towards a method for predicting oyster growth rates in the field	K. Kurkowski VIMS Gloucester Pt VA
10:30 a.m.	Polyculture of the American oyster and striped bass in an estuarine environment	F. Wishner Hofstra Univ. Hempstead NY
11:00 a.m.	Integrated kelp and bay scallop aquaculture in China	C. Yarish UCONN Stamford CT
11:30 a.m.	Bay scallop management methods	R. Karney M.V. Shellfish Group Martha's Vineyard MA
11:45 a.m.	Distribution of hard clam (Mercenaria mercenaria) abundance and larval dispersal in the eastern Great South Bay: Implications for recruitment	J. Kassner Town of Brookhaven Medford NY
12:15 p.m.	LUNCH	DICKENS ROOM
1:00 p.m.	The Beals Island regional shellfish hatchery: Public aquaculture downeast	B. Beal University of Maine Machias ME
1:30 p.m.	Declining habitat in Norwalk Harbor	R. Harris Harbor Watch Westport CT
2:00 p.m.	Impact of pipelaying on Long Island Sound shellfish beds	M. Ludwig NOAA/NMFS Milford CT
2:30 p.m.	Municipal management of shellfish resources	P. Bagnall Shellfish Department Edgartown MA
3:00 p.m.	BREAK	CHURCHILL ROOM

Wednesday, February 26, 1992

3:30 p.m.	The final conclusions of the 1990 shellfish register	E. Slaughter NOAA/NOS Rockville MD
4:00 p.m.	Shellfish safety: Communicating with the media and consumer	L. O'Dierno New Jersey Department of Agriculture Trenton NJ
4:30 p.m.	Observed increases in the abundances of the Asiatic clam, Corbicula fluminea Moller, in the lower reaches of the Connecticut River	D. Morgan Northeast Utilities Environmental Lab. Waterford CT
5:00 p.m.	Impact of the Asiatic clam on the Potomac Estuary: Cusp catastrophe model	H. Phelps University of the District of Columbia Washington DC
5:30 p.m.	Concluding remarks	W. Blogoslawski Conference Chairman

Thursday, February 27, 1992

9:00 a.m. to 4:00 p.m.	TIAC Meeting - NRAC	CHURCHILL ROOM

Auditing Marina Utilization by Boaters

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Until recently little empirical data existed concerning the daily use of marina resources during the boating season. Despite this, assumptions have been made as to the potential environmental impacts associated with marina operations. In an effort to fill this void, environmental auditing procedures were used to determine and evaluate boating activity at a typical Connecticut marina. Seasonal boating activity varied with time of day, day of week, and weekdays compared to holidays. Variations in seasonal weather conditions (wind, rain, temperature) and sea conditions did not deter boating activity. Most boats had a USCGS Type II sanitation device. Landside toilets were used 85% compared to use of on-board heads while boats were occupied at dockside. Vehicle parking at the marina varied with boating activity, increasing throughout the day, on weekends, and on holidays. Neither the ratio of the number of autos parked per boats in use nor the cars parked per berth varied significantly from the U.S. national average. Marina planning may also be facilitated as a result of the audit.

Monday, 7 - 10:00 p.m. POSTER

Effects of Alexandrium tamarense on the New Zealand Mussel, Perna canaliculus

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Sandra E. Shumway

Department of Marine Resources
and
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New Zealand mussels, Perna canaliculus, were maintained in quarantine conditions with low food availability. Opening behavior and byssus production over 24 h were measured at approximately 5 day intervals over a 30 day experimental period. At 20°C, mean byssus production ranged from 3.43 to 6.17 threads per day. Byssus production decreased with time corresponding to changes in the dry weight condition index. Individual P. canaliculus were exposed to bloom conditions (10^5 cells L^{-1} of Alexandrium tamarense (GT429, toxic; PLY173, non-toxic). Mussels readily consumed both clones and grazing rates were similar to those recorded for Mytilus edulis feeding on GT429. There was no significant difference in byssus production or opening behavior between experimental groups and mussels produced normal feces within 24 h. The results suggest that P. canaliculus does not have a mechanism to isolate itself from potentially toxic dinoflagellate blooms. It remains open with the mantle extended and maintains its filtration rate in the presence of GT429. Following 2 weeks exposure, mussels showed no adverse effects of GT429 on grazing activity. Oxygen uptake of individual P. canaliculus (dry weights 54-127 mg) was measured prior to exposure to GT429 or PLY173, after 1 h exposure and following 24 h recovery period. Oxygen uptake was similar for all conditions and time intervals, with no significant short-term effect on oxygen uptake. Like other mussels, continued exposure to GT429 results in accumulation of toxins to levels unsuitable for human consumptions (> 80 μg saxitoxin equivalent/100 g tissue). Following twice daily exposure to bloom conditions of GT429, tissues of P. canaliculus accumulated toxins at levels (1295 μg STX equiv/100 g) equivalent to the highest previous level recorded for field collected Mytilus edulis in Boothbay Harbor (1518 μg STX/100 g).

Variations in Levels of Paralytic Shellfish Toxins Among Individual Surfclams (Spisula solidissima)

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Julianne Nassif
David K. Whittaker

Massachusetts Department of Public Health
Boston, Massachusetts 02130

A knowledge of the variation in biotoxin levels among individual shellfish in the same area is important for ecological and physiological considerations and is necessary for developing statistically sound testing protocols for fisheries management and public health purposes. Since 1989, surfclams (Spisula solidissima) from Georges Bank in the Gulf of Maine have contained high levels of paralytic shellfish toxins. Monitoring studies of toxin levels in these large animals from August 1990 until May 1991 included 21 sets of replicate tests of individual animals collected from several locations in the vicinity of Cultivator Shoals and Georges Shoal. Mouse bioassay tests were conducted on individual, whole surfclams (n = from 6 to 40, mostly 10) taken at random from dredge hauls covering 200 to 700 m. Shell lengths ranged from 11 to 17 cm. Mean toxin levels of the 21 sets ranged from 340 to 3,360 μg/100g; the overall mean was 1370 μg/100 g. The variation in toxin content was such that the standard deviation for each set ranged from 19 to 62% of the mean value of the set. There was a tendency for the degree of variation among individuals to decrease as toxin levels increased. The degree of variation found here among individual surfclams is in general agreement with the few reports that consider the variation in paralytic shellfish toxin levels among individuals of other shellfish species. There was no significant correlation between toxin level and shell length over the size range tested.

