Gulf of Maine NEWS

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Overview of Aquaculture: The University of Maine Perspective

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Global Aquaculture

As predicted by Ryther (1969), world fisheries production since 1989 has remained essentially unchanged at about 100 million metric tons (FAO, 1995a). At the same time, however, world population is increasing by 86 million people per year and per capita consumption of seafood is increasing (Avault, 1994). Projections are that worldwide demand for seafood will thus increase another 25% by the year 2010, resulting in a shortfall in world seafood supply of 10-15 million metric tons (FAO, 1995b).

Controlled production of aquatic species (aquaculture) has been expanding to meet this rapidly increasing demand (Rana, 1997). The annual contribution of aquaculture to total aquatic production increased from 14.4% in 1989 to 23.0% in 1995, with over a quarter of total world supply of food fish being

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In This Issue:

Re-Engineering the Sea Scallop Industry

Ron Smolowitz, Coonamessett Farm

Sea scallops have the potential to become the most economically important living marine resource food crop in the Northwest Atlantic. They are a high value native species that is easy to culture. It is not far-fetched to envision a year in the near future when ex-vessel landed value of sea scallops from the United States and Canada will be several billion dollars; a tenfold increase over today's landings. There are many obstacles that need to be overcome to get to this point; however, they are primarily social and political; not scientific or technical. A key issue is to decide what portions of the traditional fishing grounds off our coast are to be used for the sustainable production of marine crops and what areas will be set aside as wildlife preserves.

The New England fishing industry is facing hard times. The fish and shellfish resources that the industry depends upon are seriously depleted. Conservation measures are restricting catches at levels that have put many fishermen out of business and remaining fishermen are operating at lower levels of production. The ripple effects on the economy, including processors and suppliers, continue to be devastating. The value of the sea scallop industry to Southeastern Massachusetts easily exceeds half a billion dollars annually in good years. This could all be lost quite suddenly by management actions.

The decline of the scallop resource has been blamed on overfishing, usually thought of in terms of harvest removals. In addition, there are other fishing impacts that play significant roles. Frequent towing over the bottom impacts the productivity of the scallops and other species in ways we don't understand clearly. But there is evidence of non-catch mortality to

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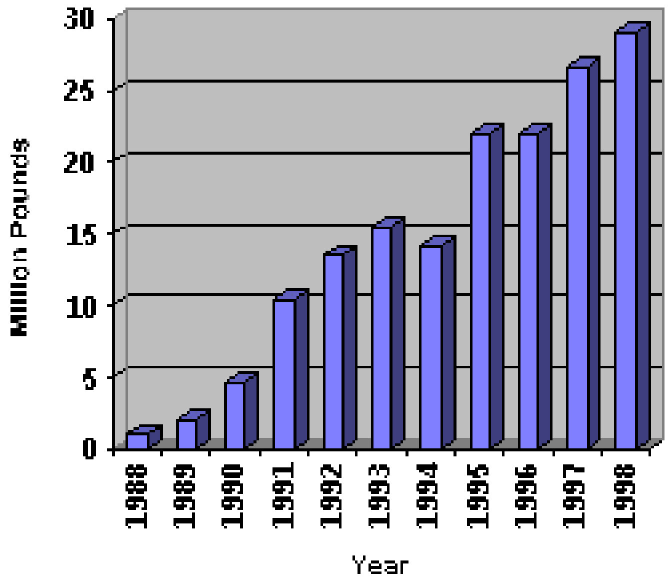

Figure 1. Production of Atlantic salmon and trout in Maine, 1988-1998

derived from aquaculture. By 1995, the total production of cultured finfish, shellfish and aquatic plants reached a record 27.8 million metric tons, worth an estimated $42.3 billion U.S..

Aquaculture in the United States

After Japan, the United States is the world's largest importer of fisheries products (FAO, 1995a). In 1994, 45.8% of all fisheries products consumed in the United States were imported, resulting in a trade deficit of $4.6 billion, second only to that of petroleum (NMFS, 1995). In 1998 the United States seafood trade deficit was just under $6 billion. It is predicted that United States demand will increase by 1.4 million metric tons by the year 2000 (NOAA, 1995). To help meet this increasing demand, United States aquaculture production has increased from 140,000 metric tons in 1983 to 302,000 metric tons in 1994. The present value of cultured United States products is estimated to be $980 million (farm gate value), or 3% of world production. Aquaculture in the United States accounts for approximately 181,000 jobs and has a total economic impact of $5.6 billion annually (Dicks et al., 1996). Thus the United States has an opportunity to strengthen its domestic aquaculture industry to serve both national needs and a global marketplace.

According to the National Research Council (1992), the United States will accrue a number of benefits from an economically viable, technologically advanced, and environmentally sensitive marine aquaculture industry. These include providing wholesome seafood to replace declining harvests of wild fish, products for export to improve the nation's balance of trade, enhancement of commercial and recreational fisheries that are threatened, economic opportunities for rural communities, and new jobs for skilled workers, particularly in coastal communities. Besides production of edible fish and shellfish, the United States aquaculture sector can provide other outputs for national and international markets, including ornamentals, baitfish, specialty chemicals, goods, supplies, and services to the industry, value added processing, pharmaceuticals, and biotechnological products. Future success of marine aquaculture in the United States will depend on: 1) the establishment of a policy framework for resolving coastal use conflicts and related institutional obstacles; 2) the development and application of new technologies to diminish or mitigate harmful environmental impacts and to establish economic feasibility for aquaculture operations; and, 3) the development of dependable and predictable domestic and export markets for marine aquaculture products.

Federal agencies (in particular USDA and DOC) have recognized the potential importance of aquaculture to the economy of the United States. Specific objectives (as stated in the DOC Aquaculture Policy) by the year 2025 are to:

1. Increase the value of domestic aquaculture production from the present $900 million annually to $5 billion
2. Increase the number of jobs in aquaculture from the present 180,000 to 600,000
3. Develop aquaculture technologies and methods both to improve production and safeguard the environment
4. Develop a code of conduct for responsible aquaculture by the year 2002 and have 100% compliance within federal waters
5. Double the value of non-food products and services produced by aquaculture
6. Enhance depleted wild fish stocks through aquaculture
7. Increase exports of U.S. aquaculture goods and services from the present value of $500 million annually to $2.5 billion

Aquaculture in Maine

Maine currently ranks near the top in the United States in value of cultured products produced and is the leading producer of cultured Atlantic salmon in the United States (USDA, 1996). According to the Maine Department of Marine Resources (1999), 1 million pounds of Atlantic salmon and trout were produced in 1988; in contrast, production in 1998 was 29 million pounds, worth about $50 million (Figure 1).

There are currently 22 holders of 45 finfish leases, having a total area of 738 acres (Maine Department of Marine Resources, 1999). Full use of present leases would result in an estimated $200 million output. In 1996, 960 jobs were directly related to salmon aquaculture, providing a total income of $30 million (Young et al., 1998). Given continued improvements in production efficiencies, projections are that in seven years, salmon culture could account for 3,000 jobs and $140 million in personal income, surpassing the forestry products industry in Washington County (Young et al., 1998).

Cultured shellfish (mussels and oysters) account for an additional $6 million in economic activity per year. There are 26 holders of 32 shellfish leases, having a total of 385 acres. In addition, there are the seven land-based shellfish hatcheries in the state that produce seed (primarily oysters, clams and scallops) for sale throughout the country.

Several factors favor the continued growth of aquaculture in Maine. Maine has an extensive coastline (up to 5,000 miles including islands) that includes a variety of environments suitable for the culture of numerous species of commercially important cold-water, marine organisms. Maine is close enough to major markets so that fish can be harvested, processed, and delivered to Boston within 24 hours. The existing "fishing" infrastructure for boat-building and harvesting and processing seafood also lends itself to aquaculture. As natural stocks of fish and shellfish continue to decline, aquaculture has the potential not only to satisfy increasing demands for seafood but at the same time reduce pressure on natural stocks and support local communities that have in the past relied on fishing. The Maine Lease Law (enacted in 1973 and amended in 1990) gives lease holders exclusive rights to use designated areas. This combination of attributes exists in no other state in the country.

Realizing this potential, Maine was one of the first states to produce an aquaculture plan (completed in 1980), entitled "A Development Plan for Maine's Aquaculture Industry". In 1987, then Governor John McKernan commissioned a report titled "An Economic Development Strategy for the State of Maine", which identified aquaculture as having strong economic potential. In 1990, the State Planning Office and the Department of Marine Resources convened a committee that produced "An Aquaculture Development Strategy for the State of Maine". This strategy, updated in 1997 as "Maine's Aquaculture Strategy", calls for increases in the economic impact of aquaculture to $192 million and employment in aquaculture-related jobs to 1,620 by 2002 (Maine Department of Marine Resources, 1997).

