Aquaculture White Paper

EXECUTIVE SUMMARY

AQUACULTURE: The manipulation of marine or freshwater organisms and/or their environment before eventual release, harvest, or capture; the controlled cultivation and harvest of aquatic animals and plants. (USDA National Aquaculture Development Plan, 1983).

In Massachusetts, the aquaculture industry is small, but growing steadily. Bush and Anderson estimate that aquaculture contributed approximately $8 million to the Commonwealth economy in 1992. The industry is roughly split between inland and marine aquaculture in terms of economic value. Most industry analysts would agree that there has been a steady rise in production since 1992, both in the marine and inland sectors.

Marine aquaculture in the state is presently limited to the cultivation of shellfish (quahogs, oysters and scallops) for commercial, research, and propagation purposes. There are no coastal fish farms or ocean ranches in the state and only very limited work, primarily for research purposes, is dedicated to seaweed culture. Proposals for offshore fish farms and shellfish culture have just recently been proposed in the state and are undergoing permit review. The inland aquaculture industry is comprised primarily of a handful of highly technical recirculating facilities located mainly in the western part of the state (with one on Cape Cod). These facilities produce hybrid striped bass, tilapia, trout and other finfish. Additionally, there are a number of small pond and flow-through facilities located in Massachusetts.

The wild stock of both finfish and shellfish is currently dwindling, a trend that, despite the imposition of limits and closed seasons, has shown every indication of continuing. The recent closures of groundfishing on George's Bank are indicative of a larger problem both in Massachusetts and to some extent, worldwide. While fish stocks are undeniably declining, the demand for high quality marine protein for a variety of uses continues to grow. Aquaculture has been viewed by many as a means to address the gap between wild seafood availability and consumer demand. The development and support of the aquaculture industry is therefore a priority for the state of Massachusetts, not only in terms of increased seafood supply but also as a source of employment, particularly in rural areas.

State aquaculture programs are a reflection of local attitudes for or against the industry. These attitudes are created and influenced by historic and cultural trends, traditional uses, education, environmental and economic conditions, and the manner in which a state chooses between conflicting uses and limited resources. Massachusetts has, to date, reacted to the aquaculture industry on a case by case basis with very little attention given to the larger picture. As a result, the state has been viewed by many as an impediment to growth in the industry. This viewpoint is due, in part, to a complex and duplicative permitting system as well as a paucity of technical assistance provided by state agencies.

With significant attention now being paid to the potential of the aquaculture industry, the Executive Office of Environmental Affairs, acting on behalf of the Governor, has initiated this study to identify how the state can proactively assist the aquaculture industry. The purpose of this report is to review the status of the aquaculture industry in the state both from a biological and technological standpoint as well as from a legal/regulatory perspective.

This White Paper includes information on the biology, technology, support systems, water quality, seafood safety, legal, and economic aspects of the aquaculture industry. Problems attendant to aquaculture are distilled in the Conclusion section.

This report reflects the aquaculture industry today in Massachusetts in that the focus of much of the review is on species currently being cultured. It should be kept in mind that the aquaculture industry in Massachusetts is in the process of rapid growth and change.

The White Paper addresses both inland and coastal (marine) aquaculture. A distinction must be drawn between inland aquaculture and coastal aquaculture. Inland aquaculture utilizes ponds, tanks, and enclosures that are dependent upon the aquaculturist for maintenance of water quality, food supply, and waste removal. Inland aquaculture is generally (with the exception of state-run hatcheries and stocking facilities) conducted on private property by private culturists. The primary product of inland aquaculture is finfish.

Coastal aquaculture utilizes enclosures, cages, or pens for mobile marine species such as silver and Atlantic salmon; baskets, rafts, racks, and trays for surface culture or water column (off-bottom) culture for sessile molluscan shellfish; nursery trays and pens placed on the bottom for the cultivation and grow-out of seed shellfish or placement of cultch (natural or artificial) for attachment of molluscan spat. All coastal aquaculture uses existing, unaltered water.

The private and public interests affected by competing uses of the sea, the coast, and the tidelands raise complex issues. The alteration, whether temporary or permanent, and private use of public resources provides a broad basis for potential conflict if not managed prudently. Similarly on land, aquaculture is in many ways a complex activity with potentially controversial implications. It is the intent of this study to both characterize the state of the aquaculture industry in Massachusetts today and establish a foundation for effective management of a diverse and sustainable industry for the future.

Section A of the White Paper focusses on Inland Aquaculture while Section B concentrates on Marine Aquaculture.

Section A

INLAND AQUACULTURE

1. INTRODUCTION TO INLAND AQUACULTURE

Commercial aquaculture (or fish farming) is a valuable and growing industry in the U.S. and around the world. Two major factors driving the industry's expansion are increased public demand for high quality fishery products and reduced yields from harvest of wild stocks. Many commercially important wild fish stocks are declining as a result of overfishing, environmental degradation and habitat loss. In addition, the possibility of contaminants in wild fish may also limit the available supply of fresh fish to the public. At the same time, America is becoming more health conscious and consuming more fish because of its nutritional value and low fat content. Per capita consumption of edible fishery products in the United states reached an all-time high of 15.4 lbs. in 1987 (Robinette et al. 1991). The Department of Commerce has projected that total fish and shellfish consumption could increase by 30 percent between 1990 and 2000. To satisfy U.S. demand, this would require an additional 1 billion pounds of fishery products annually. Longer term projections are even more dramatic. World seafood demand is projected to increase nearly 70 percent by 2025 which would require a seven-fold increase over current aquaculture production levels (Joint Subcommittee on Aquaculture 1993)

The United States is the world's largest exporter of seafood products ($2.8 billion in 1990). At $9 billion a year, the U.S. is also the second largest importer of seafood in the world. In terms of the U.S. trade deficit, fisheries products are the largest contributor among agricultural products, and second largest, after petroleum, among all natural resource products (Joint Subcommittee on Aquaculture 1993).

U.S. aquaculture has been growing rapidly, with production and revenues increasing nearly 400 percent in the 1980's. Aquaculture and its support industries such as feed mills, processing plants, and equipment dealers, create jobs in rural communities. According to the National Fisheries Institute, the total economic impact of U.S. Aquaculture is $8 billion and the industry generates for approximately 300,000 jobs (Joint Subcommittee on Aquaculture 1993).

Despite these impressive figures, aquaculture still accounts for only 10-15 percent of the U.S. seafood demand (Joint Subcommittee on Aquaculture 1993). This "shortfall", however, means opportunity. Aquaculture can provide farmers with an additional or alternative source for generating income and opportunities for capital investment by others. Much of the recent expansion of aquaculture has been in the southeast U.S. with the catfish and crayfish industries. Annual production of farm-raised catfish is estimated at over 350 million pounds and represents more than a 400 percent increase in the industry since 1980. Crayfish culture has also increased significantly since the early 1980's with more than 150,000 acres now in production in an industry valued at over $90 million. Trout production, now at over 55 million pounds, has potential for expansion as do numerous other fish species including Atlantic salmon, hybrid striped bass, catfish, and tilapia (Robinette et al. 1991).

Cultured fish also play a major role in providing and enhancing recreational fishing opportunities, augmenting existing fish stocks, and restoring fisheries resources. Hatcheries are an important management tool used by state and federal fish and wildlife agencies to enhance and restore freshwater fisheries for public benefit. In Massachusetts, there are five hatcheries operated by the Division of Fisheries and Wildlife which culture fish for purposes of put-and-take fishing, restoration and enhancement of native fish species, and augmenting existing fish populations to diversify fishing opportunities.

Expansion of aquaculture will most likely be limited more by availability of suitable sites than by saturation of the market. Good quality water is the primary limiting factor. Idaho is the largest producer of trout in the U.S. because they have a tremendous supply of high quality, free-flowing cold ground water. In the Mississippi Delta catfish farming region, the abundant supply of good quality ground water is now beginning to show signs of drawdown and expansion of the industry may be hampered as a result. If good quality water in sufficient volume can be found, land cost can become the second most limiting factor. Private aquaculture generally cannot compete for land that can be utilized for condominiums, resorts, planned private communities, or even industrial developments.

Currently, most states with emerging aquaculture interests are developing regulations to protect their existing aquatic resources. Because of aquaculture's rapid expansion and the uncertainty of the risks (e.g. disease problems, genetic contamination, escape of exotics, eutrophication, etc.), most state resource agencies are taking a conservative approach to regulating the industry (e.g. the species allowed to be cultured, facility design requirements to prevent fish escapement into the wild, fish health inspections, etc.). This "conservative approach" is often viewed by aquaculturists as the primary stumbling block to the full development of the aquaculture industry. It should not be surprising, however, that agencies charged with the responsibility of natural resource stewardship owe their primary allegiance to the protection of those natural resources.

User conflicts in both inland and coastal waters can be expected to intensify as aquaculturists, recreationalists of all types, developers, environmentalists and commercial fishermen compete for use of the same bodies of surface and ground water. The challenge to local, state, and federal governments will be to accommodate all interest groups in a fair and equitable manner.

In Massachusetts, there are approximately 50 inland aquaculture operations licensed by the Division of Fisheries and Wildlife. The intent of this White Paper is not to be a step by step guide to starting up an aquaculture operation, but is to provide a general overview on inland aquaculture in Massachusetts and includes the following information: aquaculture systems and technologies; life history and biological requirements on some of the commercially important fish species in inland aquaculture; fish health; drugs and chemicals in aquaculture; genetics and exotics; legal and regulatory issues; economics; public health and safety; and recommendations.

2. AQUACULTURE SYSTEMS AND TECHNOLOGIES

The following information about aquaculture systems and technologies is found in Stickney (1979), Wheaton (1977), Piper et al. (1982), Brown and Gratzek (1980), and Leitritz and Lewis (1980).

Currently, four different systems account for the majority of inland aquaculture in Massachusetts: earthen ponds, tanks, raceways, and recirculation systems. Additionally, net-pen culture systems are also a possibility for limited inland use in the future. For any culture system, the main consideration in terms of growing fish is the water supply. The quantity and quality will determine not only what species can be grown and how many, but also which life stages can be cultured and by what technique. Tanks and raceways use the most water of any system for producing a given weight of fish and are reliant on a continual and clecan water supply. Ponds use the least water during the course of a growing season, as only evaporative losses or outflow must be replaced, but must be monitored for gradual water quality loss due to stagnation. Recirculating systems also require small amounts of water but maintain water quality. Conditions such as water temperature, dissolved oxygen levels and water quality requirements vary widely among species. Frequently, a combination of raceways, earthen ponds and tanks are employed at the same location to accommodate the culture of a variety of species and life history stages. Additionally, the production technique employed is dependent on the size of the starting product (i.e. eggs, feeding fry, fingerlings etc.) and the desired end product (i.e. broodstock, market-size fish etc).

For more information about hydrology and water availability in Massachusetts, contact the Information Office of the U. S. Geological Survey, Water Resources Division at (508) 490-5058.