Monday, 7 - 10:00 p.m. POSTER

Overwintering Survival of Triploid and Diploid American Oysters

Greg M. Shatkin
Robert O. Hawes

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Standish K. Allen, Jr.

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In the Damariscotta River, Maine, oysters are frequently grown in floating trays as juveniles. To avoid freezing in winter, these immature animals are stored in one of several ways: at high salinity oceanic sites, on bottom, or in cold humid air. Triploid and diploid control oysters were overwintered at a high salinity site at the Darling Marine Center, Walpole, Maine and underground in cold, damp storage at Mook Seafarms, Damariscotta, Maine. As a control, replicates were held in a recirculating seawater system at a constant temperature of 12°C. The oysters ranged from 3-10 mm and were divided into 9 groups of 800 triploids and 9 groups of 800 diploids. Three replicates of each genetic type were overwintered at each of the three locations. There was no change in percent moisture in cold, moist winter storage. Shell length, mortality and percent triploidy were determined at the initiation and the termination of winter storage and one month later. Unexpectedly, we found diploids growing in the "triploid" groups larger than diploid controls. Oysters overwintered on land experienced faster subsequent growth than did those stored in water. Oysters held in native waters suffered lower mortality than did those at the other two locations. Finally, we found no differences in overwinter survival between triploids and diploids.

Tuesday, 8:45 a.m.

Historical Perspectives - Shellfish Biology Seminar

Walter J. Blogoslawski

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National Marine Fisheries Service
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The first meeting of the Milford Shellfish Biology Seminar occurred in 1975 as a technical exchange between disease staff at Milford Lab and shellfish managers of the F.M. Flower Company, Bluepoints Company, and Long Island Oyster Farms. There were nine industry attendees along with six staff from the NMFS Milford Lab. The meeting was held in the library/conference room at the laboratory. In future years the forum broadened in technical scope covering topics like algal rearing, genetics, and water quality control, but kept the basic format until 1980 - a technical exchange from Government scientists to shellfish industry representatives.

Since then, the scope of the seminar expanded to include presentations of shellfish scientists from Sea Grant, universities, the state and other Federal Government agencies as well as the commercial aquaculture companies. Because of the large number of attendees, the meeting moved to its present location.

The primary purpose of these annual gatherings of shellfish biologists is to share current ideas and methodologies in shellfish research. The ideas exchanged are cross-fertilized through multi-disciplinary discussions and eventually turned into research publications. The seminar series often serves as a springboard for national and international shellfisheries meetings.

Past seminars have discussed the effects of coastal development and increased urbanization--emphasizing how those trends have served to reduce shellfish habitats. Other topics have included how sewage and industrial pollution have adversely affected the survival of larval shellfish. In addition, various aquaculture techniques been presented.

Recent meetings of the Shellfish Biology Seminar at Milford have provided information concerning the adverse impacts of toxic shellfish blooms; the use of marinas for aquaculture under appropriate conditions; advanced aquaculture techniques and enhanced natural recruitment methods for replenishing shellfish stocks; and genetic methods to increase survivability of the Eastern American oyster, Crassostrea virginica, which is currently being adversely affected by oyster diseases termed MSX and Dermo in Chesapeake and Delaware Bays.

Tuesday, 9:00 a.m.

Unexplained Mortalities in Juvenile Hatchery Raised Oysters

David Relyea

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During the summer of 1991, Frank M. Flower & Sons experienced significant die-off of 1/4" - 1" juvenile oysters (Crassostrea virginica) in a grow-out raft system located at Mill Neck Creek, NY. These mortalities took place in June, July, and August and resulted in loss of more than 65% of the year's production. The die-off was identical in nature to the die-off experienced in July and August of 1990 and reported at the 11th Annual Shellfish Biology Seminar in 1991. Many qualified scientists have observed the problem and have spent considerable time researching it. All agreed that the oysters were dying as a result of lesions in the mantle area. There are varied opinions on what caused those lesions.

Tuesday, 9:15 a.m.

A Study of Juvenile Oyster Mortalities at the Frank M. Flower & Sons Oyster Hatchery

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Samples of juvenile oysters, collected from the Frank M. Flower & Sons hatchery from early July through mid-November 1991, were examined histologically for possible causes of mortalities suffered by juvenile oysters in the hatchery over the past two years. Histological examination showed typical inflammation and lesions primarily at the basal aspect of the pallial epithelium in connective tissue and in the pallial space, in some cases involving relatively limited areas of necrotic pallial epithelium. The lesions consisted of infiltrating blood cells, and, in the more advanced lesions, rounded detached epithelial cells. A few lesions showed necrosis occurring at the apical aspect of the epithelial cells, while the basal portion remained intact. In some cases, larger "round cells" could be seen, mostly in the pallial space, along with hemocytes, phagocytes, bacteria, and necrotic debris. The sub-epithelial inflammation occurred under extended areas of the epithelium, but the lesions of the pallial epithelium were focal and limited in extent. The focal nature of the lesions, and the necrosis at the apical portion of the epithelial cells in the early lesions, suggests that an irritating stimulus gains entry to the oysters either through breach of the ligament, between the mantle edge and shell margin, or through the shell. Although entry through the shell would be more consistent with the focal occurrence of the lesions, no indication of shell penetration was observed. The lesions are similar to those observed in other studies to be caused by bacteria, but at this point, no definite etiology has been determined.

UNEXPLAINED OYSTER MORTALITIES OF HATCHERY-REARED OYSTERS, *Crassostrea virginica*, IN THE NORTHEAST: A PRELIMINARY STUDY.

Borrero, Francisco J.[1], **Bricelj**, V. Monica[1], **Ford**, Susan E.[2], **Perkins**, Frank O.[3] [1] Marine Sciences Research Center, SUNY, Stony Brook, NY 11794. [2] Haskin Shellfish Research Laboratory, Rutgers University, Port Norris, NJ 08349. [3] School of Marine Sciences, VIMS, Gloucester Point, VA 23062.