To achieve these goals, however, several challenges will have to be addressed by the State. Among these are removing regulatory constraints, increasing access to capital, and improving the capability to "further build its research infrastructure in genetics, disease resistance and control, physiology of marine shellfish and finfish, nearshore ecosystem dynamics, and on resource economics and policy" (Maine Department of Marine Resources, 1997). To help address these needs, marine aquaculture has been identified as a target area in both the Maine Economic Development Strategy and the Maine Science and Technology Plan. Associated with this, the state legislature has considerably increased its allocation to R & D funding, largely through the formation of the Maine Technology Institute.

Thus Maine's aquaculture industry is presently in a position to become a national leader in the culture of cold-water marine species, given an adequate technological infrastructure and relevant technical expertise. The University of Maine, because of its existing academic and research strengths in the marine sciences and aquaculture, has a unique opportunity to become a national leader in research focused on the culture of cold-water, marine organisms and to play a pivotal role in the future development of this important national industry.

Aquaculture Research at the University of Maine

Toward that end, the University of Maine System identified marine aquaculture as one of five strategic research areas poised to stimulate Maine's economic development. In 1997, a successful proposal was submitted to the National Science Foundation's EPSCoR Program for enhancing the research infrastructure for cold-water, marine aquaculture at the University of Maine, the state's Land Grant/Sea Grant institution. The primary objectives of this effort were to hire new research faculty and upgrade research facilities. As a result, we have recently hired Ione Hunt von Herbing, a fish physiologist; Paul Rawson a quantitative geneticist; Mark Wells, a chemical oceanographer; Eric Anderson, a virologist; and Carol Kim, an immunologist. These faculty were chosen because they filled identified research needs within Maine relating to marine aquaculture and complemented existing strengths at the University of Maine in fish nutrition, fish health, shellfish culture and disease, engineering, economics and food science. They will also contribute to our B.S. program in Aquaculture, one of the few in the United States.

Federal and state R & D funds are being used to augment existing research facilities. The Aquaculture Research Center in Orono, part of the Maine Agriculture and Forestry Experi-

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ment Station, is currently used for teaching and small scale, controlled experiments. It also houses a 120 foot wave/tow tank, used for the design and engineering of marine structures. Later this year, this building will be undergoing $700,000 in renovations.

Plans for a $2 million Marine Culture Laboratory at the Darling Marine Center (Walpole, Maine) are near completion. Work at this facility will focus on the biology and culture of marine invertebrates (primarily oysters, mussels, scallops, and urchins) in collaboration with industry members. Much of the technology presently utilized by the shellfish culture industry in Maine was developed by University of Maine researchers (Hidu et al., 1981, 1988a). A major advancement was achieved with the production of the first triploid bivalves (Stanley et al., 1981; Allen et al., 1982; Tabarini, 1984; Hidu et al., 1988b; Mason et al. 1988). More recently, University of Maine research has resulted in genetic improvement of oysters both in terms of growth and disease resistance (Barber et al., 1998; Davis and Barber, 1999). Research on alternate species of shellfish (European oysters, scallops, and urchins) will ultimately provide diversity to this component of the industry (Zabaleta and Barber, 1996; Barber and Davis, 1997; Garrido and Barber, unpublished). Several current industry members received graduate degrees at the University of Maine or training at the Darling Marine Center.

Recently, the University of Maine purchased a former commercial salmon hatchery located on Taunton Bay in Franklin, Maine, which has been named the Center for Cooperative Aquaculture Research. This facility will be developed so that university researchers and industry members can work together on projects aimed at increasing the economic impact of aquaculture in Maine. An additional goal is to involve federal scientists from the Agricultural Research Service of USDA in this effort. The size of the facility (23 acres), will allow us to conduct research on a scale relevant to industry. Access to both fresh and salt water mean that research on salmonids as well as marine species will be possible. The first industry driven research initiative will be aimed at the genetic protection and improvement of salmon. In addition, we will be maintaining broodstocks of marine species such as halibut, haddock, and cod. Progeny from these fish will be used for ongoing research into the energetics and nutrition of early life stages (Hunt von Herbing, 1996a, 1996b; Baskerville-Bridges and Kling, 2000). This research is an outgrowth of collaborations with scientists at the Department of Fisheries and Oceans Canada in St. Andrews, the U.S. National Marine Fisheries Service and University of Rhode Island, and the University of New Hampshire. Current funding will be used by the University of Maine to produce juvenile haddock for growout in offshore net pens maintained by the University of New Hampshire. Only after some basic knowledge is acquired will commercial culture of these “alternate” species become an economic reality.

Additional resources have been identified for aquaculture extension and education activities. The Maine Sea Grant Program now employs Chris Bartlett as a finfish extension specialist (based in Eastport) and Dana Morse as a shellfish extension specialist (based at the Darling Marine Center). Both Chris and Dana are actively involved in helping industry identify problems that can be addressed via research and applying the results of University of Maine research to the benefit of the industry.

References

Allen, S. K., Jr., P. S. Gagnon and H. Hidu. 1982. Induced triploidy in the soft-shelled clam: cytogenic and allozymic confirmation. *J. Heredity* 73:421-428.

Avault, J. W. 1994. What is happening to our ocean fisheries? What is the implication for aquaculture. *Aquaculture Magazine* July/August 1994:80-84.

Barber, B. J. and C. V. Davis. 1997. Growth and mortality of cultured bay scallops in the Damariscotta River, Maine (U.S.A.) *Aquaculture International* 5:451-460.

Barber, B. J., C. V. Davis, and M. A. Crosby. 1998. Cultured oysters, *Crassostrea virginica*, genetically selected for fast growth in the Damariscotta River, Maine, are resistant to mortality caused by Juvenile Oyster Disease (JOD). *J. Shellfish Research* 17:1171-1175.

Baskerville-Bridges, B. and L. J. Kling. 2000. Larval culture of Atlantic cod (*Gadus morhua*) at high stocking densities. *Aquaculture* 181:61- 70.

Davis, C. V. and B. J. Barber. 1999. Growth and survival of selected lines of eastern oysters, *Crassostrea virginica* (Gmelin 1791) affected by juvenile oyster disease. *Aquaculture* 178:253-271.

Dicks, M. R., R. McHugh, and B. Webb. 1996. Economy Wide Impacts of U.S. Aquaculture. Oklahoma Agricultural Experimental Station Publication P-946. 26 pp.

Food and Agriculture Organization of the United Nations. 1995a. Aquaculture Production Statistics, 1984-1993. Rome. 186 pp.

Food and Agriculture Organization of the United Nations. 1995b. The State of World Fisheries and Aquaculture. Rome. 57 pp.

Hidu, H., S. R. Chapman and D. Dean. 1981. Oyster mariculture in subboreal (Maine, United States of America) waters: Cultchless setting and nursery culture of European and American oysters. *J. Shellfish Research* 1:57-67.

Hidu, H., S. R. Chapman and W. Mook. 1988a. Overwintering American oyster seed by cold humid air storage. *J. Shellfish Research* 7:47-50.

Hidu, H., K. M. Mason, S. E. Shumway and S. K. Allen. 1988b. Induced triploidy in *Mercenaria mercenaria* L.: Effects on performance in the juveniles. *J. Shellfish Research* 7:202.

Hunt von Herbing, I., T. Miyake, R. G. Boutilier and B. K. Hall. 1996a. Effects of temperature on morphological landmarks critical to growth and survival in larval Atlantic cod (Gadus morhua). *Marine Biology* 124:593-606.