<u>2.1 Ponds</u>

Earthen ponds are extremely popular among Massachusetts' fish growers due in part to ease of construction, low maintenance, relatively small area requirements and ability to grow a wide variety of species. Additionally, because earthen ponds mimic nature, they may produce fish of an overall healthier appearance than other techniques. A natural supply of food is often available in earthen ponds which may lead to better fish health. Pond culture can vary from all life stages naturally occurring in a single pond to elaborate systems with discrete ponds for holding broodstock, spawning, rearing, growing and catch-out or harvest. Earthen ponds used for the production of fish are generally of two types: embankment and excavated. Embankment ponds are created by constructing a berm to impound water while excavated ponds are formed by removing soil to form a depression which is then filled by water from a stream, spring or surface run off. Provisions should be made to allow the pond to be drained.

Two major factors to consider in deciding upon embankment versus excavated pond include the topographic layout of the site location and the quality and quantity of the water supply. Depending on the surrounding topography, a combination of excavating and impounding may be necessary. The water source for the pond will in part dictate the species and numbers of fish which may be propagated. Spring fed ponds can be used to rear a wide variety of both cold and warm water species in the same pond. Earthen ponds vary in size from small, shallow, circular excavations of considerably less than one acre in surface area to large, relatively deep, rectangular ponds of several acres. Pond banks should be as steep as the soil will support to minimize the area less than one meter deep. This will minimize the accumulation of waste materials, limit growth of aquatic plants and discourage avian predation.

2.2 Raceways

Raceways are essentially rectangular troughs of varying dimensions pitched to allow a shallow stream of water to flow directly from one end to the other. Generally, raceways are constructed of concrete and are the popular method for raising trout. This type of technique is easily constructed and maintained, and due to a steady flow of water, they are able to support higher densities of fish than in ponds. Additionally, disease treatment and harvest of fish is much easier in raceways than in ponds. Their disadvantage lies however, in that they require large flows of high quality, well oxygenated water and a relatively large amount of space. Raceways are generally constructed in one of two configurations; in parallel and in series. When constructed in parallel, the water source splits to flow through multiple raceways arranged parallel to each other. The water then exits the raceways into a common outflow pipe. This type of system utilizes less space but requires high water flows to maintain the proper level in each raceway. When constructed in series, water enters the upper raceway then exits into a second raceway just downstream. This flow continues to the last raceway in the series. This design requires lower flows and less space, but can result in oxygen deficiencies between raceways and accumulation of metabolic wastes in lower raceways. The raceway concept may also be employed with natural earthen channels or by troughs with concrete sides and earthen bottoms. The dimensions of raceways will vary depending on available space and desired species, however, a length:width:depth ratio of 30:3:1 is frequently employed. Fish in raceways should be of comparable size to minimize cannibalism and harassment of smaller fish. A smaller version of the raceway trough is frequently used to incubate and hatch eggs and hold developing fry generally housed inside a building.

2.3 Tanks

Tanks essentially act as ponds but are generally constructed of concrete or fiberglass. Wood can also be used but must first be treated to prevent rotting. Concrete tanks have the advantage of being less expensive, easily constructed and formed into various shapes. Because they are heavier than fiberglass tanks, however, they tend to be permanent structures and their interior surface is not as smooth as that of fiberglass tanks. This can be overcome by the use of sealers to provide a smooth finish. Fiberglass is the most common material for fish culture tanks. Tanks of this type are light, relatively inexpensive, and inert to fresh and salt water. Like concrete, fiberglass tanks can be molded into a variety of shapes and sizes. The potential size of tanks used for fish culture is limited only by expense and engineering capabilities. Most tanks used in fish culture are circular or oval with the water inlet causing a rotary circulation. The inlet is generally above the water level in the tank to provide aeration as it enters. The water usually exits through a standpipe or bottom drain in the center of the tank. Circular tanks have several advantages over other tank shapes and raceways. Water velocities tend to be higher, feed distribution is better, they are easier to maintain, require a lower flow rate, and generally cost less to construct and install.

2.4 Net-Pen Culture

Net pen culture consists of raising fish in box shaped nets suspended in the water column. To date, most of the culture of this type in the northeast has been for salmon in shallow bays along the coast. However, recent advances in designs of floating pens have allowed the culture of trout and other species in inland waters and man made lagoons. There are two types commonly used in fish culture. The first employs a rigid structure such as pilings driven into the substrate. Nets are then stretched over the pilings to create pens. The second type is floating net enclosures anchored to the bottom. The first type is expensive to construct and limited to relatively shallow waters. In either case, good water circulation is essential since water and wind action carries away waste products and continually provides well oxygenated water.

Advantages of this technique are that fish are easily observed and harvested and relatively little space is required. Net pen culture is especially desirable in areas that cannot be drained or otherwise hamper harvesting of cultured fish. Disadvantages, however, are that because these pen structures are generally constructed in open water, they are subject to numerous factors beyond the control of the fish propagator. Wind, waves, currents and predators are just a few. Additionally, fouling caused by suspended matter in the water column adhering to the nets will dramatically increase the effect of these factors. For example, fouled nets create twice the tidal resistance than clean nets. These parameters may also change throughout the season, therefore, a thorough site analysis is recommended before this type of culture is attempted. Use of a second larger mesh net outside the confinement nets will aid in limiting predation and escapes. Because the pens are continually submerged, the material used for construction must be resistant to corrosion and weather well. Disease control is also very difficult, and labor requirements are high.

2.5 Recirculating Systems

As the name implies, recirculating systems filter and reuse all or a portion of their water. Currently, this technique is in very limited use due to its high start-up and maintenance costs. It has several advantages, however, in that this systems is highly desirable in areas where a constant water supply may be questionable or a discharge is not appropriate. Additionally, other advantages of this type of system are the ability to incorporate the growth of a second product through hydroponics and the use of settled material as fertilizer. As the technology evolves and water withdrawal and discharge requirements become more stringent, this technique is bound to see an increase in utilization. Most closed systems consist of four primary components: culture chambers, a primary settling chamber, biological filters and a clarifier or secondary settling chamber. These systems can vary in size from a compact portable unit to warehouse-sized buildings. The culture chambers are generally tanks or raceways. Multiple culture chambers may be linked to the remaining components. The effluent from the culture chambers then flows into the settling chambers. Settling chambers are designed to slow water flow to allow particulate matter to settle. Water then exits the settling chamber and enters the biofilters. Biofilters remove dissolved metabolites and convert ammonia, which is lethal to fish, to nitrate. A secondary settling chamber may be employed to remove suspended materials that may pass through the biofilter. Upon exiting the biofilters, the flow reenters the culture chambers to complete the loop. Systems which replace water at regular intervals but also recirculate a portion of their water are referred to as semi-closed systems. As a result of small losses of water due to evaporation, leakage, etc. all closed systems require replacement of small amounts of water either continually or intermittently. The obvious drawbacks to this type of system are high initial start-up costs and large amount of space required for most systems.

3. COMMERCIALLY IMPORTANT FINFISH

The following information on commercially important finfish is found in Boschung et al. (1983), Scott and Crossman (1973), Scarola (1973), Tomelleri and Eberle (1990), Clayton et al., Lee et al. (1983), and Page and Burr (1991).

Currently, there are eleven major fish species cultured in significant numbers in Massachusetts. They are the Atlantic salmon, bluegill, brook trout, brown trout, channel catfish, golden shiner, hybrid striped bass, koi, largemouth bass, rainbow trout, and tilapia. The American eel also has potential in the aquaculture industry. These species run the gamut from those native to the Commonwealth such as brook trout and Atlantic salmon to truly exotics such as the African tilapia. The reasons for culturing these species are as varied as the fish themselves. From recreational fishing to food to restoration efforts, aquaculture in the northeast is growing rapidly and shows promise for continuing expansion in the future. Following are summaries of life histories and environmental requirements for these species.

Atlantic Salmon

The distribution of Atlantic salmon *(Salmo salar)* includes the basin of the North Atlantic Ocean from the Arctic Circle to Portugal in the eastern Atlantic, from Iceland and southern Greenland, and from the Ungava region of northern Quebec south to the Connecticut River. Atlantic salmon are anadromous fish in that part of their life cycle occurs in saltwater and part in freshwater. Atlantic salmon were extirpated in Massachusetts due in part to overfishing, pollution, dam construction and habitat loss. As a result of a joint effort between the MDFW and other cooperating agencies to restore Atlantic salmon, they now occur in 9 of the state's 32 watersheds.

The life cycle of the Atlantic salmon begins when females deposit up to 8,000 eggs in redds (nests) constructed in the gravel substrate of clean, well oxygenated streams in October and November. The eggs hatch in the spring, where the sac-fry (or alevins) remain in the gravel until the yolk-sac has been completely absorbed. The young salmon (now referred to as parr) remain in the streams from one to three years. At this time, the juvenile salmon undergo physical changes which prepare them for their migration to the ocean. At this stage they are referred to as smolts. Salmon return to spawn after spending two winters at sea. They return primarily in May and June and attempt to reach the same streams they left as smolts. The summer months are generally spent in deep pools prior to spawning in the fall. They then return to the ocean in late fall or early spring. Parr and smolts in streams feed primarily on aquatic insect larvae. While at sea, Atlantic salmon eat crustaceans and fish. Adult salmon do not feed from the time they enter fresh water to spawn until they return to salt water in the late fall or spring.

Atlantic salmon are cultured extensively at state, federal and private facilities throughout the northeast for restoration efforts, recreational fishing opportunities and as a food fish. Under culture conditions, Atlantic salmon eggs should be incubated at 42^{o} F. Upon hatching, the temperature should be dropped to 38 F until the sac fry begin to accept prepared food. At this point the temperature should be raised to 50^{o} F then slowly increased to a final maintenance temperature of 60^{o} F. The pH should be greater than 6 and dissolved oxygen levels should remain above 7 ppm.

American Eel

The Atlantic distribution of the American eel *(Anguilla rostrata)* includes the entire eastern seaboard of the United States, southeastern Canada, and the gulf of Mexico. They are as far inland as the Great Lakes.

Although currently not popular as a food fish in the United States, American eels are considered a delicacy in European and Asian countries. Traditionally, fish were harvested from the wild at edible size but young eels have recently been captured and cultured to market size.

American eels are catadromous species, meaning that they spend their juvenile life in fresh water and migrate to the ocean to spawn. Adult eels move from rivers into the ocean in the fall, travelling to the southwest part of the North Atlantic, called the Sargasso Sea. After spawning, the adults die and the eel larvae travel on ocean currents back toward the mainland, feeding and growing along the way. The eel larvae undergo metamophosis from the leptocephalus larvae to a glass eel stage and finally, when pigment forms, the elver stage. The elvers reach stream mouths in the Spring and travel up the rivers.

Bluegill

The distribution of bluegills *(Lepomis macrochirus)* includes most of southern Canada and the United States east of the Rocky Mountains. It has been introduced throughout the United States and northern Mexico. As a result of early stocking as a forage fish, it is widely distributed in Massachusetts occurring in 30 of the state's 32 watersheds.