Heavy, unexplained summer mortalities of hatchery-reared oysters have been experienced in the past 3-4 years by commercial oyster growers from several northeastern states. In order to provide an initial data base for characterization of the timing, magnitude, characteristics, and environmental parameters correlated with these mortality events, a detailed sampling program of the performance of juvenile oysters was conducted throughout the summer of 1991. This program was implemented in collaboration with two oyster growers in New York: Flower & Sons, Bayville, and The Clam Farm, Fisher's Island. At each site, replicated groups of 2 age classes (small and large) of juvenile oysters were sampled every 2 weeks starting in mid-June. Stocking densities and routine handling were similar to standard commercial practices at each site, but no culling was performed. A parallel sampling of low density control groups was carried out to assess the potential effect of typical high density culture methods. A third oyster group, composed of oysters from the same year class that set later in the season ('June set') was sampled weekly at Flower & Sons. At each date, subsamples were collected for assessments of cumulative mortality, shell height, tissue weight, condition index, size of dead oysters, incidence of mantle retraction, and for pathological condition including screening for potential pathogens. In addition, water temperature and salinity data were recorded.

At Flower & Sons, heavy mortalities of both oyster cohorts occurred during the month of July (57% by late July), when water temperature was highest (24-25 °C). Mortality among the low density controls coincided in time, but reached lower levels (about 30%). No further mortality was observed among these oysters. Mortality does not appear to be clearly correlated with maximum temperatures, since the June cohort exhibited mortality 3-4 weeks later (reaching 75% by late August) when water temperature was 20-22 °C. Furthermore, earlier sets at this hatchery first exhibited heavy mortality in the first week of July, when water temperature reached about 22 °C. Visual examinations for potential predators including the flatworm *Stylochus* sp. indicated that mortalities were not due to predation. The rates of growth in both shell and tissue decreased prior to the mortality events, and resumed high levels subsequently. Histopathological examination of samples collected immediately before the start of mortalities showed that 80% of the oysters had mantle inflammation, sloughing of mantle epithelium, or both. This was followed by mantle retraction, abnormal conchiolin deposition on the inner shell, coincident with peak mortalities. No causative agent has so far been identified by either light or electron microscopy, although bacteria were present in some lesions.

Tuesday, 10:30 a.m.

Infectious Agent, Ulceratus spraguei g.n., sp.n. Protista incertae sedis), Associated with Fatal Disease in Juvenile Oysters, Crassostrea virginica, in New York Waters

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Mortalities of juvenile oysters began in Long Island Sound in 1989 and continue to the present time. Dying oysters to 25 mm in length had mantle recession and conchiolinous shell deposits, primarily on the cup valve. A sample of juvenile oysters from Long Island Sound revealed ongoing 30% mortality and variable-sized, spherical organisms *in vitro*. Histology showed mantle ulcerations associated with protistan organisms 1-20 μm in diameter. Schizont and merozoite-like stages were also found. These organisms have not been observed before and tentatively have been named *Ulceratus spraguei* g.n., sp.n. (Protista incertae sedis) and described in this communication. Mixed (hyaline hemocyte/phagocyte), infiltrative, inflammatory lesions occurred in the connective tissue underlying ulcers. Early lesions showed cytozoic parasitic invasion of mantle epithelial cells. A fungus, possibly a secondary invader, was found to be associated with the conchiolin deposits but was not found in tissues.

Tuesday, 11:00 a.m.

A Theory on the Life Cycle of Haplosporidium nelsoni (MSX)

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In spite of more than 30 years of extensive research on the oyster parasite Haplosporidium nelsoni (Haskin, Stauber, and Mackin 1966), there remains considerable uncertainty about its life cycle, including a lack of knowledge of the actual infective stage. It is theorized here that the infective stage is the single-cell ameboid stage. In the ameboid form the parasite might live freely for a time on the oyster bed and/or in the host oyster. In the host oyster, it perhaps could reproduce by normal binary fission until certain environmental factors, such as low oxygen tension, bring about anaerobic metabolism in the oyster. The anaerobic conditions would produce certain metabolites which could induce the sporulation cycle producing the commonly observed plasmodia. For an as yet unexplained reason, the sporulation cycle appears to go to completion only in the oyster's digestive tubules. This theory can be used to explain a number of observations of the disease in oysters, including but not being limited to, the lack of a need for extensive sporulation, the lack of a need for a diminishing of the supply of infectious stages with the reduction of the oyster populations, the inability to transmit the disease in the laboratory, extensive plasmodial formation without any apparent empty spore cases being seen in the tissues, and the lack of a need for an alternate host (although an alternate host need not be ruled out).

Tuesday, 11:30 a.m.

Monoclonal Antibodies Recognizing Normal Hemocytes Cross Reacts with a Sub-Population of Leukemia Cells, Suggesting a Common Origin in Mya arenaria

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An endemic disease in Mya arenaria has been variably termed hematopoietic neoplasia, leukemia, or sarcoma and is found in high prevalence in New Bedford Harbor and at lower prevalence in other coastal areas of the northeastern United States. Neoplastic cells are first noted within the circulatory system. The disease is often progressive, invasive, and causes the death of the clam. Diagnosis is accomplished by examination of paraffin embedded tissues and by cytological or immunocytological hemolymph examination. We have previously described two monoclonal antibodies specific for Mya arenaria cells. MAb 1E11 specifically recognizes neoplastic cells, and MAb 4A9 recognizes both neoplastic cells and a subpopulation of normal hemocytes. Additionally, MAb 4A9 recognizes most sinus lining cells in tissue sections of severely diseased clams, and rarely, sinus lining cells in normal clams. Examination of fluorescence-tagged circulating hemolymph cells with a cell sorter demonstrates that a new antibody, MAb 2A4, recognizes 89% of normal cells and 27% of the neoplastic cells. Additionally, MAb 2A4 recognizes most sinus lining cells in normal clam tissue secretions. Western blot analysis of the normal clam hemocyte protein tagged by MAb 2A4 identifies a subunit molecular weight protein of 130 kDA which differs from the 100 and 150 kDA protein subunits identified by MAb 1E10 (a sister antibody to MAb 1E11) in neoplastic cells. We propose that the neoplastic cells share a common origin with normal hemocytes, and the cell of origin is related to the sinus lining cells.