Hunt von Herbing, I. and R. G. Boutilier. 1996b. Activity and metabolism of larval cod (*Gadus morhua*) from Scotian Shelf and Newfoundland source populations. *Marine Biology* 124:607-617.
Maine Department of Marine Resources. 1997. Maine’s Aquaculture Strategy. Maine Department of Marine Resources, August, ME. 21 pp.
Maine Department of Marine Resources. 1999. Maine Department of Marine Resources Aquaculture Lease Inventory. Maine Department of Marine Resources, West Boothbay Harbor, ME. 92 pp.
Mason, K. M., S. E. Shumway, S. K. Allen and H. Hidu. 1988a. Induced triploidy in the soft-shelled clam *Mya arenaria:* energetic implications. *Marine Biology* 98:519-528.
National Marine Fisheries Service, National Oceanic and Atmospheric Administration, U.S. Department of Commerce, 1995. Fisheries of the United States, 1994. Current Fisheries Statistics No. 9400. Washington, D.C. 113 pp.
National Oceanic and Atmospheric Administration, U.S. Department of Commerce. 1995. NOAA’s role in the Development of Marine Aquaculture. 8 pp.
National Research Council. 1992. Marine Aquaculture- Opportunities for Growth. National Academy Press, Washington, D.C. 290 pp.
Rana, K. J. 1997. Trends in Global Production, 1984-1995. FAO Fisheries Circular No. 886 FIRI/C886(Rev.1), Rome.
Stanley, J. G., S. K. Allen, Jr. and H. Hidu. 1981. Polyploidy induced in the American oyster *Crassostrea virginica* with cytochalasin B. *Aquaculture* 22:1-10.
Tabarini, C. L., 1984. Induced triploidy in the bay scallop, *Argopecten irradians*, and its effect on growth and gametogenesis. *Aquaculture* 42:151-160.
United States Department of Agriculture, 1996. Aquaculture Outlook. National Agriculture Statistics Service, LDP-AQS-3 (3-96), Washington, D.C., 6 pp.
Young, K., F. O’Hara, C. Lawton, and C. Colgan. 1998. Report on current practices and benefits of finfish aquaculture in Maine. Prepared for the Maine Department of Marine Resources by Ken Young and Co., Hallowell, ME. 48 pp.
Zabaleta, A. I. and B. J. Barber, 1996. Prevalence, intensity, and detection of Bonamia ostreae in *Ostrea edulis* L. in the Damariscotta River Area, Maine. *J. Shellfish Research* 15:395-400.

(Scallops continued)

scallops caused by the dredge while on the bottom (i.e., mechanical damage, sediment suspension effects, etc.), and harvesting small scallops contributes to the loss of spawning potential and market value. Existing management options address these problems by decreasing fishing effort, which leads to reduced employment and the consolidation of the industry. A much better approach would be to expand the resource base while correcting the harvesting deficiencies.

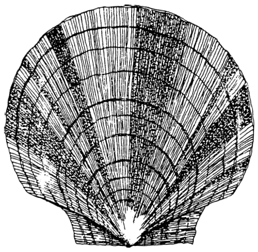
One of the most promising growth opportunities is sea scallop (*Placopecten magellanicus*) aquaculture and resource enhancement. Many of the prerequisites for success exist. There is a large supply of small scallops, the infrastructure is in place, the unit value is high, and the market is established. Most importantly, the scallops can be reared on naturally occurring feed. The potential is vast; however, much needs to be accomplished to make sea scallop resource enhancement and aquaculture a reality in this geographic area. In the interim, there needs to be a logical progression from today’s wild capture fishery to one of husbandry.

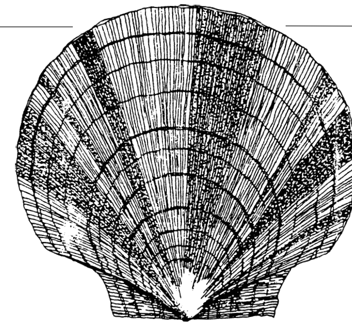
The Seastead Project

The Seastead Project has been a five-year effort to demonstrate sea scallop, *Placopecten magellanicus*, resource enhancement off the coast of Massachusetts. Initially approved for funding in FY 1994-95 by the NOAA Saltonstall-Kennedy Program, the project now continues at a much lower level of activity. The project objective has been to enhance sea scallop production using the existing Massachusetts fishing industry base. The goals were to develop (a) means to transport scallops live, (b) methods to grow-out transplanted scallops on the bottom and in the water column, (c) criteria for managing scallop grow-out areas, and (d) means to identify potential grow-out areas. The emphasis has been to develop and demonstrate the technology to enhance sea scallop production, on a sustainable and environmentally sound basis, using the existing New England fishing industry and infrastructure.

Seastead is a collaborative effort between scientists and the sea scallop fishing industry. Together, the team examined potential scallop enhancement/production strategies. After 30 months, all required permits were secured for the first aquaculture research area in U.S. federal waters. The twenty-four square-kilometer area, established by Amendment Six to the Sea Scallop Fishery Management Plan, is located 15 kilometers south of Martha’s Vineyard, Massachusetts, USA, and is now closed to mobile gear and dedicated to researching culture and enhancement strategies. The site, (with average depths of about 30 meters), is marked by large lighted yellow buoys. The site is in an open ocean location subject to large waves and strong currents.

The site has been stocked with wild-caught scallops. Approximately 40,000 scallops, ranging in shell height from 40-100 mm, were placed in bottom cages, suspended nets, and loose on the bottom in 1997. 80,000 scallops, ranging in shell height from 50-140 mm, were direct seeded on the bottom in 1998.





The scallops are being monitored for growth and mortality. The scallops seeded on the bottom are monitored using an underwater video camera sled. The scallops in the cages were hauled and measured. Sub-samples of all groups of scallops were evaluated for health and condition at times during the project. Data was collected to allow for an economic analysis of the culture strategies.

The project has overcome big obstacles of a regulatory and social nature with great success. Members of the project worked to (a) form the Sea Scallop Working Group in Massachusetts, (b) create an Aquaculture Committee within the New England Fishery Management Council, (c) develop scallop industry awareness of enhancement/area management strategies, and (d) establish the first working aquaculture site in federal waters.

Scallop Culture

Scallop culture, as practiced today, was pioneered in the Mutsu Bay region of Japan. The scallop fishery in that area was subject to significant fluctuations in abundance, a factor common to most scallop fisheries, including sea scallops. In 1935, Japanese researchers started on a program to overcome the fluctuations in scallop abundance. The early scientific efforts concentrated on ways to collect scallop spat, the stage in the scallop's life, after the planktonic phase, when it settles to the bottom.

By 1953, local fisheries cooperatives were collecting spat to re-seed fishing grounds. In 1955, they started to hold the spat for short periods of time before re-seeding, in order to increase scallop survival. In 1964, a breakthrough occurred in spat collector design that significantly increased the number of spat collected. The increase in spat availability lead to improved methods to hold large numbers of scallops in captivity until fully grown. Today, seventy percent of Japan's scallop harvest is cultured. The harvest is stable from year to year and is an order of magnitude larger than the previous wild harvest fishery. There are over 1900 scallop harvesting firms in the Mutsu Bay region alone and many other regions also produce cultured scallops.

Since the 1970s, countries in all parts of the world have begun scallop culture operations based on the Japanese model. Some depend on collecting spat, others use hatcheries to produce the spat. Canada has been working on culturing the sea scallop and is on the verge of successfully starting an industry based on culturing. While the world moves forward creating jobs and wealth through aquaculture and resource enhancement, the United States finds itself importing cultured scallops.

Culturing

Scallop culture operations depend on obtaining a large supply of spat, commonly called seed. Two sources of seed are hatcheries and spat collecting devices. Hatcheries usually collect sexually mature scallops from the wild population and spawn them in captivity. Scallops are easily induced to spawn by raising the water temperature. There are variations in the rearing techniques, and different levels of difficulty, depending on the species of scallop. The Canadians are successfully spawning sea scallops in hatcheries and rearing them through the spat stage.

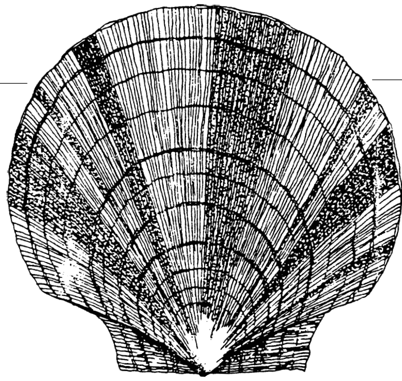
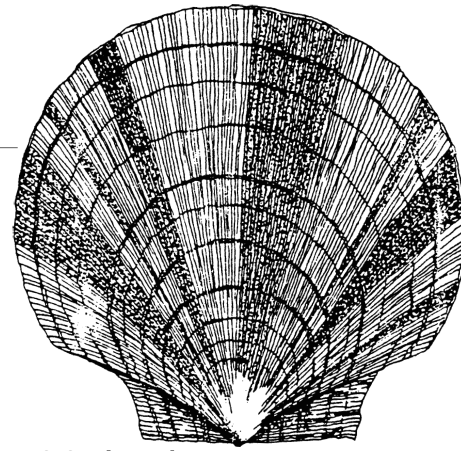
The Japanese, however, have found that hatcheries are expensive to operate when compared to wild spat collection. Their culturing system depends on setting out spat collectors. The spat collectors consist of submerged longlines to which onion bags, stuffed with monofilament netting, are attached. The small swimming scallop larvae pass through the mesh of the onion bag and attach to the monofilament netting. After a month or two, they detach, but are now too large to pass through the onion bag mesh, so they collect inside the bag.