Bluegill prefer clear warm pools of streams, lakes and ponds usually inhabiting shallow, weedy waters. Bluegills generally travel in schools at depths from one to twenty feet. Their diet consists mainly of aquatic insects, but they will also consume small fish and eggs and aquatic vegetation. Bluegills spawn in spring and summer in shallow water. If water temperatures remain high, spawning may continue into early fall. As with other members of the sunfish family, the male excavates a shallow nest preferably on gravel substrate. Males then guard this nest while tempting females to lay eggs. A large female may produce as many as 27,000 eggs spread out over several nests. The fry are generally guarded by the male for a short period prior to their dispersal.

Bluegill are the most common sunfish and a highly prized game fish throughout the United States. They are cultured in private facilities mainly to provide recreational fishing on site or for stocking as a forage fish in smaller ponds with species such as largemouth bass. Under culture conditions, optimal temperatures for embryo development are 72-81° F while 81° F is optimal for growth of adults. The pH should remain between 6.5 and 8.5 for all life stages and although dissolved oxygen levels of less than 1.0 ppm may be tolerated for short periods, a level of greater than 5.0 ppm should be maintained.

Brook Trout

The distribution of brook trout *(Salvelinus fontinalis)* includes northeastern North America from the Atlantic seaboard south to Cape Cod, the Appalachian Mountains southward to Georgia, west in the upper Mississippi and Great Lakes drainage to Minnesota and North to Hudson Bay. Their natural range has been greatly expanded through artificial propagation. In Massachusetts, brook trout can be found in 31 of 32 watersheds.

Brook trout occur in a wide variety of habitats from small streams to large lakes. Their only true requirements are a year-round supply of cold, well oxygenated water and areas of gravel on which to spawn. As water temperatures rise, stream dwelling brook trout may move downstream to larger bodies of water. Brook trout diet consists of a wide range of aquatic and terrestrial insect and larvae with occasional plant material. Brook trout spawn in late summer or autumn generally in the shallow headwaters of streams or along gravel bars of lakes. Females clear away debris by rapidly fanning the substrate with their tail. Upon completion of spawning, the female covers the eggs with gravel in much the same way she cleared the redd. The number of eggs produced by a female is dependent on body length but may be as high as 5,000. The eggs develop through the winter hatching in about 140 days.

Brook trout are raised in large quantities by state facilities for stocking into public lakes and streams. They are also cultured in private facilities for both recreational fishing on site and for stocking into private ponds. Additionally they are utilized by the supermarket and restaurant trade as a food fish. Under culture conditions, brook trout should be maintained at a temperature of about 59° F for optimal growth. The pH should remain close to neutral with an acceptable range of 6.7 to 8.2. As with most salmonid species, dissolved oxygen levels should remain above 5.0 ppm.

Brown Trout

The distribution of brown trout *(Salmo trutta)* includes Iceland, the British Isles and the Eurasian mainland from Cape Kanin to the Aral Sea and Afghanistan westward throughout Europe. Brown trout have been widely introduced into many parts of the world. As a result of stocking beginning in the late 1800's, they are widely distributed throughout Massachusetts occurring in 25 of 32 watersheds. The habitat requirements are essentially the same as for brook trout, however brown trout are slightly more tolerant of higher water temperatures. They have been found to survive in waters as high as 80^{o} F. They are frequently found in the slower, deeper pools of streams where they coexists with brook trout. The diet of young brown trout consists of a wide variety of aquatic and terrestrial insects and their larvae as well as fish and other vertebrates. Larger fish feed mainly during the twilight and nighttime hours with fish and crayfish playing a much more important role in their diet. Brown trout spawn in late autumn to early winter as water temperatures approach 45^{o} F. Spawning habitat is essentially the same as for brook trout, namely shallow gravelly headwaters. Generally brook trout have completed spawning before brown trout begin, however. The number of eggs produced by a single female is dependent on body size but ranges from 2,000 to 6,000. The eggs develop over winter in the gravel and hatch in the spring.

Brown trout are cultured in large numbers in state facilities for stocking into public waters. Culture also occurs in private facilities mainly for recreational fishing on site and for stocking into private ponds. Under culture conditions, the optimal temperature range for embryo development is 41 to 55^{o} F. For adults, a temperature range of 54 to 66^{o} F should be maintained. The pH should remain between 6.8 and 7.8 while dissolved oxygen levels should be above 5.0 ppm.

Channel Catfish

The distribution of channel catfish *(Ictalurus punctatus)* extends from the St. Lawrence and its tributaries in Quebec, south, west of the Appalachian Mountains, to southern Georgia and Central Florida, west through the Gulf states to eastern Texas and northern Mexico, northwest through the eastern part of the states from New Mexico to Montana, east to the Red River System in Manitoba, southwestern Ontario, southern Minnesota, Wisconsin and Michigan and through Ontario and Quebec at the level of Lake Nipissing. A limited stocking program has introduced channel catfish into 14 of the states 32 watersheds.

Preferred habitat for channel catfish includes lakes and larger rivers in slow to moderate current over sand, rubble or gravel bottoms. They are most active at night generally seeking shelter in bottom structure during the day. Young channel catfish feed primarily on aquatic insects while adults eat a wide variety of both plant and animal matter. Spawning behavior begins as water temperatures approach 75^{o} F. Males excavate the nest and aerate and clean the eggs. A single female may produce up to 30,000 eggs. Eggs hatch in 5-10 days depending on water temperature. Males may guard the young prior to dispersal.

Channel catfish are one of the most important freshwater species cultured in the United States, particularly in the south. They are currently cultured in private facilities in Massachusetts for recreational fishing on site and for stocking into private ponds. Under culture conditions, channel catfish may reproduce naturally in culture ponds or be spawned and reared in captivity with the resultant fingerlings released into ponds for grow-out. Optimal temperature for maximum growth of channel catfish is 85^{o} F. The pH should remain at neutral (7.0) while dissolved oxygen levels should be maintained above 5.0 ppm.

Golden Shiner

The distribution of the golden shiner *(Notemigonus crysoleucas)* includes virtually all of the United States and southern Canada east of the Rocky Mountains. Additionally, it occurs west to the Dakotas and Texas. In Massachusetts, it is widely distributed occurring in all but one of the 32 watersheds.

The preferred habitat of golden shiners includes shallow, weedy, quiet regions of lakes and ponds where they move in large schools. Wherever they occur, they are a primary food source for black bass, chain pickerel and other game fish. Golden shiners are midwater and surface feeders where they consume a wide variety of plant and animal matter. The diet is consistent from young to adult and includes, among many other items, aquatic and terrestrial insects and their larvae. Filamentous algae becomes important in late summer. Spawning is initiated as water temperatures approach 68^{o} F. It may be protracted and continue throughout the summer. The adhesive eggs are scattered over beds of submergent vegetation in shallow, quiet areas of lakes and streams. A single female may produce up to 200,000 eggs and may spawn more than once during the breeding season.

Golden shiners are currently the most important species to the Massachusetts bait fish industry. Culture of golden shiners in Massachusetts consists primarily of importation of a variety of sizes (mainly from Arkansas) which are maintained on site for resale as a bait fish.

Hybrid Striped Bass

Hybrid striped bass are a cross between striped bass *(Morone saxatilis)* and white bass *(Morone chrysops)*. Pure strain white bass and striped bass are currently not cultured in Massachusetts. Although a population of hybrids is not capable of self sustaining, it may backcross with either striped bass or white bass. Life history information for striped bass and white bass is presented here in reference to the culture of hybrid striped bass in Massachusetts.

Striped bass are anadromous fish associated with coastal streams when in freshwater. They occur along the Atlantic coast from the St. Lawrence River to the St. Johns River, Florida as well as the Gulf of Mexico and tributaries in Alabama, Mississippi and Louisiana. Their distribution in Massachusetts is limited to eight of 32 watersheds associated with large coastal river systems.

As with the Atlantic salmon, striped bass spend the majority of their life cycle in saltwater, returning to freshwater streams to spawn. With the exception of migrations, striped bass are found near shore generally in salt and brackish waters. Striped bass appear in Massachusetts coastal waters in late spring to early summer. During this time, they may enter estuarine and freshwater systems. In the fall, striped bass migrate south to overwintering grounds, however, some individuals may overwinter in Massachusetts in freshwater rivers. During these migrations, they represent one of the most important recreational fish species in Massachusetts. When in coastal waters, striped bass are voracious feeders foraging on fish, crustaceans and polychaetes. While in freshwater, their diet consists mainly of small fish such as herring, menhaden, shad and alewives. Striped bass spawn in large, rapidly flowing rivers in the spring with a peak occurring at about 18^{o} F. Large, semibuoyant eggs are broadcast and drift with the current. A single female may produce up to a million eggs. The eggs hatch within two to three days depending on water temperature. Juvenile striped bass may remain in freshwater for up to two years before migrating to saltwater.

The distribution of white bass includes the St. Lawrence River west through the Great Lakes states from New York to Minnesota, west to South Dakota and south in the Ohio and Mississippi valleys to the Gulf of Mexico. Its natural range has been greatly enhanced as a result of stocking. Currently, there are no populations of white bass in any watersheds in Massachusetts.

White bass are generally found in schools in the upper water column of large streams, lakes and reservoirs. They prefer clear water and tend to be found over sand, rock or gravel bottoms. The diet of young white bass consists of small crustaceans, insect larvae and fish. Fish make up the bulk of the diet for adults. Prey items are located visually, thus their tendency to be found in clear waters. Spawning commences in the spring as water temperatures approach 55-60^{o} F. At this time, large schools begin to make inshore movements to shoals and estuaries. Adhesive eggs are fertilized as they are broadcast into the substrate. Here they attach to vegetation, gravel, boulders etc. A single female may produce up to 500,000 eggs. At spawning temperatures, eggs generally hatch within 46 hours.

Hybrid striped bass are cultured in private facilities mainly for supply to the restaurant and supermarket trade as a food fish. Currently, hybrid striped bass culture in Massachusetts begins with fingerlings imported from out of state. Under hatchery conditions, these fingerlings are reared at 79^{o} F in hard water. The pH should be maintained at between 6.5 and 8.5 and the dissolved oxygen level should remain above 6.0 ppm. There is also some limited grow-out of these hybrids occurring in culture ponds.

Koi

Koi are a color variant of common carp *(Cyprinus carpio)*. The distribution of carp includes temperate portions of Asia and Europe. It was widely introduced into North America by the U.S. Fish Commission in the mid 1800's. They occur in 16 of 32 watersheds in Massachusetts scattered throughout the state.

Carp do best in warm, shallow impoundments with abundant vegetation. They are tolerant of extremes in temperature and low dissolved oxygen. In addition, they fare well in areas of poor water quality. Carp feed on a wide variety of plant and animal matter. They are capable of taking food items floating at the surface, but generally root in soft substrate and pick out food items from the resultant cloud of silt. Spawning commences in early spring as water temperatures approach 63^{o} F. Large congregations move to shallow, weedy waters then break up into smaller groups of several males to one female. A single female may produce up to 2,000,000 adhesive eggs which are broadcast and adhere to submerged vegetation. Eggs hatch within 3-6 days depending on water temperature.