Tuesday, 1:00 p.m.

The Northeastern Regional Aquaculture Center: An Update

Henry S. Parker

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The Northeastern Regional Aquaculture Center (NRAC), headquartered at the University of Massachusetts Dartmouth, is one of five Regional Aquaculture Centers (RACs) established by the U.S. Congress. Funded by the U.S. Department of Agriculture at an annual level of approximately $750,000, and representing 12 states and the District of Columbia, NRAC develops and sponsors cooperative regional research and extension projects in support of the aquaculture industry in the northeastern United States.

A Board of Directors representing the region's aquaculture industries, academic institutions, and government agencies provides overall direction and management of NRAC. NRAC programs, like those of all the RAC's, are industry-driven; i.e. industry annually communicates research and technology transfer priorities to NRAC through the Center's Industry Advisory Council. In assessing priorities, NRAC works closely with State Aquaculture Associations. Projects supported by NRAC are developed and carried out by the Cooperative Regional Work Groups representing a team of highly qualified researchers, extension specialists, and industry representatives who agree to work together to address the industry priorities. All projects include funding for technology transfer. NRAC's Technical Committee provides technical oversight. Projects are evaluated annually for achievement of technical and industry objectives.

NRAC is presently supporting twelve regional projects. Project areas include finfish nutrition, oyster genetics and reproductive biology, fish health, aquaculture waste management, government regulations affecting aquaculture, finfish economics, and development of a regional aquaculture extension program. NRAC recently approved four additional projects in the areas of marketing, oyster larval development and mortality, striped bass domestication, and a northeastern aquaculture industry situation and outlook report. Total NRAC funding commitment to projects in progress or pending exceeds $3 million. NRAC also publishes "Northeastern Aquaculture", a quarterly newsletter highlighting NRAC projects and other topics of interest to the northeastern aquaculture community.

Resistance of oysters to MSX disease: an overview

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At a practical level, basic understanding of resistance to disease in commercial species is important because it may help design strategies for developing or improving resistant strains or for modifying growing conditions to minimize losses. Our objective was to examine certain physiological and biochemical differences, at cellular and whole animal levels, between MSX-resistant and susceptible oysters that might be potential resistance mechanisms. We concentrated on 1) physiological processes associated with energy metabolism, 2) soluble components of hemolymph including agglutinins and enzymes, and 3) in vivo and in vitro hemocyte responses to the parasite, Haplosporidium nelsoni, which causes MSX disease. The general conclusions of the study were as follows:

1) During periods of rapid initial infection proliferation and mortality in susceptible stocks, susceptible oysters were significantly less efficient energetically than resistant animals. The surviving 20% of the susceptible group (which by definition were more "resistant" than the 80% that had already died) were able to compensate physiologically for the presence of the parasite.
2) Hemolymph agglutinins for bacteria, human red blood cells, and latex beads were generally higher in resistant than in susceptible strains, but there was no evidence that agglutinins were associated with survival in individual oysters challenged by H. nelsoni or Perkinsus marinus, the causative agent of Dermo disease.
3) There was no evidence that serum enzymes were involved in resistance to MSX disease.
4) In vitro experiments demonstrated that phagocytosis of H. nelsoni by hemocytes of both resistant and susceptible oysters is very low (<5%).
5) Total and differential hemocyte counts in oysters exposed to H. nelsoni were associated with both infection intensity and genetic background, suggesting that hemocytes may be involved in wound repair of surviving oysters.
6) Commonly proposed defense mechanisms in molluscs (phagocytosis, agglutination, or extracelullar enzymatic destruction of pathogens) do not operate against H. nelsoni and we should look elsewhere for the basis of differences between resistant and susceptible stocks.

NJAES Publication No. K-32501-2-92

Tuesday, 1:45 p.m.

Growth, Survival, and Disease Levels in MSX-Disease Resistant and Susceptible Oysters at Four Locations in the Northeastern United States, 1988-1991

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Harold H. Haskin

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During the period June 1988 through May 1991, six different MSX disease-resistant oyster strains were evaluated and compared with unselected controls at four locations in the northeastern United States: Wellfleet and Cotuit Harbors, MA; Delaware Bay, NJ, and Chesapeake Bay, MD. Growth, survival, parasitic disease (MSX and Dermo), and soft tissue condition were measured in all groups. The objective was to determine whether MSX-resistant strains, developed by Rutgers in lower Delaware Bay where MSX disease is the overwhelming selective agent (only 5-10% survival of susceptible stocks), would perform well in other locations where MSX disease is not as heavy or where other factors, including Dermo disease, are important. In addition to differing physical conditions at each site, disease pressure varied among locations during the 3-year period, ranging from little or none from either MSX or Dermo, to heavy pressure from only one, to high pressure from both. This variability provided an excellent set of natural conditions for the evaluation. The major conclusions of the testing were as follows:

1) When MSX disease alone was present at all sites, relative performance (measured as overall yield of oyster biomass) was the same at all locations; the MSX-resistant strains outperformed the unselected control stocks by margins of 1.4 to 3.1.

2) When both MSX and Dermo diseases were present, an MSX-resistant strain had nearly twice as many survivors as the local control oysters.

3) When Dermo disease alone was present, MSX-resistant strains did no better than controls.

4) When neither disease was present or heavy (<30% incidence), the MSX-resistant strains performed about the same as controls.

5) A hybrid between a fast-growing, moderately MSX-resistant strain and a more resistant, slower-growing strain outperformed either pure line.

6) Evidence of inbreeding depression in one of the resistant strains has become apparent and may be responsible for failure of the line during recent field trials.

Tuesday, 2:10 p.m.