Intermediate Culture

Scallop spat usually range in size from a few millimeters to about 15 mm depending on the species and holding time. This size scallop, if placed on the bottom, suffers high mortality. Therefore most culture operations hold the scallops, in an intermediate culture phase, until the scallops are about 20-30 mm in size. The most common method of holding utilizes strings of specially designed pearl nets attached to arrays of submerged longlines. Holding the scallops in these nets, up off the bottom, reduces predation and provides better feeding conditions, enhancing growth. The Canadians have held sea scallops for one year in the intermediate phase, with success.

Final Culture

Final culture, or grow-out, can be conducted in a number of ways. Two general categories are cage culture and bottom culture (sea ranching). The most common form of cage culture utilizes a specially designed lantern net; a cylindrical cage of netting with about ten compartments stacked one on top of

Scallop graphics courtesy of Dave Packer, NMFS, Sandy Hook, NJ

another. A specific quantity of scallops is placed in each compartment and the nets are then placed on longline arrays. After a period of time, about one year, the scallops are thinned and usually placed into a larger mesh lantern net. There are many variations to this theme, such as a scallop house (or pocket net) where each scallop has its own individual compartment. Other hanging culture methods include ear hanging, where the scallop is tied to a string by means of a hole drilled in the hinge, or ear, of the shell. A third method involves gluing scallops to a hanging rope. Obviously, these methods are very labor intensive.

The least expensive method of grow-out seems to be bottom culture because it does not require expensive nets or labor. The scallops are released onto appropriate bottom to grow to market size and, in some cases, the bottom has been cleared of predators such as crabs and starfish. Upon reaching market size, the scallops are harvested by dredges or divers. Appropriate bottom is defined both by ecology and legal/regulatory constraints. The bottom needs to be suitable for scallop growth, have minimal amounts of predators, and should not be in conflict with other users. The bottom can be leased to individual operators who would own the scallops they seed. Another approach, commonly called resource enhancement, involves government supported seeding of common grounds.

For the purposes of the Seastead project, we decided to use wild-caught intermediate size (40-60 mm) or larger scallops, depending on availability. This approach was used in Japan and Peru when these countries first started their scallop culture industries. Research has shown that scallops above 30 mm in shell height have a much higher chance of survival in bottom culture operations. In effect, this project bypassed the seed problem in order to test water column culture vs. bottom grow-out technology.

The Seastead project planned to develop and demonstrate new, alternative techniques for improving scallop utilization. Today's practice of repeatedly dredging an individual scallop until it is large enough to shuck is both inefficient and wasteful. Their growth cycle is disturbed, they are smothered in sediments, and dredge and handling-induced mortality may take a high toll. Controlled harvesting in seeded areas, where most scallops are of known and near uniform size, minimizes the above effects. In the Seastead approach, scallops would be harvested once prior to seeding and once to keep. This reduction in dredging effort over these controlled-fishing sites is the key to improved growth, better survival, and the restoration of the scallop resource.

Another important focus of the Seastead project has been the development of hardware suitable for use in sea scallop culture. This hardware ranges from buoys, to mark the location of the approved experimental area, to cages, for the controlled growing of animals, to equipment for reliably observing the growth and dispersal of seeded scallops. Two goals have been paramount in the development of this hardware: cost effectiveness and maximum compatibility with fishing industry capabilities. Therefore, the project adapted existing hardware and methods rather than creating new designs.

Bottom Seeding

The SeaStead Project evaluated ocean ranching as a technology for culture of the sea scallop. Small scallops, just below the size normally harvested in the commercial scallop fishery (40-60mm in shell height), were harvested from dense seed beds and transported to potentially good grow-out sites. The approach employed in ocean ranching was to relay the scallops to the culture site where they are deposited on the bottom with no restraint from emigration or protection from predators. Ocean ranching is the least complicated culture method in terms of equipment and technology because it relies solely on a means to hold live scallops on deck with a minimum of stress.

This method is the simplest and requires the least change from current production methods. The logic behind this approach is based on the biology of the animal and the nature of its reproduction. Mature scallops each generate millions of planktonic offspring. These tiny, drifting larvae travel with the currents for several weeks, foraging on algae and other microscopic feed until they reach a stage of development that requires a surface on which to settle. This settle spat then begins to form its shell and assume its role as a filter feeder. During these early life stages, the sea scallop is prey to many other animals, suffering tremendous levels of mortality. When and where conditions are favorable for their survival, extremely dense populations of young scallops can result. Fishermen call these area "peanut piles". However, due to fishing pressure, competition for food, and predation, these piles seldom turn into a bounty of adult, harvestable scallops. By redistributing these challenged juveniles, the SeaStead Project aimed to recapture this lost productivity and develop a sustainable grow-out paradigm for the scallop fishery.

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(Scallops continued)

Two separate ocean ranching experiments were conducted during the course of the project. The first occurred during 25-26 May 1997, when 61 bushels, equivalent to approximately 38,000 individual scallops, were harvested at a site near Stellwagen Bank and relayed to one location within the SeaStead permitted area.

A second experiment was conducted using scallops collected on 5 June 1998. In the second attempt, five hundred bushels, equivalent to approximately 150,000 scallops, were relayed to a site within the SeaStead zone. The protocol for the second bottom ranching experiment increased the frequency of the observations on the relayed bed of scallops to ensure the bed could be tracked over time.

The second bottom ranching experiment resulted in a more successful tracking of the relayed bed. The strategy employed for tracking the second ranching experiment was to place a video observation sled on site during deployment and again within a week after the initial deployment. Observation on the relayed bed was continued whenever the opportunity arose where the limitation was the accessibility to the commercial scallop dragger and the video sled at the same time.

Bottom Grow-out Cages

The bottom culture in cages method of sea scallop production offered a relatively low-cost approach to contained culture. Through containment, the cage restricts the movement of the scallops so they don't "escape" and "ownership" is not in question. The cage also prevents predators from getting at them. We based our cages on the ubiquitous lobster trap, both in design and construction materials. We obtained PVC coated 14 gauge wire mesh, 1" x 1", from Riverdale Mills, a local manufacturer (the two rolls of material were donated to the project, enough for all 50 cages). A lobsterman from Fairhaven, Massachusetts fabricated the cages.

Assembly methods were as practiced for mid-sized lobster traps, except for the lack of entrances. The hinged opening for scallop handling was located on one of the long sides. It hinged from the bottom and in practice, the door was tie-wrapped to prevent or detect tampering.

The cages were arranged in typical lobster-trawl fashion, with 10 fathom of main line between each cage. Gangion lines 6-feet long lead to each cage. The trawls, two of 20 cages and one of 10 cages, were fitted with buoys at each extreme end. A high-flier was used on the eastern ends of the three trawls.

In general, the method proved troublesome, in that all the surface buoys were lost before the first scheduled recovery for maintenance and growth measurements. Two trawls were recovered and we thereby obtained growth and survival data from 40 cages. We have concluded that the cage approach is technically sound except for the hardware used for the surface buoy and line. Standard industry practice proved inadequate for the extended periods of soak time combined with the harsh exposure of the site.

Those scallops that survived the relaying and deployment in the bottom cages performed relatively well. They grew from 68.5mm to 89.5mm for a total growth of 21 mm in 236 days. This translates to a daily growth increment of 0.089mm/day. This growth rate approaches the growth noted for the population of scallops left untouched in their native habitat (0.106mm/day). We concluded that this method could be viable, once there is a better understanding of the environmental requirements of the sea scallop, with more control of handling stresses and on issues such as stocking densities, which were not carefully controlled in these cage experiments primarily due to extensive mortalities.

Suspended Scallop Array

The evaluation of the off-bottom culture of sea scallops using a large-scale scallop grow-out array was an additional objective of the project. The approach was to be similar to the suspended lantern nets used in Japan for oyster and scallop culture, but scaled up to be compatible with servicing by a typical scallop dragger. These units were to be arranged in a line array that was kept taut by four opposing anchors, a pair of spherical floats and underwater tom weights. A tom weight is a weight suspended halfway down the mooring line to take out any slack as the tide changes. The scale and robustness of this approach raised the concern of marine mammal specialists at NMFS. An alternative approach was developed: the large-scale suspended grow-out units are moored individually, suspended in the water column by a cluster of trawl floats with a pick-up line running to a small surface buoy. This approach eliminated the entangling potential of the previous array, particularly its anchors and the horizontal main line.