Koi are cultured in private facilities for sale as an ornamental fish for stocking into private ponds of for the aquarium trade. Under culture conditions, optimal growth for young koi is between 81 and 93^{o} F, while 68 to 82^{o} F is optimal for adults. The pH should remain between 6.8 and 7.5, and while koi are capable of surviving in warm waters with low oxygen, dissolved oxygen levels should remain above 5.0 ppm for good growth.

Largemouth bass

The native range of largemouth bass *(Micropterus salmoides)* includes the lower Great Lakes, the central part of the Mississippi River system south to the Gulf Coast, Florida and north on the Atlantic coast to Virginia. As a result of its popularity as a game fish, the largemouth bass may now be the most widely introduced of fish in North America. It occurs over virtually the entire Atlantic coast from Maine to Florida, west to Texas and northeastern Mexico, north through the eastern parts of the states from New Mexico to North Dakota and east across southern Canada to western New York. Additionally, it has been introduced throughout the UK, Europe, South Africa, Hong Kong, the Philippines and Brazil. Largemouth bass are widely distributed throughout Massachusetts occurring in all 32 watersheds.

Largemouth bass are predominantly found in shallow, small lakes and bays of larger lakes and in large, sluggish rivers. In all cases, they generally occur over soft substrates typically associated with structure. Largemouth bass feed from the surface, water column and bottom on a variety of food items. Young bass eat primarily aquatic insects with fish, mollusks and crayfish playing an important role in the diets of adults. Largemouth bass spawn from late spring through mid-summer as water temperatures approach 60^{o} F. Males construct a 2-3 foot nest over gravel in shallow, protected areas which they defend vigorously. A single female may produce from 2,000 to 10,000 eggs and may spawn with several males on different nests. As with other sunfish species, the male defends the nest and fans the eggs to ensure they are well oxygenated. Eggs generally hatch within a week to ten days. The fry remain in a brood guarded by the male for several weeks prior to dispersal.

Largemouth bass are cultured at private facilities for recreational fishing on site and for stocking into private ponds. Under culture conditions, largemouth bass may be spawned and reared artificially or allowed to reproduce in culture ponds with the resultant young moved to other ponds for grow-out. Optimal temperature for growth of largemouth bass is between 75 and 86^{o} F. Although largemouth bass may survive short exposures to pH as low as 4.0, for best growth, pH should remain between 6.5 and 8.5. As with Ph, largemouth bass can survive brief exposure to low dissolved oxygen levels, optimal growth however, occurs at dissolved oxygen levels above 5.0 ppm.

Rainbow Trout

Rainbow trout *(Oncorhynchus mykiss)* originally occurred in the eastern Pacific Ocean and freshwater west of the Rocky Mountains from northwest Mexico to the Kuskokwim River, Alaska. As a result of introductions outside its range, rainbow trout are now found throughout North America. Additionally, sea-run forms, referred to as steelhead trout, migrate to saltwater then return to freshwater to spawn. They are widely distributed throughout Massachusetts occurring in 23 of 32 watersheds.

As with all trout, rainbow trout do best in cold, well oxygenated waters. As with brown trout, however, they are much more tolerant of warmer temperatures than brook trout. They are capable of surviving in waters as high as 85^{o} F provided the water remains well aerated. They occur both in lakes and rivers with moderate flow and gravel substrate. Young fish are generally found in riffle sections of rivers and streams while older fish frequent quiet, deeper pools. Rainbow trout generally feed off the bottom foraging on virtually all aquatic insects and their larvae that occur in their habitats. Where they occur in lakes, fish can become a primary food item.
Spawning commences in early spring as water temperatures approach 50^{o} F. Spawning takes place in smaller tributaries of rivers or inlet and outlet streams of lakes and ponds. As with other trout, the female excavates a nest in gravel generally in a riffle above a pool. Eggs are broadcast into the nest then immediately covered with gravel by the female. Eggs numbers may be as high as 12,000 per female. Eggs hatch within two months depending on water temperature with the resulting alevins becoming free swimming within seven days.

Rainbow trout are cultured in large numbers at state facilities for stocking into public waters. Culture also occurs in private facilities for recreational fishing on-site, stocking into private ponds and as a food fish for the restaurant and supermarket trade. Culture conditions for rainbow trout are identical to those of brook trout. Temperature should be maintained at about 59° F for optimal growth. The pH should remain close to neutral with an acceptable range of 6.7 to 8.2. As with most salmonid species, dissolved oxygen levels should remain above 5.0 ppm.

Tilapia

Tilapia (*Tilapia sp.*), which includes about 80 different species, were originally found throughout the African continent. As a result of transplants, particularly in extreme southern United States, they are now found outside their native range. Due in part to their inability to survive at temperatures much below 50° F, they are not found in Massachusetts' waters.

Tilapia are generally found in warm, shallow, turbid waters of rivers and lakes. They are herbivores feeding mainly on plankton, filamentous algae, aquatic macrophytes and other vegetable matter. In the wild, tilapia spawn year round with females producing up to 1,200 eggs. There are two types of spawners, substrate or mouthbrooders, depending on the species. Substrate spawners, as the name implies, broadcast eggs into the substrate. With mouthbrooders, the female incubates the fertilized eggs and resultant fry in her mouth to guard them against predation. Eggs generally hatch within seven days.

Tilapia are cultured in private facilities for sale as a food fish to the restaurant and supermarket trade. Under culture conditions, broodstock are held on site and spawned to produce eggs. Mouthbrooders are generally used as broodstock due to their large fry clusters and successive breeding cycles. Under ideal conditions, females may spawn every seventeen days. The eggs and resultant fry are maintained at a temperature of 80 to 84° F. The pH is maintained at 7.5 to 7.8 while dissolved oxygen levels should remain at or above 8.0 ppm. Under these conditions, market sized fish (1/2 lbs.) can be obtained in about seven months.

4. FISH HEALTH

Fish diseases constitute one of the most important problems and challenges confronting fish culturists. Fish diseases do not occur as a single caused event but are the end result of interactions of the disease, the fish and the environment. Fish in intensive culture are continuously affected by environmental fluctuations and management practices such as handling, crowding, transporting, drug treatments, undernourishment, fluctuating temperatures, and poor water quality. All of these factors can impose considerable stress on the homeostatic mechanisms of fish rendering them susceptible to a wide variety of pathogens. Parasites, viruses, and bacteria are all causes for concern to aquaculturists. Many of these pathogens are easily treatable and are not transferrable to humans. On the other hand, there are fish diseases that are not treatable and cause widespread mortality both in the hatchery and wild fish. Disease also reduces hatchery efficiency and production, which in turn, increases costs and reduces profit.

Another major issue pertaining to fish health is the concern over the introduction of infectious diseases, particularly those that are not endemic to the area, through fish culture facilities to wild fish populations. The impacts of infectious diseases are generally misunderstood or seriously underestimated, and it is not uncommon to find resistance to their assessment and control. Many of the fish health programs, guidelines and regulations are simply regarded as another bureaucratic impediment and cost placed in front of the aquaculture industry. This attitude is due, in part, to the "old school of thought" that significant epizootics rarely if ever occur in wild populations and to the abiding faith that once fish are released into the wild they will recover. Wild fish stocks can become infected and suffer high mortalities through the release of pathogens in untreated hatchery effluent or through the stocking or escapement of diseased fish into aquatic systems.

For example, the State of Colorado stocked hatchery-reared trout known to be infected with whirling disease (*Myxobolus*) on a population of wild trout in a major Colorado river fishery. Result: the wild population was infected and suffered high mortalities. Three state fish & wildlife officials lost their jobs for introducing the disease infected fish.

A state fish hatchery in Paradise, Utah, withdraws water from the Little Bear River for culture purposes and discharges it back into the river. Biologists were made aware of deformed wild fish in the Little Bear. Upon investigation 8 - 22 percent of the native population had been infected by the disease *Myxobolus*. The source of disease was traced back to the Paradise Hatchery.

In Michigan, a pathogen-contaminated hatchery discharging into a nearby river infected the wild fish population in that river. All fish in the hatchery and river were eradicated to prevent further spreading of the pathogen throughout the watershed.

Closer to home, the state of New York last year ordered that 43,000 pounds of fish be destroyed from four state hatcheries because they were infected with whirling disease. This same disease is also now plaguing state fish hatcheries in Connecticut.

The Division of Fisheries and Wildlife considers disease a serious potential threat to the health of our public aquatic resources. Some of the measures employed by the Division at its own facilities relative to fish health include annual diagnostic inspections; standard disinfection procedures on tanks, raceway and fish hauling trucks; inter-hatchery fish movement restrictions; and requiring a fish health certificate from any facility which the Division obtains fish eggs or live fish from. The Division does not require private aquaculture facilities to have annual fish health inspections at this time. However, any private facility wanting to import fish eggs or live fish into Commonwealth must obtain an importation permit from the Division of Fisheries and Wildlife (except aquarium trade fish species as defined in our regulations - 321 CMR 9.01(2)). The applicant must provide us with a copy of a fish health certificate from the source of the importation as part of the permit application process. Although the Division does not require private facilities to have annual fish health inspections, it is in their own best interest to do so.

The following section is a description of some of the more common and hazardous pathogens encountered in freshwater aquaculture. It is by no means a complete listing of all parasites, bacteria, and viruses that may impact the health of freshwater fishes.

4.1 Parasites

Parasites can be defined as animals that live on or in another animal at the expense of that animal. Parasites are the most diverse and common pathogens the aquaculturist will likely encounter. External parasites can be found on the skin or gills of their hosts while internal parasites occupy areas such as the flesh or internal organs. Many of the common parasites to freshwater fish have complex life cycles involving more than one host, usually involving changes in life stage from one host to the next. Parasites are capable of causing damage to all hosts involved, mostly by injuring tissues or organs while burrowing or consuming food. Despite the ubiquitous distribution of many of these parasites, infestation of a host is usually limited unless the host is subjected to increased stress. Increased stress may take the form of crowding, insufficient oxygen levels, or poor water quality. The damage done to the host will usually be directly proportional to the level of infestation.

Most fish parasites would not develop in humans even if eaten raw. None are harmful to humans if the fish are thoroughly cooked. All reports of people being infected with fish parasites were as a result of ingestion of raw fish or insufficiently cooked fish. Some of the more common parasites found in freshwater fish are listed as follows:

Ichthyophthirius multifilis ("ich") - Ciliated protozoan:

"Ich" is a large ciliated protozoan that is capable of infecting most species of fish. Ich can be seen by the naked eye and when full grown appears as a white spot on the fish. These parasites are commonly found in small numbers on wild warmwater fish and can also be a serious parasite of salmonids. Fish will flash or scrape on objects due to the irritation caused by the parasite. When fish are stressed, heavy infestations can occur. Heavy infestations of the gill can interfere with respiratory exchange and result in mortality, especially in fingerlings. There are no reported cases of people becoming infected with this parasite by eating fish. The parasite is difficult to control in the wild. Formalin can be used in raceways at 250 ppm, up to 1 hour. In earthen ponds: 15-25 ppm indefinitely.