Genetics of Growth and Survival in Diploid and Triploid MSX-Disease Resistant, Susceptible, and Hybrid Crassostrea virginica

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In the summer of 1990, American oysters from an MSX-disease resistant strain (R) and an MSX-susceptible population (S) were crossed in a full factorial mass spawn to produce four diploid and four triploid crosses: RR, RS, SR, SS and RRR, RRS, SSR, SSS. The following season these groups were weighed, measured, examined for infection by the parasites Haplosporidium nelsoni (MSX) and Perkinsus marinus (Dermo) and assayed for change in proportion of triploids. Mortalities in all groups were related to heavy infections of MSX, but not Dermo. The order of survival in the crosses was as follows: RR=RRR>RS=RRS=SR=SSR>>SS=SSS, indicating that (1) diploid and triploid oysters survived equally well in the face of disease pressure and (2) survival of hybrid crosses was higher than the mid-point between pure resistant and susceptible crosses. Survival of triploids was analyzed in more detail by examining the change in the proportion of triploids within the triploid crosses themselves: slight but significant changes occurred through the study period. Growth rate in triploids was greater only during periods of gametogenesis.

Tuesday, 2:40 p.m.

Selection for Growth Rate in the American Oyster

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In 1986 the University of Maine commenced a selective breeding program for genetic improvement of the American oyster. This work is now part of a regional effort toward improving shellfish stocks through genetic manipulations as coordinated by the Haskin Shellfish Research Laboratory, and sponsored by the U.S. Department of Agriculture's Northeastern Regional Aquaculture Center.

Preliminary information for the first (1988) selected generation of animals from the Milford "High Line" and a Rutgers University "MSX resistant" line show increases of 35.5% and 42.0%, respectively, in total weight for the selected vs. the control populations, at seven months of age.

A random sample of broodstock was taken from 3 lines of oysters and subdivided into "control" and "select" groups. These lines had been evaluated for pure line performance at 18 months of age in the fall of 1987. The control group was composed of animals representing an equal distribution of all weight classes based on whole wet weight at 18 months of age. The select group consisted of the remaining animals from the top 20% of the population. Animals were spawned in April or July, 1988, and reared for two growing seasons in floating, screened trays in the Damariscotta River, Maine. The mean maximum summer temperature at the growing site was 21°C.

A summary of the cross-line performance and the performance of selected animals will be presented.

Wednesday, 9:00 a.m.

Are Prorocentrum Strains Toxic to Bivalve Mollusks? Evidence from Field and Laboratory Studies

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During the summer of 1987, western Long Island Sound (LIS) experienced an exceptionally widespread and persistent phytoplankton bloom composed primarily of several species from the dinoflagellate genus Prorocentrum. At two western LIS research stations established as part of Milford's hard clam study program, growth rates of caged hard clams were severely inhibited during the bloom. In contrast, clams at an eastern station not affected by the bloom grew rapidly during the summer.

Laboratory studies were conducted subsequently to investigate the hypothesis that Prorocentrum strains interfere with bivalve growth. Two Prorocentrum isolates were mass cultured and fed, alone and in combination with a standard molluscan food alga (T-ISO), to post-set juvenile hard clams, Mercenaria mercenaria, and bay scallops, Argopecten irradians. Clams filtered all algal diets and survived well for 10 weeks. Clam growth was relatively rapid on T-ISO and T-ISO/ P. micans, and mediocre on P. micans alone. Clams fed mixed T-ISO/P. minimum did not grow.

Unfed scallops showed incremental mortality to 100% in five weeks; whereas, T-ISO, P. micans, and T-ISO/P. micans supported 50% survival after ten weeks. Feeding scallops the combined diet of T-ISO/P. minimum caused 100% mortality in one week in one trial, and in four weeks in a second. P. minimum depletion from suspension, and observation of P. minimum cells in the stomach, showed that scallops ingested this dinoflagellate. Histological observations of scallops sampled after one week of feeding T-ISO/P. minimum revealed appreciable differences from scallops feeding on natural phytoplankton. In P. minimum-fed scallops, digestive diverticula were poorly developed and showed attenuation of the epithelium with abnormal vacuolation and necrosis. Residual cells were more numerous. These findings, and the presence of large thrombi in the open vascular system of the mantle, digestive diverticula, heart, gill and kidney tissues, suggested the systemic effects of a toxin.

Wednesday, 9:25 a.m.

Phytoplankton Pigments Accumulated by the Arctic Surfclam, Mactromeris polynyma

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The Arctic surfclam, Mactromeris polynyma (previously Stimpson's surf clam, Spisula polynyma), is an oceanic, infaunal bivalve with a distribution encompassing both north American coasts. Although historically unimportant as a commercial species in America, a modest fishery for this clam has developed recently in New England, based upon a high-value market in Japan. The value of this clam is attributed to the bright red color of the foot, which becomes apparent when cooked and is prized for use in sushi dishes. The nature of pigments responsible for the color, deep purplish red in life, had not been investigated.

Dissection of clams, landed commercially in Gloucester, MA, revealed that pigment-containing cells appear to be restricted to the epithelium of the foot, siphon, and mantle edge. These organs were analyzed for pigments using UV/visible spectrometry and HPLC with detection and quantitation by a UV/visible spectrophotometer. Ninety-percent acetone extracts of M. polynyma foot tissue showed an absorbance peak at about 430 nm -- presumptive evidence of carotenoid pigments of phytoplankton origin. Initial analysis by HPLC revealed that α and β carotene represented only minor components in M. polynyma foot, mantle, and siphon tissues; whereas, several xanthophyll pigments were present in relatively high concentrations. Because HPLC methods employed initially could not resolve the relatively fast-eluting xanthophylls, modified methods were developed. Several xanthophyll pigments were identified in M. polynyma tissues, based upon comparisons of clam extracts with cultured algae having known pigment profiles.

Potential applications of this information include deducing components of phytoplankton communities supporting offshore benthic communities based upon the presence of algal taxa-specific pigments in clams. More pragmatically, it may be possible to ensure even pigmentation of commercially-landed clams by applying a "finishing-tank" treatment in which clams are fed cultured phytoplankton containing the appropriate pigments.

Wednesday, 10:00 a.m.