While this design became more refined, the preliminary economic modeling was occurring. Initial results of this model revealed a very poor economic return for the use of this suspended array approach due to high labor and capital costs. Therefore, we decided to seek information on the biological implications of suspended culture without investing project funds into the costly hardware of our large-scale plan.

A modest-sized, midwater lantern net array was purchased from a commercial aquaculture supplier. The manufacturer developed the design and the specifications with an understanding of the site requirements. The system was installed and loaded with scallops by the project industrial partner. No trace of the system was ever seen again.

Conclusion

Seastead has demonstrated that relaying sea scallops and deploying them in an ocean ranching situation is biologically feasible. The scallops can be tracked and monitored and scallop growth can be demonstrated. More extensive experimentation will need to be developed to monitor ranched populations to assess the overall survival and growth, thereby allowing the culturists to develop a more complete assessment of the biological and economic feasibility of ocean ranching of sea scallops.

Atlantic Salmon Genetics at Huntsman

Brian Glebe, Huntsman Marine Science Centre

The Huntsman Marine Science Centre is administering a new genetics program designed to enhance New Brunswick's position in the increasingly competitive global market for cultured Atlantic salmon. Although New Brunswick salmon production is only 5% of the combined total of Norway and Chile (300,000 metric tonnes), recent improvements to the research hatchery in Chamcook have made it into a world class salmon-breeding centre on par with these countries.

For centuries, animal breeders have recognized that the use of the best individuals as parents produced superior offspring in succeeding generations. The application of this principle to agricultural animals has resulted in modern day stocks that are quite different in appearance and production characteristics than their wild ancestors. However, the application of the same genetic principles to salmon is quite recent by comparison. After two decades of genetic manipulation, cultured salmon stocks still remain indistinguishable in appearance from their wild counterparts. However, improvements in production efficiency and faster growth have occurred. This suggests the long-term response to genetic selection will be similar to that experienced in agriculture.

The idea to apply genetic improvement to Atlantic salmon is not new. Huntsman, in conjunction with the Atlantic Salmon Federation (ASF) and the Department of Fisheries and Oceans (DFO), began the genetic manipulation of several wild salmon stocks in a sea ranching program in 1973. In this context, sea ranching refers to the culture of salmon smolts in freshwater, their subsequent release for oceanic feeding migration, and their return to their release point as adults. Sea ranching has been used world-wide in aquaculture trials involving the harvesting of returning adults, and for stock enhancement where returning adult salmon are allowed to proceed upriver for natural spawning. The goal of the Salmon Genetics Research Program (SGRP) was to evaluate genetic selection as a tool for increasing the adult return rate. This program used the facilities of a recently constructed hatchery at Chamcook. The Atlantic Salmon Federation (ASF) had raised $1.4 million from the private sector to build the hatchery.

Ten years later, the SGRP shifted its focus from sea ranching to assisting the fledgling salmon aquaculture industry in the Bay of Fundy. The premise that a successful local industry would ease the pressure on threatened wild stocks eventually proved to be true. Over a number years, six New Brunswick wild stocks were grown in sea cages, and then assessed for performance. As a result of these trials, the Saint John River salmon stock became the preferred strain for local farming. A broodstock development plan involving economically important traits such as growth rate and late maturity for this strain was highly successful. Most of the salmon grown in our province originated from the SGRP selection programs either directly, or as seed stock, for corporate breeding programs. The Bay of Fundy industry generates about $150 million annually.

Another milestone in the effort to improve New Brunswick aquaculture stock genetically came in 1998. Recognition of the importance of salmon farming to the local economy (one in four jobs in Charlotte County), and increasing outside competition, prompted changes in the direction of the breeding program.

The new program is called the Atlantic Salmon Broodstock Development Program (ASBDP). Major improvements to the hatchery facility were made. These included interior renovations, 154 new tanks in the nursery area, 80 new outdoor smolt-rearing tanks, the installation of new fish-feeding and grading systems, and the upgrading of water treatment facilities including oxygen injection. Approximately 50% of the cost of renovations, now approaching $800,000, is being defrayed by the Atlantic Canada Opportunities Agency's (ACOA) Business Development Program. A measure of the importance of the ASBDP is also reflected in the range of funding partners. Funding partners include eight major aquaculture companies, the DFO, and the New Brunswick Department of Fisheries and Aquaculture (DFA). The ASF has continued its commitment to the program by leasing the hatchery to Huntsman on a long-term basis. Huntsman provides the overall management of the program and a committee of international geneticists provides the scientific protocols for breeding. In addition, the eight growers have signed five-year contracts involving the purchase of smolts, the holding of pedigree broodstock, and annual contributions to research funding.

Presently, 300,000 salmon parr (3-4 inches long) from 100 families are being maintained for transfer to salmon farms this spring. Once there, they will be evaluated, and the best pedigree performers selected as broodstock for the next generation. A "family" is the progeny from mating one female to one male. In addition, another 1.5 million fry (1-2 inches long) from 150 families are being reared for transfer as smolts (6 inches or longer) in the year 2001.

In general, the ASBDP exemplifies the vision held by all individuals, companies, and agencies involved, that genetic improvement can be the key to the long-term viability of the salmon industry in this region. Both the level and duration of commitment by industry is unique and further strengthens the common goal - the sustainability of a strong and viable local aquaculture industry.

Flounders: the Next Aquaculture Species?

John H. Allen, Huntsman Marine Science Centre

Scientists from a number of Huntsman's member universities have been studying different features of Bay of Fundy flounders since the facility opened in 1969. During the last decade, there have been intermittent programs to determine if any of them are potential aquaculture species for this area. These various studies have helped to determine that most of the foreseen potential problems in raising these fish from egg to adult can be surmounted. The challenges now focus on whether rearing and farming these small flatfish can be done at a commercial scale and whether such ventures can be economically viable.

Working with industry partners from Grand Manan, Huntsman has commenced a program to provide up to 50,000 juveniles of a number of different flounders for their test grow-out facilities. This program is lead by Dr. Puvanendran who recently joined Huntsman after obtaining his Ph.D. from Memorial University of Newfoundland.

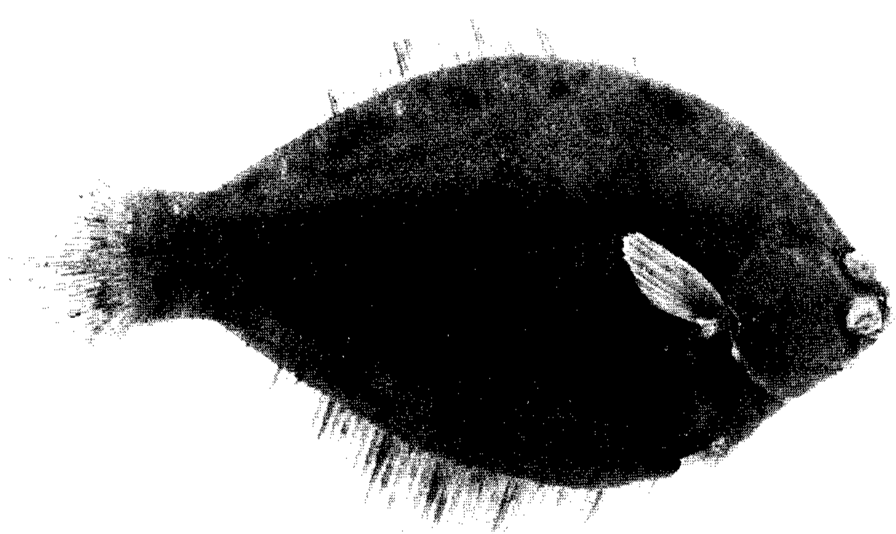
Our industry partners, the Atlantic Canada Opportunities Agency (ACOA), the National Research Council's IRAP program and the New Brunswick Department of Fisheries and Aquaculture, have joined forces to assist Huntsman with this project. The hatchery has been set up in a 68 ft. x 131 ft. Quonset Hut. The flatfish program shares the building with the pilot rearing of halibut juveniles. Both programs utilize a "live-food" facility, also contained in the building, because, unlike salmon, marine fish cannot proceed from the yolk-sac stage directly onto pelleted food.

In the live feed rooms, Stephanie Warrington tends to the broods in various shades of yellow, green and brown. Three different groups of organisms are grown - algae, rotifers and *Artemia* (or brine shrimp). Small single-celled algae are grown under sterile conditions in five-foot high clear cylinders surrounded by bright lights. Every morning, about half of the volume of a cylinder is drained off and replaced with clear water and chemical nutrients. The algae cells reproduce quickly, and in a few days the number of cells are back up to 5-20 million cells/millilitre and can be harvested again. This algae is then added to the larval fish tanks to provide a "green water" environment which helps larval feeding and survival once the small fish have absorbed their yolk-sacs.