Trichodina spp., Ambiphyra spp., Epistylis spp., Chilodonella spp., Trichophyra spp.- Ciliated protozoa:

These ciliated protozoans can inhabit the gills and body surfaces of most species of fish. They occur in small numbers in almost all fish populations. They can cause problems when the host is subjected to undue stress, allowing heavy infestations to develop. Heavy infections are more common in aquacultural situations where fish are crowded and water quality is poor. Moderately to heavily infected fish may go off feed. The parasites can produce bloody lesions on scaled fish and erosion of fins and spines in all species. Gills can become swollen, hemorrhagic, and produce heavy mucus. Mortality can result with heavy infections. There are no reported cases of people becoming infected with these parasite by eating fish. These parasites are difficult to control in the wild. Formalin can be used in raceways at 250 ppm, up to 1 hour. In earthen ponds: 15-25 ppm indefinitely.

Ichthyobodo (Costia) spp.-Protozoan flagellate:

These protozoans can inhabit the gills and body surfaces of fish. Like other protozoans, it is present in small numbers in almost all populations of fish. These can cause problems when the host is subjected to undue stress, allowing heavy infestations to develop. Heavy infections are more common in aquacultural situations where fish are crowded and water conditions are poor. Infected fish will commonly flash or scrape against objects. Infected fish may also stop eating and may gasp at the water surface. Infected fish that have been off feed for a period of time may show signs of starvation. A characteristic sign of ichthyobodiasis is excess mucus production, which has been referred to as blue slime. Sometimes complete removal of the epithelium may be seen and the pigment may be missing from the skin. There are no reported cases of people becoming infected with these parasites by eating fish. These parasites are difficult to control in the wild. Formalin can be used in raceways at 250 ppm, up to 1 hour. In earthen ponds: 15-25 ppm indefinitely.

Gyrodactylus spp.-Monogenetic trematode:

These worms are ubiquitous parasites of the skin, fins, and gills of many freshwater fishes, particularly salmonids, ictalurids, and cyprinids. They exist in small numbers in almost all populations of fish and only become a problem when fish are subjected to stressful situations. Heavy infections can cause overall darkening in color in fry, erosion of the fins, obvious secretions of mucus sometimes described as blue/grey slime, and emaciation (especially in young fish). Detachment of catfish barbels due to necrosis may occur. There are no reported cases of people becoming infected with these parasites by eating fish. These parasites are difficult to control in the wild. Formalin can be used in raceways at 250 ppm, up to 1 hour. In Earthen ponds: 15-25 ppm indefinitely.

Neascus spp. (Black spot)-Digenetic trematode:

These parasites encysts within the skin of many species of freshwater fish. The fish in turn, surround the cyst with a black-pigmented tissue giving rise to black spots. These parasites do not usually cause mortality, but can be very unsightly. There are no reported cases of people becoming infected with these parasites by eating fish. There is no known direct control for these parasites. Indirect control has been attempted by controlling the snails that serve as intermediate hosts to the parasites.

Clinostomum marginatum (Yellow grub)-digenetic trematode:

This parasite is found in many species of freshwater fish in small numbers. Infestations are seldom extremely heavy but individual fish may be highly parasitized. The grubs are often discovered in the musculature of infected fish by fishermen and considered very unsightly. Clinostomum spp. has been reported to develop in the oral cavity of humans who eat infected fish that are under cooked.

There is no known control for this parasite. Indirect control has been attempted by controlling the snails that serve as intermediate hosts to the parasite.

Proteocephalus ambloplitis (Bass tapeworm)-Cestode:

Although bass tapeworm is capable of infecting many species of fish, only heavy infections with adult tapeworms are believed to be detrimental. However, the plerocercoids can be much more damaging. The plerocercoids can migrate through the body cavity and internal organs causing adhesions to develop. Severe adhesions in the reproductive organs caused by plerocercoids can render female fish incapable of normal egg production. The migrating plerocercoids may actually kill small fish by penetrating a vital organ. There are no reported cases of people becoming infected with this parasite by eating fish. There is no known control for this parasite.

Posthodiplostomum spp. (White grub)-Digenetic trematode:

These parasites exist in small numbers in many freshwater fish species. The larval forms appear as white cysts in many internal organs of fish. When the cercariae penetrate the fish , they can cause hemorrhaging at the point of entry. However, for the most part these parasites are not considered problematic, just unsightly. There are no reported cases of people becoming infected with these parasites by eating fish. There is no known control for these parasites. Controlling the snail population has been attempted.

Ceratomyxa shasta (CS)-Protozoan myxosporidian:

CS is common in anadromous fish in the Western U.S., particularly the Columbia River basin. It is capable of infecting wild and captively reared salmonid populations with juvenile rainbow and cutthroat trout being especially susceptible. The parasite manifests itself in the gut, liver, spleen, and muscle causing abdominal distension due to production of spore-containing fluid. Under no circumstances should eggs or live fish be transferred from contaminated areas. Treatment of the disease is not yet possible. Contaminated water supplies need to be filtered by ultra-violet treatment or be used to culture species other than salmonids.

Myxobolus cerebralis - "whirling disease" -Myxosporidian:

This parasite infects the head cartilage of salmonids and is responsible for major economic impacts to trout culture in Europe and America. The parasite damages the cartilage and impairs balance, often causing the fish to swim in circles. The parasite is also capable, in the advanced stages of the disease, of infecting the spine, causing deformities and a change in color. Severely infected fish appear black and twisted posterior to the dorsal fin. The older the trout prior to exposure to the disease, the less the potential for mortality and severe infection. Fish at the alevins stage often suffer total mortality. Older fish will still become potential vectors for the disease by being relatively asymptomatic carriers. The myxosporidian spores are highly resistant to treatment and are long lived, making eradication, especially in earthen ponds, extremely difficult.

4.2 Viruses

Viruses are extremely small infectious agents that multiply only within the living cells of a host by using components of the host cells. They are made up of simple genetic material and are incapable of growing in size or undergoing typical cell processes like cell division. Some of the more problematic viruses are discussed.

Infectious Pancreatic Necrosis (IPN)-RNA Virus:

IPN is capable of infecting all ages of many salmonid species resulting in a chronic infection affecting many organs, particularly the kidney. This pathogen often causes severe mortalities in salmonid fry. IPN can be transmitted to the eggs from the adults (vertically) or through the water by fish excretions (urine or gametes) or by fish consuming dead fish or fish offal (horizontally). This virus has been isolated from North America, Europe, and Japan. There are no means of controlling infections in fish other than by avoiding the contraction of the virus. Eradication of the virus from a facility requires the sacrifice of all infected and presumed infected fish and proper sterilization.

Viral Hemorrhagic Septicaemia (VHS)-RNA Virus:

VHS is capable of infecting all ages of salmonids. The disease usually infects rainbow trout but can also infect Atlantic salmon, brown trout, and brook trout. It may result in acute disease in under two weeks or take up to a year to manifest itself in a population. The time period depends mostly on the temperature of the water with outbreaks usually occurring below 15 degrees Celsius. The disease, which manifests itself in most highly vascularized tissues, causes the most severe mortality in fingerling trout in their first winter but will also cause mortality at other ages.

The disease becomes apparent in three stages. The first stage is characterized by high mortality in fish that are dark, lethargic and have hemorrhages at the base of fins and gills. The second stage is recognized by very dark colored, anaemic fish. Pale gills and exophthalmos is common. The third stage is characterized by atypical swimming behavior (looping) and a swollen and discolored kidney. This disease is widespread in many European countries. In the United States, thus far, the disease has only been found in the state of Washington. There are no methods to control or treat this disease once introduced.

Infectious Hematopoietic Necrosis (IHN)-RNA Virus:

This virus is found in the wild in salmonid populations on the Pacific coast of North America. It can infect chinook and sockeye salmon and rainbow trout. The virus causes the most severe mortality in yolksac fry to two-year old fish and may inflict up to 80% mortality in infected populations when the water temperature is at 10 degrees Celsius. Infected fish exhibit lethargy and sporadic hyperactivity, dark coloration, anemia, exophthalmia, abdominal distentions, long off-white casts trailing from the rectum, and hemorrhages at the base of fins. Disease in hatcheries is common and capable of transmitting epizootic conditions to wild populations. Epizootics have occurred throughout the United States due to transport of infected fish from the west coast. The disease has also been reported in Japan. Fish can contract the virus through direct contact with or ingestion of infected fish. Ovarian and Seminal fluids have the highest concentration of viral agents.

The virus can not be eliminated from infected or diseased fish. A rise in water temperature to 15 C will diminish acute levels of disease but only as long as the elevated temperature persists. The only way to avoid disease to prevent contamination by introduced fish, eggs and water supply.

Channel Catfish Virus Disease (CCV)-DNA Virus:

This disease occurs in fry and fingerling channel catfish when the water temperatures rise to 25-30 degrees Celsius. Other Ictalurids may also serve as carriers for the virus. Fish surviving the disease may serve as viral carriers. Effected fish will display a loss of equilibrium, spiral swimming movement, and assume a vertical position in the water column. Gill, skin, and internal organ hemorrhages and abdominal distension occur. The disease effects the liver, spleen, kidney and digestive tract. The virus is shed by diseased fish. Control of the disease is only possible by preventing infected fish or water supplies from contacting uninfected populations.

4.3 Bacteria

Bacteria are all single prokaryotic cells that break down organic material for their energy needs. All bacteria present on fish will be killed if the fish are properly cooked. Some of the more common bacterial pathogens found in freshwater fish are described here.

Motile Aeromonas spp.:

The bacteria belonging to the genus *Aeromonas*, may under certain adverse environmental conditions, cause serious conditions in most species of fish. The bacteria may also infect frogs, turtles and snakes. These bacteria are found in soil and most natural waters. *Aeromonas* spp. has been credited with causing several diseases in fish, including motile aeromonas septicemia, bacterial hemorrhagic septicemia, tail/fin rot, redsore disease and others. Clinical symptoms include, the presence of small surface lesions, local hemorrhages particularly in the gills and vent, ulcers, abscesses, exophthalmia and abdominal distension. Internally, there may be accumulation of ascitic fluid, anemia, and damage to the organs, especially the kidney and liver. Terramycin can be used to control diseases in salmonids and catfish in aquacultural settings. The dosage regimen is 2.5 to 3.75 g/100 lb/day for 10 days.

Pseudomonas spp.:

The bacteria belonging to the genus *Pseudomonas*, are present in most natural waters and infect most species of fish. These parasites are considered opportunistic pathogens, causing disease when the host is subjected to some type of stress. *Pseudomonas* spp. have been credited with causing pseudomonad septicemia, red spot disease, fin/tail rot, and others. Clinical symptoms include, hemorrhages in the mouth region, opercula, and ventral side of the body. Small petechial hemorrhages can occur through out body cavity. Organs such as the liver and kidney may also be affected.
Terramycin can be used to control diseases in salmonids and catfish in aquacultural settings. The dosage regimen is 2.5 to 3.75 g/100 lb/day for ten days.