Towards a Method for Predicting Oyster Growth Rates in the Field

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Variations in growth rates of oysters (*Crassostrea virginica*) between field locations, even those well within basic physiological limits, can be considerable. Explaining the source of this variation is of general ecological interest, and selecting good growing sites is imperative to the further development of oyster aquaculture.

We are presently involved in efforts to develop an *a priori* predictive model of oyster growth rates based upon physical parameters (e.g. salinity, temperature, D.O.) and the quantity and quality of food available at a site. For two consecutive years we have conducted field experiments at a number of sites (6 in the first year and 10 in the second) to evaluate the contribution of food flux to oyster growth. In each year, hatchery-reared oysters from a single cohort were used in a 30-d field experiment to assess shell and tissue growth rates at each site. During two 48-hr intensive sampling periods, concentrations of Chl *a*, phaeophytin, POC, PON, total suspended load, and total particulate organics were measured at all sites, and relative water flows were estimated using the dissolution rates of chlorine tablets. Multiple regression was used to explore the relationship between growth and water flow, seston concentration and seston composition. In our first year's experiment, we were able to explain as much as 93% of the observed variations in growth between sites, based upon this *a posteriori* approach. The second year's study is being used to test predictions based upon the first year's results and to refine the model.

Our findings suggest that relatively simple, short-term estimates of the quantity, quality and flux of food at a site may be used to provide reliable predictors of oyster growth rates in the field.

Wednesday, 10:30 a.m.

Polyculture of the American Oyster and Striped Bass in an Estuarine Environment

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It has been suggested that finfish and shellfish can live in a symbiotic relationship. We attempted to show that a cage of fingerling striped bass, suspended in a cage dockside in the Hudson River, would benefit from having several thousand juvenile American oysters in close proximity. Two cages of identical size and construction were used over a period of three months. Fish were fed equal rations in both cages on a periodic basis. Fish held in the cage with oysters in close proximity had 97% survival. Placing oysters inclose proximity to the finfish had a decided beneficial effect on the survival of the striped bass. The oysters grew well at a rate similar to those seen in commercial production situations. Local oysters grew much faster than those obtained from sources in Maine.

Wednesday, 11:00 a.m.

Integrated Kelp and Bay Scallop Aquaculture in China

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Successful artificial cultivation of Laminaria japonica (known as "haidai") in China began in the 1950's. The development of techniques for (1) indoor sporeling culture in greenhouses in the north and south of China; (2) raft (long-line) culture; and (3) artificial fertilization with manure has lead to a kelp industry which produces over 250,000 dry metric tons annually. There are 17 large sporeling culture centers that have a capacity of delivering 6.4 billion germlings to meet the needs of a kelp industry which farms over 13,500 ha of nearshore waters. The value of the kelp harvest has an approximate value of U.S. $300 million. Scallop culture developed in China using long-line technology was adopted from the kelp industry. In 1982, Argopecten irradian irradians (the bay scallop) was introduced to China from the northeastern U.S. Annual production of the bay scallop may be as high as 120,000 metric tons (fresh weight) with a productivity of 30-45 metric tons per ha. This leads to an annual production of 4-7 metric tons of scallop muscles per ha. Hatchery-produced bay scallops are reared at 21°C in early spring, and a crop is harvested within a year. An overview of the Chinese bay scallop industry will be presented. A discussion of the multiculture of bay scallops with kelp will illustrate how these industries are now being integrated.

Wednesday, 11:30 a.m.

Bay Scallop Management Methods

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Hatchery and field management techniques employed to enhance bay scallop (Argopecten irradians) populations on Martha's Vineyard are presented. Hatchery methods developed over the past dozen years are reviewed.

Longlines of biodegradable burlap bags provide a labor saving field nursery system. Early postset juveniles are encouraged to attach to swatches of burlap which serve as a vehicle for transfer of the tiny hatchery seed to surface-floated burlap bags in the field. The burlap bags become a protective field nursery from which the scallops slowly drop off following crowding and the decay of the burlap; thereby, effectively self-seeding natural beds.

Scallop spawning sanctuaries appear to improve spawning success, especially when natural populations are at low levels. Several hundred adult scallops are concentrated in floating cages. In theory, the scallops in the floating cages are exposed to fluctuating temperatures of the surface waters which should stimulate spawning. Concentrating the spawning adults in a small area should increase the chances of sperm uniting with eggs. Ideally, these sanctuaries are anchored in the back waters of bays so that any resulting larvae are not flushed from the bay before they set.

Control of predatory crabs appears to be a key component of a successful bay scallop management program.

Wednesday, 11:45 a.m.

Distribution of Hard Clam (Mercenaria mercenaria) Abundance and Larval Dispersal in the Eastern Great South Bay: Implications for Recruitment

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Annual hard clam (Mercenaria mercenaria) population censuses in the eastern Great South Bay, Long Island, New York, since 1985 have shown that hard clams occur in discrete and stable areas of high and low abundance. To assess the possible contribution of larval supply to this distribution of hard clam abundance, a particle dispersion model was used to predict the movement of hard clam larval patches originating from 6 different source areas in the eastern Great South Bay for days 11 - 17 following spawning, and the movement then compared to the observed distribution of hard clam abundance. In general, the movement of the larval patches was consistent with the distribution of hard clam abundance. Comparing the clam abundance in the source areas to the distribution of clam abundance: two high abundance areas had high abundance source areas; one high abundance area had a low abundance source area; a low abundance area had two high abundance source areas; and, one low abundance area had a low abundance source area. The predicted movement of the larval patches also suggests that no area lacks a supply of larvae. It therefore appears that site conditions overwhelm larval supply in determining clam abundance.

Wednesday, 1:00 p.m.

The Beals Island Regional Shellfish Hatchery: Public Aquaculture Downeast

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Until recently, the soft-shell clam (Mya arenaria) industry in Maine traditionally ranked second in landings of commercially important marine resources behind lobster. Since the early 1980's it has fallen to fifth or sixth due to dramatic decreases in standing stocks. Since accurate landings records have been kept (beginning around 1940) the catch has shown two large peaks (one in 1945 in which 10 million pounds were harvested and the other in 1976 when 7.8 million pounds were landed). During these times of record harvests, clamming was considered one of the best ways to make a living on the coast of Maine. A typical Downeast coastal community of 1,000 people may have had between 100 to 200 clammers. Of these, forty to sixty were full time harvesters. Today, that same town may sell twenty licenses, but there are no full time clammers. In 1990, only 2.4 million pounds of clams were landed along the entire coast. Usually, between 45% to 58% of all clams harvested each year in Maine come from the eastern two counties (Washington and Hancock) and the recent declines in clam abundance have been especially devastating to those who harvest clams there.