Harvested algae are also fed to small planktonic invertebrates, called rotifers. Different species of larval fish vary in mouth size when they hatch. Rotifers are required to feed the smaller mouthed flat fish larvae that cannot immediately eat *Artemia*, a substantially larger prey item. Rotifers can be cultured continuously on a diet of algae and yeast. They are grown in 1000 L vats which are partially harvested daily. Following harvest, clean water is added, allowing the rotifers to multiply and replenish their numbers. A typical culture density is 400-500 rotifers/ml. Once harvested, rotifers are enriched with special fatty acids over a 12-24 hour period. First-feeding flounder larvae are then fed these enriched rotifers several times daily for a number of weeks, until they are big enough to accept *Artemia*.

Dried *Artemia* eggs are purchased from companies that harvest them from brine ponds in sub-tropical areas. They are hatched in 300 L conical tanks under bright illumination in

Pseudopleuronectes americanus (Walbaum, 1792) WINTER FLOUNDER



warm seawater. Before the *Artemia* are fed to the fish larvae, they are also enriched with special fatty acids. Once the fish are physiologically ready to accept dry feed, they are weaned from the live brine shrimp diet onto small commercial pellets.

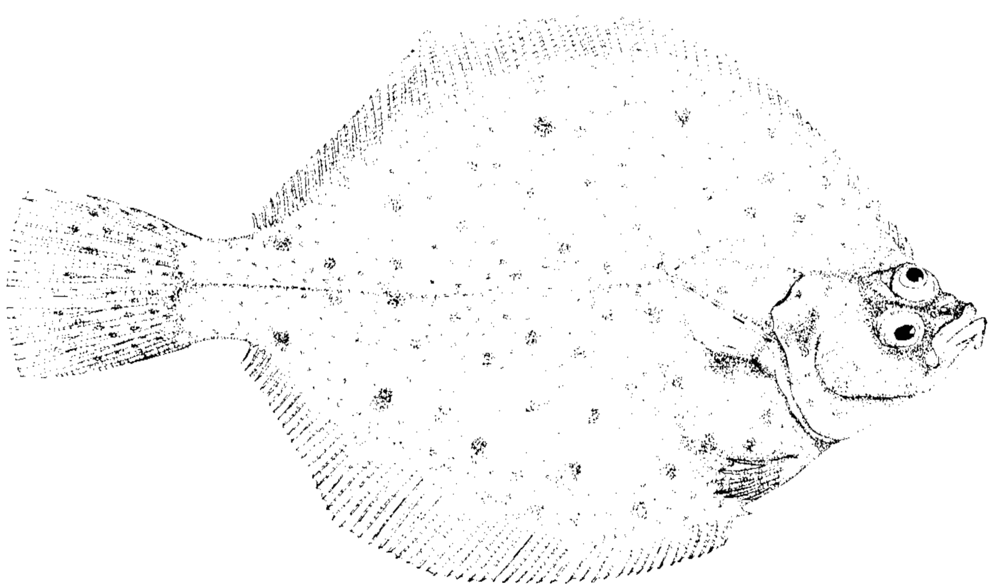
The small flat fish eggs are incubated in vertically mixed inverted conical tanks of about 250 litres at about 100-200,000 eggs/ tank. After a week or so, depending on species and temperature, they hatch and the yolk-sac larvae are moved into clean identical conical tanks, clear of the debris of egg coatings and dead eggs. A few days later, the live feeding commences. The yolk sac is absorbed after one to two weeks, depending on the temperature. Once the feeding is established, the larvae are moved into larger tanks. Live feeding continues, but after a week or so, pelleted feed is gradually introduced and the larvae begin to change from a tiny "normal" looking round fish to become the flattened version that we expect.

It is at this time that one eye begins to migrate around the head so that both eyes are on what will become the upper side of the fish. Some species of flatfish, such as yellowtail and winter flounder, lie down on their left side while others such as the summer flounder and the windowpane, lie down on the right side of their body. In most flounder species, juveniles settle down on the bottom of the tank and, after 2 months post-hatch, are recognizable as a miniature of their parents. One exception is the witch flounder, which has to be fed live feed for nearly four months before it settles on the bottom. By this time, however, it is 2-3 inches long, compared with the 0.5 to1.0 inch of the other newly settled flounders. Throughout this time, the intensity and duration of light and the temperature of the water is critical for the optimum and safe growth of the larvae.

These juvenile flatfish will then be held in nursery tanks for 3-6 months to obtain the 3-6 inch size believed necessary to place them in grow-out sites where they may be more vulnerable to parasites and disease. The larger witch flounder spends less time in the nursery stage because of its greater growth prior to settling on the bottom. At this stage, temperature and feeding are manipulated to obtain maximum growth.

The optimum configuration of economical grow-out farms for flat fish in the Bay of Fundy is still speculative. Ideas range from nets placed inside old herring weirs to tank farms on the shore. Flat fish get seasick if they are placed on the solid bottom of floating cages and subjected to a lot of wave motion. Some flounders are found naturally in shallow water, so sunburn is not the same concern as it is when farming halibut or witch flounder, which are deeper-water fish. Also, fish that naturally inhabit estuaries and bays are attuned to taking the extreme swings in temperature, which can occur as the tidal waters move over exposed sand banks. European experience with turbot, a sister species of the windowpane, suggests that the land-based tank farm concept will be a strong contender. It is hoped that, in three to four years, we will know many of the answers and be able to provide the basis for another viable aquaculture industry in this region.

Limanda ferruginea (Storer, 1839) YELLOWTAIL FLOUNDER



ICES Symposium on Environmental Effects of Mariculture

David Wildish, Fisheries and Oceans Canada, St. Andrews Biological Station

Mariculture, the culture of plants and animals in the sea, is a recent development in the commercial production of seafood or industrial chemicals. Extensive mariculture refers to the condition where production per unit area is close to the natural carrying capacity. Where it is substantially increased above the natural carrying capacity it is referred to as intensive. Intensive culture may involve complete food supplementation to achieve the desired levels of high production, as in the Gulf of Maine salmon mariculture industry. Extensive mariculture has a relatively long history; for example, the Romans knew oyster culture. By contrast, modern intensive mariculture is only approximately 30 years old**.** Intensive mariculture produced a steadily increasing proportion of the world's seafood during the 30-year period. Thus, by 1996, aquaculture (inclusive of freshwater fish production), represented about one-fifth of the world total and is still expanding, whilst traditional fishing production is declining. Mariculture is a competitor for space in the nearshore coastal zone and it is generally believed that its development and daily operations must be compatible with existing coastal zone uses. Such uses include traditional fishing, recreation, industrial and municipal water disposal, mineral resource extraction, as well as commercial shipping.

The ICES Symposium was held from the 13th to the 17th September, 1999 in St.Andrews, N.B., at the Algonquin Hotel. Over 100 delegates attended both from ICES and non-ICES countries, including Australia, Canada, Chile, Croatia, Denmark, France, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, South Africa, Russia, the U.K., and U.S.A.

The usual purpose of a scientific symposium is to bring together members of an "invisible college" to discuss recent research findings. Commonly, this involves a narrow discipline, e.g., benthic ecology. In the case of the ICES Symposium on the Environmental Effects of Mariculture, the common factor was the fish or bivalve farm, with participants representing a multidisciplinary approach to a central practical problem. Two major questions were addressed during the symposium: (1) what are the environmental effects of fish and bivalve farming on the coastal zone and (2) how does the local environment affect mariculture productivity? Thus geneticists, disease specialists, parasitologists, biochemists, analytical chemists, engineers, physical oceanographers, sediment geochemists, physiologists, and ecologists contributed. Resource managers and representatives from the maricuture industry were also present because they use scientific information in their daily management decisions. Communication within this diverse group was improved by an afternoon trip to see the local salmon culture industry in action, a dinner with folk music entertainment afterwards, and, for the few left on Saturday following the Symposium, a wonderful canoe trip down the St.Croix river.

Five theme sessions were held to address the environmental effects of fish and bivalve farming on the coastal zone. The sessions, and chairs, included (1) harmful algal blooms and mariculture, Patrick Lassus, Institut Francais de Recherche pour l'Exploitation de la Mer, France (IFREMER); (2) sediment biogeochemistry and mariculture, Marianne Holmer, Odense University, Denmark; (3) disease/environmental factors in mariculture, James Stewart, DFO Canada; (4) environmental monitoring in mariculture, David Wildish, DFO Canada; (5) other ecological issues in relation to mariculture, Maurice Heral, also from IFREMER, France. The last session included presentations on remediation and the genetic consequences of escaped fish.