Flexibacter psycrophilus:

This bacteria infects salmonid fishes and causes "Coldwater Disease", also referred to as bacterial coldwater disease, peduncle disease, or low temperature disease. The precise reservoirs of the bacteria are unclear, but it may occur naturally in the aquatic environment. This disease occurs when water temperatures are 12 C or below, however some outbreaks have occurred at temperatures of up to 16 C. This disease primarily affects juvenile fish, but infections can occur in yearlings. Skin and muscle lesions are the most common signs of this disease. Lesions are frequently seen in the peduncle area, but they may also occur on other areas of the body surface. If the fish survive long enough, they may suffer the loss of their caudal fins. Following a severe epizootic, at least two disease conditions may be observed. In the first, fish appear lethargic and later on spinal deformities and chronic mortality occur. In the second case, fish display a spiral swimming behavior, dorsal swelling, and dark pigmentation on one side of the body. There is no approved treatment for this disease.

Renibacterium salmoninarum:

This bacterial pathogen causes bacterial kidney disease (BKD). BKD is typically chronic, characterized internally by a large edematous kidney that can appear gray and corrugated. The kidney often exhibits off-white lesions that vary in size and number. The lesions sometimes occur in other organs such as the liver and spleen. Externally, fish can appear normal or they can exhibit one or more of the following signs: exophthalmos, abdominal distension, skin petechiation, and vesicles in the skin.

Renibacterium salmoninarum has been detected in both wild and hatchery fish and may be transmitted both vertically and horizontally. Infections can occur at any life stage, but clinical signs are uncommon in fish less than six months old. Mortality has been reported between a wide range of temperatures. There is no approved treatment for BKD.

Flexibacter columnaris:

This bacteria, capable of infecting most species of freshwater fish, causes "Columnaris Disease". The disease affects fish of all ages and occurs in warmwater conditions (14 C and up). The precise reservoirs of the bacteria are unclear, but it is thought to occur naturally in the aquatic environment. When highly virulent strains of the pathogen are involved, fish may die without any gross clinical symptoms. With less virulent strains, external lesions may occur on the body surface and gills. On scaled fish, grayish-white lesions occur on the fins, head, and trunk. If the pathogen is present in large numbers, the lesions may appear yellow or orange, reflecting the yellow-pigmented cells of the bacteria. On scaleless fish, lesions appear to be a dark blue area covered by a milky veil with a red tinge around the margin. There is no approved treatment for this disease.

Aeromonas salmonicida:

This bacteria causes a condition known as furunculosis in many species of freshwater and marine fish. The disease was named furunculosis because of the formation of furuncules, boil-like lesions that occur in various tissues of the body. This organism was discovered almost 100 years ago, but the exact route of transmission is still not completely understood. The occurrence of furunculosis is generally seasonal, acute cases occur when water temperatures are about 20 degrees Celsius and chronic infections occur when temperatures are 13 degrees Celsius or lower. In acute cases, fish may darken and go off feed. Internally, the viscera are hemorrhagic, kidney tissue is very soft, the spleen is enlarged, and the liver is pale or mottled with petechiae. In chronic cases there is a more gradual onset of mortality. Externally, fish have skin lesions or furuncules, along with internal lesions.

In addition to furunculosis, A. salmonicida has also been implicated in other conditions, including carp erythrodermatitis and goldfish ulcer disease.

Romet-30 and Terramycin can be used to control furunculosis in salmonids in aquacultural settings. Romet-30 @ 50 mg/kg/day for 5 days. Terramycin @ 2.5 to 3.75 g/100 lb/day for 10 days.

Proliferative Kidney Disease (PKD):

PKD is a pathogen that commonly effects young trout. Very little is known about PKD and is origin. Some evidence exists to link the infection of fish with the presence of an amoeba. Whole populations of young trout can be infected, especially right after introduction into a growing facility. Affected fish become dark in color, anaemic, and have some abdominal swelling. Despite impaired growth, losses are usually minimal until some other stress (grading, treatment for other diseases) is introduced. Catastrophic losses soon follow. Because of the associated losses, attempted treatment is counterproductive and not yet possible.

Yersinia ruckeri - Enteric Redmouth (ERM):

ERM has been isolated in the United States, Canada, and Norway. An outbreak is characterized by escalating losses in cultured fish due to severe congestion and hemorrhage in the head tissues with erosion of the lower jaw being common. The spleen, kidney, and intestine can also be infected. This disease is capable of infecting all salmonids, isolations have also been made in goldfish, cisco, largemouth bass, emerald shiners, sturgeon, fathead minnows, and walleye. Crayfish and muskrats have also been found to harbor large numbers of Yersinia ruckeri cells.

4.4 Fungi

Fungi are single celled, multinucleate organisms that secrete digestive enzymes and gain nutrition through absorption of dissolved inorganic and organic food materials. Fungi are generally considered secondary symptoms in fish as they usually only occur where other trauma, such as injury or disease, have created an opportunity for fungal infection.

Saprolegnia spp.:

Saprolegnia is a ubiquitous fungus and inhabits all freshwater. It invades most species of fish that have been subjected to some type of stress. It is also capable of infecting insects and amphibians. Handling injuries, malnutrition, temperature shock, external parasitism, and spawning increase the susceptibility of fish to infection by Saprolegnia. There is potential for infection whenever fungal zoospores are present in excess of 23,000 spores/liter. Infections left unattended can result in high mortality. Saprolegnia appears as white cottony tufts of non-septate filaments on the skin and other surfaces of infected fish. Fish eggs are highly susceptible to this pathogen.

Treatment consists of formalin at 1000 to 2000 ug/L for 15 minutes for salmonid and esocid eggs. There is no approved treatment to control Saprolegnia on fish.

5. AQUACULTURE DRUGS AND CHEMICALS

The use of therapeutic drugs in aquaculture is one of the single most important issues facing aquaculture operations across the country. The crisis is the lack of properly approved drugs to reduce disease-related mortality and improve production efficiency and product quality on both public and private aquaculture facilities. Public concerns about human food safety, human health, and environmental impacts have resulted in increasingly strict interpretation and enforcement of regulations by the U.S. Food and Drug Administration. Such actions have drastically curtailed the availability and use of drugs essential to maintain fish health in hatcheries. Lack of approved drugs and chemicals dramatically reduces the effectiveness and increases the cost of fish production. Over 30 species of fish and shellfish are cultured for food in the U.S. The on-farm value of these animals was estimated at $1 billion for 1992 and the total annual economic activity generated by aquaculture for food at over $8 billion. In addition, some of the fish from private aquaculture are used in public and private recreational fisheries. Baitfish and aquarium fishes add at least $150 million to the value of private sector aquaculture. Some estimates place the economic impact of the aquarium fish industry at over $500 million. Many of the $50-60 billion U.S. recreational fisheries, as well as some commercial fishing, depend upon the production from the 78 federal and 438 state fish hatcheries. Losses to uncontrolled diseases in these facilities have been estimated to be 10-25 percent of the total production, and have exceeded 90 percent in some situations.

Drug and chemical manufacturers are reluctant to undertake the FDA-mandated approval protocols because the $3.5 million expected cost per drug is not warranted by market potential for these products. Only 3 therapeutic (formalin, terramycin and Romet-30) and one anesthetic (MS-222) drugs are currently approved and available to aquaculturists. To address this problem, 39 state fish and wildlife agencies, including the Division of Fisheries and Wildlife, have entered into an unprecedented cooperative agreement. Each agency is contributing $100,000.00 over the next 5 years to support efforts to fully certify a few essential drugs that are already being used in aquaculture operations under special F.D.A. provisions. Appeals are being made to the 11 other states that are not yet signatories to the cooperative agreement. The total combined contribution of all the states is still just a fraction of the cost needed to register these drugs with the F.D.A. Despite the fact that the private sector has a vested interest in this matter and will benefit directly, they have contributed little financially to these efforts. Private aquaculture needs to expand its commitment to these efforts and make a good faith effort to generate a stable funding strategy for aquaculture drug approvals.

6. GENETICS AND EXOTICS

Cultured fish commonly represent genetically exogenous populations or crosses between them. In addition, the genetic makeup of cultured populations has frequently been altered as the result of inbreeding, selective breeding, or domestication. Biotechnologies are also now making it possible to genetically manipulate aquatic organisms to promote economic advantages through increased growth rates so that aquaculture food production is more efficient and profitable. For example, researches at Fisheries and Oceans Canada in West Vancouver have altered the DNA of Pacific Salmon to create fish that are on average, more than 11 times larger than their natural counterparts (Vames 1995). Thus, cultured fish can represent distinct gene pools and their escape or intentional release into the wild could adversely impact natural populations.

For instance, the Division of Fisheries and Wildlife, in partnership with other state and federal agencies and the private sector, have been working for over 20 years to restore Atlantic salmon to southern New England. These fish are now returning in the low hundreds to the Connecticut and Merrimack Rivers. In contrast, the numbers of pen-reared Atlantic salmon in Maine far outnumber wild fish returning to Massachusetts, to all of New England and in the entire North Atlantic combined. With so few salmon returning to the rivers, any "catastrophic event" causing a massive release of pen-reared salmon could result in a significant degree of genetic contamination to those wild stocks. Even a "slow trickle" of pen-reared fish escaping could have a negative impact over time on natural salmon populations.

The escape or release of exotic fish species and other aquatic organisms cultured for food, management or recreation can also have serious ecological consequences for native flora and fauna. Besides the possible genetic implications, impacts resulting from escaped or intentionally released aquatic species may include habitat, trophic, and distributional alterations as well as the introduction of parasites and diseases.

Regulations are important to safeguard wild populations from escaped, released or exotic aquaculture species. The Division of Fisheries and Wildlife's new aquaculture regulations address the issue of exotics in the permitting process. Species permitted to be cultured are based on the type of facility (closed vs. open system), the location of the facility, and the species found in the watershed.

7. STATE AND FEDERAL AQUACULTURE FACILITIES

Fish hatcheries in Massachusetts play a major role in providing some of the finest freshwater fishing found anywhere in the Northeast. Freshwater fishing is big business in Massachusetts. According to the 1991 U.S. Fish and Wildlife Survey, freshwater anglers in the Commonwealth spend over $100 million each year to pursue their sport. That generates some $8 million in state sales and income taxes while supporting approximately 3,000 full time jobs. In addition to recreational fishing, hatcheries are critical to restoring Atlantic salmon to their native watersheds in the Commonwealth.

State Facilities

Bitzer, McLaughlin, Sandwich, and Sunderland hatcheries use tank, pond, and raceway culture to annually produce 450,000 to 500,000 pounds of brook, brown, and rainbow trout. These fish are subsequently stocked into ponds, lakes, rivers, and streams during the spring, fall and winter across the Commonwealth to provide fishing opportunities all year long.

Roger Reed Hatchery in Palmer is dedicated to producing Atlantic salmon, landlocked salmon, and northern pike. Annually, some one million Atlantic salmon fry are produced as part of the Division of Fisheries and Wildlife's effort to restore Atlantic salmon to their native habitats. The Palmer facility also holds Atlantic salmon broodstock for egg and fry production. Other products from this hatchery include 10,000 to 12,000 northern pike fingerlings (10-12") that are cultured in tanks at the station and then stocked into several waters statewide to enhance trophy fishing opportunities and nearly 10,000 landlocked salmon fry used to maintain a recreational fishery in Quabbin Reservoir.