In 1987, six communities in Washington County organized themselves and formed the first-ever regional shellfish hatchery and management program based on stock enhancement using hatchery-reared soft-shell clams. The goal of one million one-half inch animals per community was met and exceeded that year and the program is now sponsored by ten communities ranging from Brunswick in the west to Edmunds and Trescott in the east. I will discuss 1) how the program began, 2) how soft-shell clams are produced at the Beals Island Regional Shellfish Hatchery, 3) some of the results from a three-year, Sea Grant-funded research field project to determine the biological and economic efficacy of such a management program, and 4) the development of an Education Center at the Regional Hatchery named in honor of Dana Wallace, a shellfish biologist with the state of Maine for 35 years.

Wednesday, 1:30 p.m.

Declining Habitat in Norwalk Harbor

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Severe hypoxia occurred in Norwalk Harbor during late September 1991 when water temperatures had already declined 6°C from the August maximum. Bunker kills began on September 21st and continued unabated to mid-October. It is hypothesized that this unusual event occurred due to a coalescence of factors (1) heavy rains flushed harbor storm drains and caused hydraulic overloading at the Norwalk sewage treatment plant; (2) the seasonal die off of large beds of Ulva and dense phytoplankton blooms, and (3) the presence of accumulating dead fish on the harbor floor. All this happened in a harbor with poor flushing characteristics which further complicated and extended the hypoxic event.

It was subsequently determined that damage to fish stocks extended well beyond schools of bunker. Benthic stocks of juvenile winter flounder, tautog and cunner (among others) were found to be missing from the harbor floor. Hypoxic events which include bunker kills should be more closely investigated to determine the full extent of the biological damage. It is probable that juvenile benthic stocks are severely reduced or eliminated in many of these hypoxic episodes.

Impact of Pipelaying on Long Island Sound Shellfish Beds

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In 1986 the Iroquois Gas Transmission Company proposed placement of a twenty-four inch, natural gas pipeline from Canada to Long Island, New York. In the winter of 1991 construction was initiated. The pipeline crosses approximately four hundred water-ways, including Long Island Sound. The authorizing permits require that the pipe be placed so that sensitive habitats and resources, along the alignment, be disrupted for the least time practicable. Typically, the identified period of disruption was to be a single growing season. These stipulations were for the natural and cultivated oyster (Crassostrea virginica) and hard clam (Mercenaria mercenaria) beds located off Milford, Connecticut.

In a classic example of the "Peter Principle" (anything that can go wrong... will) the restoration activities have been hindered by difficulties associated with leveling a two plus mile long swath that varies in depth from intertidal to approximately fifty feet. Compounding the problems associated with the "simple" backfilling exercise have been the loss of stockpiled material during storms, the inability to accurately restore the area and the secondary impacts created by the restoration efforts. Today, one year after initiation of the construction, the work area continues to contain artificial, relatively sharp rises and depressions that could make mechanical shellfish harvesting difficult.

There also may be an increase in fine grained sediments. The increase in fine material come from winnowing of the material handled during construction. The fine sediment accumulates in less dynamic areas (i.e., remaining holes and "shadow" zones downcurrent of piled materials.) Site inspections as recent as early December of 1991 reveal the continued presence of this problem.

Unexpected shellfish mortality levels were reported and investigated during August/September 1991. The mortality may be, at least partly, the result of burial-induced suffocation.

Discussions with the pipeline construction team have revealed that, although the contractor agreed to perform the restoration services, they were unprepared and inexperienced. The contractors agreed, in writing, to a restoration performance level of plus or minus one foot. They have spent much of the fall and early winter discussing the use of a "leveling" beam and the accuracy of the benthic profiling system used to confirm contract and permit compliance.

Wednesday, 2:30 p.m.

Municipal Management of Shellfish Resources

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The Town of Edgartown has abundant shellfish resources. Seven shellfishing areas together comprise over 4,000 acres of productive shellfish beds within town boundaries. Species harvested include: soft-shell clams (*Mya arenaria*), oysters (*Crassostrea virginica*), quahogs (*Mercenaria mercenaria*), and bay scallops (*Argopecten irradians*). This presentation describes each area and the management strategies used within them, including rotational closure, spawning sanctuaries, bottom conditioning and a seeding program with stock received from the Martha's Vineyard Shellfish Group hatchery.

Land use policy within the town is equally important in the protection of shellfish resources. Edgartown currently has a surface water zoning by-law, a policy of no new piers in shellfishing areas, as well as involvement of Martha's Vineyard Commission (a regional land and water use authority) in development of coastal properties.

Wednesday, 3:30 p.m.

The Final Conclusions of the 1990 Shellfish Register

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The Register provides evidence for the need for closer surveillance and management of coastal resources. While shellfish declines indicate the need for more attention from Federal and State managers, scientists, and citizens, the declines cannot be deterred by concentrating management solely on that group of animals. There is need for an integrated and comprehensive effort at all levels of decision making in the entire coastal ocean zone. For example, the Register documents that pollution from upstream sources affects 21 % of the harvest-limited shellfish-growing waters. In addition, up to 38 % of the harvest-limited shellfish-growing waters are affected by non-point sources. These facts suggest that the current coastal zone boundaries may need to be expanded, and support the pending CZMA legislation focusing on non-point source pollution.

The Register is also among the first Federal reports to point out that shellfish aquaculture cannot be expected to replace the loss of harvests because land and water use conflicts already restrict access to the required high quality water. Such conflicts and issues cannot be resolved without expanding both comprehensive resource management and the development of information and tools for this purpose.