All 32 papers from the five sessions addressing the first question will be considered for publication, following peer review, in the *ICES J. Marine Science*, and are slated for publication in the first issue 2001. Because of the delay in publication, the full text of each paper accepted after the review process is completed will be published on the ICES web site at: http://www.ices.dk/sympoisa/eem.htm. The guest editors are David Wildish and Maurice Heral.

In addition to updates on research for each of the environmental problems mentioned above, one session dealt with various ways to monitor the environmental effects of mariculture. The session was chaired by Jon Grant, Dalhousie University, Halifax, Canada. Papers presented in this session considered how environmental variables affect the productivity of shellfish and finfish farms. This included the design of predictive models to determine carrying or holding capacity. The work is of obvious practical importance in choosing the best sites for mariculture and in predicting the production capacity sustainable at each site. Practical methods of monitoring for organic enrichment in Norway, Canada and the USA were also presented and demonstrated a lack of consensus on how to do this. Operational criteria to aid in the choice of practical monitoring include scientific defensibility, statistical validity, relevant decision points (to trigger remediation measures) and cost effectiveness. Besides organic enrichment, other subjects covered included chemical contamination and bacterial contamination of cultured mussels. For the latter, monitoring involved rain gauges in New Zealand that indicated, with a few days lag, when coliform counts would be high due to runoff in the Malborough Sound. The few days warning allowed farmers to plan harvesting prior to them becoming contaminated by coliform bacteria.

Because of the different nature of the question associated with this session, the papers from it will be submitted to a different journal. Jon Grant will act as guest editor and papers are to be submitted to the *Canadian J. Fisheries and Aquatic Science*.

Rockweed Workshop

Linda Mercer, Maine Department of Marine Resources

A workshop, "Gulf of Maine Rockweed: Management in the Face of Scientific Uncertainty", was held at the Huntsman Marine Science Centre, St. Andrews, New Brunswick, December 5-7, 1999. The workshop resulted from two 1998 meetings sponsored by the Global Programme of Action Coalition for the Gulf of Maine (GPAC), at which stakeholders from the region identified issue of "harvesting and management of low trophic level resources." Rockweed (*Ascophyllum nodosum*) was selected as the focus for the workshop because of concerns about potential impacts to the coastal ecosystem from commercial harvesting of rockweed.

The objectives of the workshop were to identify and prioritize essential knowledge gaps in the role of rockweed as an essential habitat and the consequences of ecosystem-level changes to rockweed populations in the Gulf of Maine; and to provide management decision-making tools for ecologically sustainable low trophic level harvesting. Participants included state, provincial, and federal representatives, industry members, academic researchers, and non-governmental organizations. Experts in various fields gave talks on the habitat use of rockweed, the role of rockweed in the coastal ecosystem and managing under uncertainty.

Several topics were identified for further research. These include: the role of rockweed as critical habitat for eider ducklings, pollock, and other species; contribution of rockweed to nutrient budgets; harvest impacts on rockweed structure and rockweed recruitment; landscape effects of rockweeed harvest perturbations; faunal changes resulting from harvest; biomass extimates; impacts of climate changes, and longterm monitoring.

Recommendations were also made for management of the resource. These include: establishing permanent protected areas; involving the local community in management decisions; reacting flexibly to problems, in a timely manner; and use of the precautionary approach.

The workshop report is being prepared, the plan is to complete this publication by the end of May. For further details and updates, check the web site at:
http://personal.nbnet.nb.ca/scepnet/rockweed/intropst.htm

Maine Dept. Marine Resources Announces John Sowles will Direct Ecology Division

John Sowles has recently accepted the offer to serve as Director of the MDMR Ecology Division, a position vacated by Rich Langton, and will begin service with the MDMR in June. In this capacity, Sowles will plan and direct fishery habitat studies and surveys, oversee the aquaculture lease permit and monitoring program, GIS mapping, and research and management initiatives on a variety of species, including seaweeds, mussels, and horseshoe crabs.

Sowles comes to the MDMR from the Maine Dept. of Environmental Protection, where he has been assessing the natural chemical variability of water, sediments, and tissues of several marine species representing various trophic levels. This work has become the basis for assessing spills and discharges as well as predicting impacts from proposed activities. One example includes an evaluation of the effects of aquaculture on the benthos and development of a predictive model to estimate potential impact. Sowles hopes to integrate some of this past work with his new responsibilities and looks forward to fresh challenges.

Measuring 'Fallout' on Fish Farms

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See: http://www.Oceanspace.co.uk

Ocean Scientific International Ltd. (Petersfield, Hampshire, U.K.) recently supplied an underwater video surveillance system to the Scottish Environment Protection Agency (SEPA), an organization which plans to keep a close eye on the fallout of particulate material at fish farms. The FPC 2000 camera is held inside a compact support frame, which can be lowered from a fixed platform or boat to depths of up to 100 meters. Once in position, the operator views live images on an LCD monitor, with real-time positioning data generated by a global positioning system (GPS) receiver. Special image capture software allows the recorded video images to be archived on a PC.

A spokeswoman said the camera would enable SEPA researchers to carry out monitoring and comparison of particulate levels at specific sites and to accurately record geographic positions. The video camera produces high-quality, high-resolution digital images with the use of auto-focus features. The support frame houses an integrated lighting system, whose intensity can be adjusted during filming. The video camera uses a 12/24 volt power supply, ideal for operation on small boats. Alternatively, the video system can be operated for up to six hours by way of a battery pack. E-mail the company at:
robert.holland@oceanscientific.co.uk.

Reports Received

Cadrin, S. X. and E. M. C. Hatfield. Stock Assessment of Longfin Inshore Squid, *Loligo Pealii*,A Report of the 29th Northeast Stock Assessment Workshop, Northeast Fisheries Science Center Reference Document 99-12, September 1999, 107 pp.

Cargnelli, L. M., S. J. Griesback, and W. W. Morse. Essential fish Habitat Source Document: Atlantic Halibut, *Hippoglossus hippoglossus*, Life History and Habitat characteristics, NOAA Technical Memorandum NMFS-NE-125, September 1999, 17 pp.

Fahay, M. P., P. L. Berrien, D. L. Johnson, and W. W. Morse. Essential Fish Habitat Source Document: Atlantic Cod, *Gadus morhua*, Life History and Habitat Characteristics, NOAA Technical Memorandum NMFS-NE-124, September 1999, 41 pp.

Gibson, J. A. Northeast Fisheries Science Center Publications, Reports, and Abstracts for calendar year 1998, Northeast Fisheries Science Center Reference Document 99-15, September 1999, 22 pp.

Jearld, Jr., A. (ed.) Expanding Opportunities in Oceanic and Atmospheric Sciences, Proceedings of a Conference to Strengthen Linkages among HBMSCUs, NOAA and Graduate Studies in marine and Atmospheric Sciences, March 29-31, 1999, University of Maryland Eastern Shore. Northeast Fisheries Science Center Reference Document 99-18, December 1999.

Johnson, D. L., P. L. Berrien, W. W. Morse, and J. J. Vitaliano, Essential Fish Habitat Source document: American Plaice, *Hippoglossoides platessoides*, Life History and Habitat Characteristics, NOAA Technical Memorandum NMFS-NE-123, September 1999, 31 pp.

Kitts, A. W. and S. R. Steinback. Data Needs for Economic Analysis of Fishery Management Regulations, NOAA Technical Memorandum NMFS-NE-119, August 1999,

Maine Department of Marine Resources Aquaculture Lease Inventory. May 1999.

Maine Department of Marine Resources 1996-97 Finfish Aquaculture Monitoring Program. Annual Fall 1996 Water Quality Survey. Fall 1996. Prepared by C. S. Heinig, MER Assessment Corp.

Maine Department of Marine Resources Finfish Aquaculture Monitoring Survey. Benthic Infauna Data Summary. Fall 1996. Prepared by C. S. Heinig, MER Assessment Corp.

Maine Department of Marine Resources Finfish Aquaculture Monitoring Survey. Benthic Infauna Data Summary. Fall 1997. Prepared by C. S. Heinig, MER Assessment Corp.

Ollerhead, J., P. W. Hicklin, P. G. Wells and K. Ramsey (eds.). 1999. Understanding Change in the Bay of Fundy Ecosystem. Proceedings of the 3rd Bay of Fundy Science Workshop, Mount Allison University, Sackville, New Brunswick, April 22-24, 1999. Environment Canada, Atlantic Region Occasional Report No. 12, Environment Canada, Sackville, New Brunswick, 143 pp.