Federal Facilities

Massachusetts also has two federal hatcheries that are involved in the Atlantic salmon restoration efforts. The Richard Cronin National Salmon Station holds, spawns, and reconditions Atlantic salmon captured at the fishways on the Connecticut River. The Attleboro National Fish Hatchery holds sea-run fish for spawning, incubates the eggs, and produces fry. The Berkshire National Fish Hatchery is currently not in use.

8. LEGAL AND REGULATORY ISSUES

There are several levels of regulatory control that emanate from a multi-agency approach to permitting aquaculture facilities in Massachusetts. Local, state, and federal permits are used to meet the mandates of all regulatory authorities. Each situation or aquaculture facility will have different permits to obtain based on their location, size, and activities. The following is a summary of the agencies and organizations involved in the permitting process of inland aquaculture operations.

8.1 Local Organizations

Conservation Commissions, as established in MGL 40:8C, serve to promote and develop natural resources and to protect the watershed resources of their respective towns. Conservation Commissions are responsible for the implementation of the provisions found in the Massachusetts Wetlands Protection Act (MGL 131:40) and will determine if work to be done to an aquaculture facility is significant to 1) public or private water supply, 2) groundwater supply, 3) flood control, 4) storm damage prevention, 5) prevention of pollution, 6) protection of land containing shellfish, 7) protection of wildlife habitat, or 8) protection of fisheries.

Conservation Commissions are most commonly involved with three related permitting processes: Notices of Intent, Determinations of Applicability, and Orders of Conditions.

New aquaculture facilities located within 100 feet of a wetland resource need to file a Notice of Intent (NOI) with the local Conservation Commission. If the applicant has any questions about the jurisdiction of the Wetlands Protection Act, they can request a Determination of Applicability.

After the applicant submits the necessary information to the Conservation Commission, including any additional information requested by the Commission, the Commission will schedule a public hearing, review all relevant information, and then issue an Order of Conditions. The Order of Conditions, which either approves or denies the project may be appealed to the DEP regional wetlands office.

8.2 State Agencies

8.2.1 Division of Fisheries and Wildlife

Massachusetts General Law (MGL) chapter 131 provides the primary authority for regulation of inland aquacultural activities. The statute uses general terminology to provide state agency authority over such activities as recreational fishing, importation and liberation of fish, and permitting of aquacultural facilities. The Division of Fisheries and Wildlife (DFW), operating under this chapter and its mandate to protect, conserve, restore, and manage the biological resources of the state, has the authority to make the rules and regulations necessary to carry out the provisions of MGL 131.

Anyone intending to possess, maintain, culture buy or sell any live fish (except aquarium trade fish as defined in 321 CMR 9.01) in freshwater must have an aquaculture permit issued by the DFW. Section 23 of Chapter 131 sets the guidelines by which inland aquaculture permits are issued in the Commonwealth. This section outlines the types of licenses that are available and a general description of those licenses. Section 24 is also directly relevant to inland aquaculturists as it lists some requirements for selling fish as food.

Although sections 23 and 24 are the most relevant to inland aquaculture, the regulatory authority of the DFW stems from sections 4, 5, 23, 24, 26, 30, 49, 50, 51, and 52(a).

Chapter 321, section 4.09, of the Code of Massachusetts Regulations (CMR) outlines the regulations governing inland aquaculture in Massachusetts. These regulations were revised in August of 1994 to provide a more streamline, efficient process for issuing aquaculture permits (See Appendix). These regulations use a "watershed approach" to permitting inland aquaculture operations in Massachusetts. Species that are ubiquitous in Massachusetts (occur in greater than or equal to 95% of the watersheds) may be cultured in any watershed. Species that are not ubiquitous can be grown only in the watersheds where they occur unless the facility growing the fish meets a set of strict criteria. Some of these criteria include facility location restrictions, structural requirements for the fish holding facilities and discharge water requirements. The strict requirements are designed to ensure that cultured fish are separated physically and biologically from wild fish. Uncommon or entirely exotic fish species pose an increased risk to the native species if they were to escape into the wild.

8.2.2 Massachusetts Environmental Policy Act (MEPA) Unit

The MEPA unit is responsible for ensuring that the provisions of the Massachusetts Environmental Policy Act (MGL chapter 30:61-62H) are met before any state permits are issued. The regulations concerning this provision are found in 301 CMR 11.00. The MEPA Unit reviews activities for environmental impacts. Certain thresholds, usually triggered by the size of the project and the type of activity, determine if the provisions of MEPA need to be invoked. MEPA review will usually take place if the following conditions exist:

1. The project involves an Area of Critical Environmental oncern (ACEC) and the project action is appealed to the DEP.

2. The project results in the dredging, filling, alteration, or removal of one or more acres of bordering vegetated wetlands, or ten or more acres of any other resource area protected by wetlands regulations.

3. The project needs a superseding Order of Conditions from the DEP and includes: any fill or structure within a regulatory floodway of rivers or streams delineated under the National Flood Insurance Program; alteration of a primary dune; construction in a velocity zone on a barrier beach; armoring of a coastal bank; alteration of 1000 square feet or more or salt marsh, 5000 square feet or more of a bordering vegetated wetland, or .5 acre or more of any other area subject to the wetlands protection act.

4. The project is located in an ACEC and needs a state permit listed in the thresholds (301 CMR 11.26).

   If a review is necessary, the aquaculturist will need to file an Environmental Notification Form (ENF) that describes the proposed project, the potential environmental impacts, and the alternatives available that would avoid or minimize damage to the environment. An ENF must be filed for any discharge to a Class surface water or Outstanding Water Resource. The MEPA Unit would then publish and review the ENF and determine if an Environmental Impact Report is required.

8.2.3 Department of Environmental Protection

The Department of Environmental Protection should be contacted in reference to Surface and Ground Water Discharge permits, and Water Withdrawal permits, and Water Quality Certificates.

The Massachusetts Department of Environmental Protection's (DEP's) Office of Watershed Management (OWM) administers the Surface Water Discharge Permit Program 314 CMR 3.00. This program regulates the discharge of pollutants to the Commonwealth's surface waters and reflects requirements of both the State and Federal Clean Water Acts. Massachusetts is a non-delegated state which means that the United States Environmental Protection Agency (USEPA) controlsthe permitting process. Dischargers who qualify pursuant to the state regulations must apply to the USEPA (and also the DEP) for a National Pollutant Discharge Elimination System (NPDES) permit.

Those facilities that need permits are those that contain, grow, or hold aquatic animals and discharge at least thirty days per year and also fall into one of the categories below (314 CMR 3.15):

1. Coldwater Species: Those that produce 9090 harvest weight kilograms or more of animals or fish per year, or feed 2272 kilograms or more of food during the month of heaviest feeding.
2. Warmwater Species: Those that produce 45,454 harvest weight kilograms or more of aquatic animals per year.

It should be noted that the Director of OWM can designate any facility as requiring a permit based on location of facility, quality of the receiving water, the capacities of the facility, the quantity and nature of pollutants reaching the receiving water and other relevant factors. These other relevant factors include: the location of the facility in relation to surface drinking water supplies, the presence of Outstanding Resource Waters, flow volume in receiving waters, and trophic status of receiving waters.

Applicants must apply to both the USEPA Region 1 and the DEP simultaneously for a Surface Water Discharge Permit. Applications for a non-process wastewater permit (Category BRP WM 13) are available from the DEP Information Service Center at (617) 338-2255. Application packages include instructions and all the necessary state and federal forms. Permit issuance can take an extended period of time. The USEPA and DEP are currently working on a general permit format for these types of facilities and hope to have one in place within the next twelve months.

Discharge permits under the permit code BRP WM 13 for non-process wastewater have a $500.00 application fee associated with them. There is also an annual compliance fee of $100.00. Permits are issued for five years.

The DEP should also be contacted in regard to Water Withdrawal permits. The Water Management Act Regulations (310 CMR 36.17) regulate the amount of water withdrawn from both surface and groundwater supplies on a watershed basis. Two basins are currently closed for new withdrawals (Jones River and North Coastal). The purpose of Water Management Plans is to assess localized impacts of water withdrawals to other water resources such as public and private water supply wells and wetlands.

Unregistered water users withdrawing over 100,000 gallons per day on average need to apply for a water withdrawal permit and file an ENF. (**Existing** large water users had an opportunity to **register** their 1981 - 1985 withdrawal amounts up until January of 1988. These **registered** withdrawals do not require a permit unless an increase is sought over the 100,000 gallons per day).

Applicants must apply for a withdrawal permit with the DEP's Office of Watershed Management (OWM). There is an initial application fee of $1900.00 for this permit. There is an annual compliance fee of $100.00 and the permit is issued for 20 years.

401 Water Quality Certificates (WQC) are also issued by the DEP. If a new aquaculture facility alters less than 5,000 square feet, the Final Order of Conditions may also serve as the 401 WQC. Facilities that propose to alter more than 5,000 square feet of Bordering Vegetated Wetland, Land Under Water, Isolated Wetland, or an Outstanding Resource Water will require an indivisual 401 WQC. Facilities greater than one acre may also require a 401 WQC.

8.3 Federal Agencies

8.3.1 U.S. Army Corp of Engineers (ACOE)

The ACOE is responsible for issuing a Programmatic General Permit (PGP). This permit is issued under section 404 of the Federal Clean Water Act (33 U.S.C. 1344) and section 10 of the Rivers and Harbors Act of 1899. These Acts help protect natural resources from unauthorized dredge and fill and manage obstructions in navigable waters.

There are three categories listed under the PGP: 1) alteration less than 5,000 square feet requires only a Final Order of Conditions, 2) alteration of 5,000 square feet to 1 acre requires a 401 WQC and possibly a 404 permit, 3) alterations of greater than one acre require a 404 permit.

The PGP provides a simplified review process for minimal- impact projects that fall within ACOE jurisdiction. A letter of permission will be issued to the applicant that states all requirements and universal conditions that must be met.

All other state and federal permit requirements must be met before a PGP is issued. For example, when filing a NOI with the Conservation Commission, a copy of those materials should be submitted to the ACOE.

8.3.2 United States Environmental Protection Agency (USEPA)

The USEPA is responsible for issuing National Pollution Elimination Discharge System (NPDES) Permits. These permits are jointly issued with state authorities and were previously mentioned in the section on DEP permits.

9. ECONOMICS

A complete summary of economics for aquaculture can be found in the Northeast Region Aquaculture Industry Situation and Outlook Report (Bush and Anderson, 1993). Massachusetts aquaculture farm gate value for 1992 (the most recent Situation and Outlook Report) was over 8 million dollars. The dominant species produced was the Northern quahog. Other important cultured products were oysters, trout, hybrid striped bass, scallops, baitfish/other fish, and tilapia. Most ($6,350,918) of the farm gate value for Massachusetts comes from the production of oysters, hard clams, mussels and scallops. The species cultured in freshwater (which accounted for the remaining $1,670,000) were trout, hybrid striped bass, baitfish/other fish and tilapia.

Massachusetts is listed as one of the top three Northeast states for the production of trout, hybrid striped bass and tilapia. Information on these species, although not specific to Massachusetts, lends information to the current and potential industry in the Commonwealth.