Until 1985, the Register was primarily a log of changes in the classifications of shellfish-growing areas as prescribed by the National Shellfish Sanitation Program. This was of interest, by and large, to public health officials. The 1985 data were expanded to include pollution sources adversely affecting harvest-limited waters, landings, public health issues, and state programs. The same data were collected for the 1990 conditions. This enabled NOAA to analyze trends in these data and possible relationships between them. Future Registers will continue to upgrade this procedure. In addition, NOAA is converting the hard copy shellfish chart data (280 NOS Charts, 3,172 individual areas) into a digital map base which will improve the accuracy of the classification data, simplify updates of the data, make spatial relational analyses with other data bases feasible, and provide a new management tool for State and Federal shellfish managers.

Wednesday, 4:00 p.m.

Shellfish Safety: Communicating with the Media and the Consumer

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During the past several years, there has been a great deal of attention focused on seafood safety issues. Not only were there concerns about marine pollution, beach closings, wash ups of medical supplies and garbage, but also the lack of a mandatory seafood inspection program. These concerns resulted in a tremendous gap between risk assessment, which is a function of scientific data, and risk perception, which is largely a function of the media in consort with people's personal biases and beliefs.

According to the 1988 General Accounting Office Report on Seafood Safety, "a review of FDA statistics does not indicate widespread, serious problems with seafood." Overall seafood-related illnesses reported to the Center for Disease Control in Atlanta during the period from 1978 to 1984 accounted for 5% of the individual cases and 10% of the outbreaks (2 or more cases). Forty nine percent of all reported seafood related illnesses were restricted to only four areas -- Guam, Puerto Rico, Hawaii and the Virgin Islands. Eighty seven percent of the seafood-related illnesses were confined to only a few species -- those that can become ciguatoxic or scombrotoxic and raw molluscan shellfish.

Most health risks associated with shellfish safety originate in the environment. Many of these risks can be traced to natural conditions in the environment, not human intervention. With minor exceptions, risks cannot be identified by an organoleptic inspection system. This necessitates careful environmental monitoring. In many areas environmental quality is actually improving because of the reduction in farms and livestock, better sanitation and improved handling of sewage.

Most reported shellfish-related illnesses are suggestive of Norwalk-like viral gastroenteritis. Deaths associated with shellfish are limited almost exclusively to people who are vulnerable to Vibrio vulnificus. Those persons with liver disease or compromised immune systems should be warned by their attending physician of the risks involved with the consumption of raw molluscan shellfish.

According to the Institute of Medicine, "As much as 50% of all reported, acute fish and shellfish problems might be eliminated by more careful handling and proper preparation in the home or food service establishment." A major thrust of any seafood safety program must be end-user education.

Observed Increases in the Abundances of the Asiatic Clam, Corbicula fluminea Moller, in the Lower Reaches of the Connecticut River

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Since the discovery (May 1990) of the Asiatic clam, Corbicula fluminea, in the vicinity of the Haddam Neck Power Plant (Connecticut Yankee), monitoring studies have been conducted to determine the seasonal distribution, abundance, size, recruitment, and reproductive activity for this species recently introduced to the Connecticut River. A survey in the lower reaches of the river (November 1991) found Asiatic clams as far as 25 km upstream of Connecticut Yankee (Gildersleeve Island, North Cromwell, CT).

Densities of Corbicula increased from spring to autumn of 1991. Average densities at river sites, which had been 4 individuals/m^2 in May, increased to 508/m^2 in August, and 768/m^2 in November. Densities in autumn 1991 (274/m^2 to 1642/m^2) were also higher than those reported in autumn 1990 (80/m^2 to 117/m^2).

Clams collected in 1991 were larger than those from the previous year; in autumn 1991 the largest individuals collected were 25 mm in shell length, whereas in autumn 1990 the largest were only 12 mm. In the 1991 growing season, average shell length of monitored clams increased from 9.2 to 21.4 mm, corresponding to an overall growth of 0.87 mm/wk.

Recruitment of clams to sediment trays from June to August resulted in densities of 444 individuals/m^2, and by November, densities had increased to 820 individuals/m^2. The size distribution of clams collected from the recruitment trays indicated that all size classes from approximately 2 to 16 mm in shell length were well represented. Similarities between the size distributions and overall density of clams from experimental sediment trays and from natural substrata in the river suggest that the processes observed in sediment trays (i.e., transport and recruitment of individuals, followed by rapid growth) were also occurring throughout the river near Connecticut Yankee.

Gametes were found in at least half of the individuals sampled during the 1991 study; however, embryos and veligers were present only from July to September. These months also represent the period during which brooding adults were observed to release juveniles.

Continued monitoring of the Connecticut River in the vicinity of Connecticut Yankee will determine whether the observed population of Asiatic clams is transient or permanently established.

Wednesday, 5:00 p.m.

Impact of the Asiatic Clam on the Potomac Estuary: Cusp Catastrophe Model

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Back-calculation based on an extensive survey of the exotic Asiatic clam, Corbicula fluminea, in the Potomac River estuary near Washington, DC, indicated the spring and summer population was capable of affecting water clarity through filtration. Light attenuation has been suggested as a major factor in the survival of submersed macrophyte propagules and in determining the distribution of submerged aquatic vegetation in the Potomac. Beds of submerged aquatic vegetation have developed in the river since the clams were introduced. The increase in submerged aquatic vegetation has lead to rapid increase in fish and aquatic bird populations. This is considered a success by water quality managers who cite the nearly $1 billion spent on the Washington, DC area sewage treatment plants since 1960.

However, the near-simultaneous rapid changes in the biotic aspects of the Potomac River resemble effects mathematically described by cusp catastrophe theory. This theory is used to describe non-linear change where systems undergo discontinuous transitions from one state to another under the influence of two competing control variables. In the case of the Potomac the control variables would be water clarity and the presence of submerged aquatic vegetation. Significant change in the first variable brought about by a large filter-feeding exotic clam population triggered dominance of the second variable leading to rapid change in the ecology of the estuary. It has been said the Potomac estuary returned to the conditions of 50 years ago in only 5 years. It may be that changes in some aquatic ecosystems, particularly estuaries, are better described and understood by cusp catastrophe theory than linear models.