Predicting Right Whale Distribution, Report of the Workshop October 1-2, 1998, Woods Hole, Massachusetts, Ed. Clapham, P. J. Northeast Fisheries Science Center Reference Document 99-11, August 1999, 22 pp.

Quintal, J. M. and T. D. Smith. *Marine Mammal Research Program of the Northeast Fisheries Science Center during 1990-1995*, NOAA Technical Memorandum NMFS-NE-120, September 1999, 28 pp.

Reid, R. N., F. P. Almeida, and C. A. Zetlin. Essential fish Habitat Source Document: Fishery-Independent Surveys, Data Sources, and Methods, NOAA Technical Memorandum NMFS-NE-122, September 1999, 39pp.

Rossman, M. C., and R. L. Merrick. Harbor porpoise Bycatch in the Northeast Multispecies Sink Gillnet Fishery and The Mid-Atlantic Coastal Gillnet Fishery in 1998 and during January -May 1999. Northeast Fisheries Science Center Reference Document 99-17, December 1999, 36 pp.

Roundtree, B. P., Individual Vessel Behavior in the Northeast Otter Trawl Fleet During 1982-92. NOAA Technical Memorandum NMFS-NE-113, October 1997, 50pp.

Shaw, D. G., J. W. Farrington, M. S. Connor, B. W. Tripp, and J. R. Schubel. Potential Environmental Consequences of Petroleum Exploration and Development on Georges Bank, New England Aquarium Aquatic Forum Series, Report 99-3, 64 pp.

Taylor, M. H., and C. Bascunan. Description of the 1999 Oceanographic Conditions on the Northeast Continental Shelf, Northeast Fisheries Science Center Reference Document 00-01, January 2000, 120 pp.

Terceiro, M. Stock Assessment of Summer Flounder for 1999, Northeast Fisheries Science center Reference Document 99-19, December 1999, 178 pp.

Turning to the Sea: America's Ocean Future. NOAA Office of Public and Constituent Affairs, http://www.publicaffaairs.noaa.gov

Waring, G. T. et al. *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments—1999*, NOAA Technical Memorandum NMFS-NE-153, October 1999, 196 pp.

Wigley, S. E., J. K. T. Brodziak, and S. X. Cadrin. Assessment of the Witch Flounder Stoch in Subareas 5 and 6 for 1999, A Report of the 29th Northeast Regional Stock Assessment Workshop. Northeast Fishereies Science Center Reference Document 99-16, October 1999, 153 pp.

The following DFO reports were received and are available from the Internet at http://www.dfo-mpo.gc.ca/csas

DFO 1999. Pollack in Div. 4VWX and SA5Z. DFO Science Stock Status Report A3-13 (1999).

DFO 1999. Porbeagle shark in NAFO subareas 3-6. DFO Science Stock Status Report B3-09 (1999).

DFO 1999. Processed weight to live-weight conversion factors for Atlantic Halibut (*Hippoglossus hippoglossus*) of the Scotian Shelf and Southern Grand Banks. DFO Maritimes Regional Fisheries Status Report 99/1E.

DFO 1999. Silver Hake on the Scotian Shelf (Div. 4VWX). DFO Science Stock Status report A3-09 (1999).

DFO 1999. Southern Scotian Shelf and Bay of Fundy Cod (Div. 4X/5Y). DFO Science Stock Status Report A3-05 (1999).

DFO 1999. Southern Scotian Shelf and Bay of Fundy Haddock. DFO Science Stock Status Report A3-07 (1999).

DFO 1999. Updates on Selected Scotian Shelf Groundfish Stocks in 1999. DFO Science Stock Status Report A3-35 (1999).

DFO 2000. 4VWX Herring. DFO Science Stock Status Report B3-03(2000).

DFO 2000. Atlantic Salmon Maritime Provinces Overview for 1999. DFO Science Stock Status Report D3-14 (2000).

DFO 2000. Eastern Nova Scotia Snow Crab. DFO Stock Status Report C3-02 (2000).

DFO 2000. Inshore Gulf of Maine Jonah (*Cancer borealis*). DFO Science Stock Status Report C3-66(2000).

DFO 2000. Inshore Gulf of Maine Rock Crab (*Cancer irroratus*). DFO Science Stock Status Report C3-67 (2000).

DFO 2000. Southwestern Nova Scotia Snow Crab. DFO Stock Status Report C3-65 (2000).

DFO 2000. Western Cape Breton Snow Crab. DFO Stock Status Report C3-64 (2000).

McCave Honored as 1999 A. G. Huntsman Award Winner

The A.G. Huntsman Foundation is pleased to announce that the winner of the 1999 A.G. Huntsman Award is Prof. I. Nicholas McCave of the University of Cambridge, UK. This major Canadian award recognizes Dr. McCave's many seminal contributions to the evolution of a processed-based understanding of fine-sediment grain size distributions in the sea. His efforts to unravel the environmental record stored in muds have yielded insights that extend beyond marine sedimentology and into the broader field of marine particle dynamics and physical oceanography. His dedicated pursuit of mechanistic understanding of fine-sediment dynamics has led to important contributions in a wide range of marine sedimentary environments ranging from the nearshore to the deep sea. His groundbreaking theory and observations of fine-sediment deposition, aggregation and hydrodynamic sorting continue to advance a field that in general has suffered from reliance on empirical calibration of poorly parameterized models. His work has led to greater understanding of phytoplankton bloom dynamics, vertical particle flux in the sea (a key element of the Joint Global Ocean Flux Study), and the kinematics of deep-sea circulation in the ancient ocean.

The award was presented by the Royal Society of Canada at a special ceremony at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia 26 November 1999. The presentation was followed by the annual Huntsman Lecture, given by Dr. McCave, and a champagne reception.

The A.G. Huntsman Award was established in 1980 by the Canadian marine science community, in order to recognize excellence in research and outstanding contributions to marine sciences. It honors those men and women, of any nationality, who have had and continue to have a significant influence on the course of marine scientific thought. The A.G. Huntsman Award reflects the multifaceted nature of marine research. It is presented annually in one of three categories: marine geosciences, physical/chemical oceanography, and biological oceanography. The award was created to honor the memory of Archibald Gowanlock Huntsman (1883-1972), a pioneer Canadian oceanographer and fishery biologist.

The A. G. Huntsman Award is funded by Fisheries and Oceans Canada, Natural Resources Canada, the Province of Nova Scotia, and the Canadian Association of Petroleum Producers.

Nomination information can be obtained from the A. G. Huntsman Foundation, Bedford Institute of Oceanography, PO Box 1006, Dartmouth, Nova Scotia, B2Y 4A2, Canada. The category for the 2000 award will be physical/chemical oceanography.

Calendar

May

22 **RARGOM Meeting**
University of Maine Darling Marine Center
contact: Genie Braasch, braasch@dartmouth.edu

June

5-9 "Research Across Boundaries", ASLO 2000 meeting
Copenhagen, Denmark
http://www.aslo.org/copenhagen2000/

14-15 NOAA/Gulf of Maine Council on the Marine Environment
Workshop, UNH, Durham, NH.
contact: Laura Marron, lmarron@des.state.nh.us

19-20 "Exploring Transboundary Arrangements for Management of the Gulf of Maine Ecosystem: Focus on Sewage, Toxics and Coastal Develpment"
Workshop, St. John, NB
contact: Heather Tausig, htausig@neaq.org

22-25 "Endocrine Disruptors in the Marine Environment: Impacts on Marine Wildlifke and Human Health"
Workshop, sponsored by MERI,UConn, Jackson Lab.
Bar Harbor, ME
http://www.merirsearch.org/workshop.html

July

18-20 Gulf of Maine Council on the Marine Environment
Meeting, Portsmouth, NH
contact: Laura Marron, lmarron@des.state.nh.us

19-20 GLOBEC Georges Bank Broad Scale Data Coordination
Workshop, Carriage House at WHOI, MA
contact: David Mountain, dmountai@whsun1.wh.whoi.edu

Coastal Zone Canada 2000

Scheduled to take place in Saint John, New Brunswick September 17-22, 2000, the fourth international conference will address the theme, "Coastal Stewardship: Lessons Learned and the Paths Ahead." Topics will include aboriginal practices, community-based actions, coastal health, and oceans governance. A youth conference and trade show will also take place.
For more information, see
www.gov.nb.ca/dfa/czc-zcc2000.htm
E-mail czczcc2000@gov.nb.ca
call (506) 462-5961.

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