Trout production, mostly brook and rainbow trout, makes up approximately 20% of the estimated $64.6 million Northeast cultured finfish farm gate value for 1992. Pennsylvania accounts for nearly 72% of the 4.7 million pounds of trout produced in the Northeast in that year. Trout culture has generated some 265 full-time and 250 part-time jobs in the Northeast. Nearly half of the trout production was sold to be stocked into private waters. The most common size sold for this purpose was 10-13 inches. The size of local trout operations is constrained, in part, by the amount of clean, cold water available for culture. The largest markets available to small trout producers are private waters and fee fishing operations.

Hybrid striped bass production in the Northeast accounted for 4% of the estimated $64.6 million farm gate value for 1992. This value translates into approximately 947,000 pounds of fish. The firms involved with hybrid production employ an estimated 85 full-time employees and 78 part-time individuals. Nearly half of this production is attributed to Maryland, the top producer. This is one of the more recent technological advancement forums in fish culture with an estimated 40% of the culture being conducted in recirculating systems. As this method develops, the potential for economic value will also increase as recirculating systems allow compensation for a shortfall in clean, cool available water supply, a common problem in the northeast.

Although the production values for tilapia are nearly inconsequential, this fish has perhaps the most potential to increase in the near future. Maryland, currently producing 250,000 pounds of fish, expects that their production could increase by a factor of 6 in only 2 years. Currently, only about 1% of the finfish production in the Northeast is in tilapia, approximately 280,000 pounds, to which Massachusetts is again one of the top three contributors and one of only two states in the Northeast with verified commercial harvest. Most of the production is in recirculating systems and some production has involved hydroponics. Most cultured tilapia is sold directly to restaurants and the average cost for live weight fish is approximately $2.00 per pound.

Relative to baitfish, little is grown in this region of the country. In fact, most of the baitfish grown in the U.S. is done so in the Southeast, primarily Arkansas. The fish species primarily produced as bait in the Northeast are fathead minnows and golden shiners. The demand for baitfish is reported to be high but extremely seasonal.

10. FISH CONSUMPTION/PUBLIC HEALTH AND SAFETY

Because of the chemical contamination of many of our important commercial and recreational fisheries, private aquaculture is playing a larger role in providing safe, clean, fresh fish for the public. In recent years, there has been significant media attention regarding contaminants in fish, particularly mercury and PCB's, in both freshwater and saltwater fish. The Department of Public Health has numerous fish consumption advisories out for both freshwater and saltwater fish species. These advisories, however, do not apply to fish cultured in hatcheries and stocked for recreational fishing or to fish produced in private aquaculture facilities. Fish cultured in hatcheries and private farms come from clean water sources and do not bioaccumulate contaminants during the short time they are being grown out to market or stocking size.

There are numerous other public health and safety issues, however, that do relate to private aquaculture relative to fish processing and handling for food consumption. The Department of Public Health should be consulted directly on this matter.

Section B

MARINE AQUACULTURE

11. INTRODUCTION TO MARINE AQUACULTURE

Massachusetts has approximately 1500 miles of coastline interspersed with rivers, estuarine systems, salt ponds, saltmarshes, and protected bays. These waters produce a variety of seaweeds, shellfish, crustaceans, and finfish. Many of the coastal waters are of high quality and have historically supported a significant commercial harvest as well as recreational fisheries and water-sports activities. The productivity of natural populations in Massachusetts is a good indicator that the quality of the state's waters is suitable for a variety of aquacultural activities.

Harvesting the sea, either through the taking of wild animals or through managed cultivation of impounded waters, tidelands, or submerged lands, is a practice that dates from before the first European settlers landed in the Bay colonies. However, the practice of rearing bivalve mollusks from the fertilized egg to the juvenile stage under controlled conditions did not become a commercially viable reality until the 1960's. Initially there were many failures, usually due to insufficient understanding of bivalve larval food requirements. Once realized, it became clear that millions of tiny clams, oysters, and bay scallops could be successfully produced in captivity.

During the 1970's, when methods of satisfying the nutritional requirements of larval and juvenile shellfish in captivity had been improved, a major focus in shellfish culture was the development of methods to assure the survival of hatchery-reared juveniles to market size. Attempting to rear shellfish from larvae to harvest size in "captivity" is not economically feasible. Various techniques were developed for culture under natural conditions, including "off-bottom" methods and the use of various materials spread on the bottom that protected the young shellfish from bottom-crawling predators.

By the 1980's, commercial shellfish hatcheries were operating successfully in New England, both publicly and privately run. Large numbers of juvenile hard clams (quahogs) and oysters were produced each year and transferred for grow-out to harvest size to tidal flats.

Today, aquaculture can be separated into two broad methods and techniques - intensive and extensive aquaculture. Intensive aquaculture subjects an organism to hatchery controlled-conditions for most of the life cycle. This form is most commonly applied to finfish. The cultivation of salmonids in "fish farms," either offshore or in inland ponds, is an example of intensive aquaculture; the fish are hatched from eggs, reared and fed in controlled enclosures until reaching harvest size, and then harvested.

Extensive aquaculture is the manipulation in the natural environment at one or more stages of an organism's life cycle. Examples include the growing of shellfish off the bottom on and in mesh bags, sleeves, nets, floats, trays, or racks, predator control, and removal of "seed" shellfish from a nursery area to a controlled pen until growth to full harvest size is completed.

Like agriculture, aquaculture is an attempt to propagate crops in a semi-controlled setting. This relationship has placed the entire aquaculture process in a confusing position somewhere between traditional agriculure and traditional fishing. In fact, agricultural interests have given aquaculture little support because it is an extremely foreign practice relative to other forms of crop propagation, while traditional fishing has viewed aquaculture as an unwanted competitor. The result has been either a lack of interest or outright hostility towards aquaculture providing it with little political and/or financial support.

Some problems related to agriculture are true in aquaculture as well, such as the accumulation of waste products and the potential for disease. Yet, the waste disposal issue offers an example of how aquacultural operations are often made more complex than its traditional counterpart. While farm wastes can often be composted on-site, the composting of fish wastes is restricted to a few specially permitted facilities, increasing costs to the aquaculturalist for waste disposal. A quick solution may be achieved for this issue if small scale on-site composting could be approved for aquaculture.

Aquaculture poses many unique challenges to the farmer not found in traditional agriculture such as those related to siting due to legal and traditional conflicts, and to contamination of wild fisheries due to interactions between these distinct populations. Unlike agriculture, aquaculture depends upon and directly influences public resources introducing conflicts to available uses and to traditional fisheries management issues. Similarly, marine and fresh water aquaculture is not always well-defined since anadramous species such as salmon or catadramous species such as eels depend upon both salt and fresh waters for parts of their life cycles complicating the need for resources which must be employed.

These obstacles have swayed public sentiment against aquaculture significantly reducing the availability of funding sources needed to legitimize the industry. Despite these obstacles, the growing demand by the public for seafood products coupled with the dwindling availability of natural sources to meet the demand still makes aquaculture a promising industry in the near future for Massachusetts.

12. SHELLFISH BOTTOM AND OFF-BOTTOM CULTURE

This chapter will discuss the basic biology and production techniques for shellfish (both bottom and off-bottom culture). In addition, this chapter addresses problems inherent to shellfish aquaculture, including environmental, economic, business, legal, etc.

The exclusive form of commercial aquaculture engaged in Massachusetts to date, both privately and by several cities and towns and the Division of Marine Fisheries, is mollusk culture, employing several methods of cultivation. This chapter provides significantly more detail on shellfish than other forms of aquaculture and this is a simple reflection on the dominance of shellfish in the Massachusetts aquaculture industry. Massachusetts is not alone in its predominant interest in mollusk culture. Globally, bivalve mollusk culture is second to only crustaceans as the most economically successful forms of marine animal aquaculture. While bivalve mollusk culture is well established in the state, recent proposals indicate commercial interest in finfish (cod, salmon, and steelhead trout) as well.

BIOLOGY

Hard clams (quahogs), soft clams (steamers), oysters, bay scallops, and mussels all reproduce by spawning; the discharge of microscopic eggs and sperm into the surrounding water, triggered by increased water temperature. The number of eggs released by a single female is impressive; a mature oyster may release up to fifty-million eggs in one season.

The eggs are fertilized in the surrounding water and within a matter of hours, the embryos develop into motile, swimming larvae. The duration of the larval period varies with water temperature and generally ranges between one to three weeks (these are requirements that may be artificially manipulated in commercial hatcheries to maximize fertilization and shorten developmental periods). The larval stage is terminated by metamorphosis; the transition to the early juvenile stage, which resembles a miniature of the adult form. Because shellfish larvae are essentially planktonic organisms that drift about and are subject to dispersal by currents, winds, and wave action, they may undergo metamorphosis, or set, far from the site of initial fertilization.

The behavior of the various species begins to differ at this stage of development. The early juveniles of quahogs and soft clams are capable of crawling on the bottom sediments. Upon finding an acceptable substrate, they dig in by means of a muscular foot. While still small, they are capable of emerging and wandering, searching for greater food sources, more desirable locations, etc. However, the remainder of their life is sedentary and spent beneath the sediment surface. Until they reach legally marketable size, clams at this stage are referred to as seed.

All bivalve mollusks (bivalves) are filter feeders, extracting their food from the surrounding water. Because they dwell in the bottom substrate, clams are equipped with siphon tubes that enable them to draw in the water from above. Unfortunately for bivalves, natural predators are numerous, including several species of crabs, snails, starfish, drills, finfish and waterfowl, many of which patrol the bottom.

Quahogs are hardy and long-lived. Soft clams, oysters, and mussels are more vulnerable to age and predation. Bay scallops are comparatively short-lived. All of these species are capable of reproduction by the end of their first full year of life.

The natural habitat of these mollusks varies considerably. The oyster and the soft clam can tolerate conditions of varying salt concentrations, adapting them to estuarine as well as ocean environments. The quahog, bay scallop and mussel prefer higher salinity and are more likely to occur in salt ponds and coves without appreciable inflows of fresh water. The soft clam, oyster, and mussel can all thrive intertidally. While the quahog may live in the tidal flats, its preferred location, along with the bay scallop, is sub-tidal.

The nature of the bottom sediments is critical to normal development and reproduction. Soft bottom muds are generally inhospitable, due to the potential for siltation and hypoxia. These soft muds might be indicative of situations where contaminants may be a problem.

Phytoplankton, an essential component of shellfish diet, depend upon the availability of inorganic nutrients as well as radiant energy for photosynthesis. Run-off from upstream sources, the addition of point-source pollutants, narrowing of embayments, and reduced water flow all impact upon these organisms. Excessive artificial enrichment (i.e. introduction of partially treated or untreated sewage or other fertilizing agents) may result in eutrophication, which degrades food sources and reduces viable shellfish habitat. The addition of nitrogenous compounds can stimulate the growth of several species of planktonic algae undesirable for shellfish food, which compete with desirable food species. In high concentrations, these algal cells can shade out natural stands of benthic plants such as eel-grass and, as they die, contribute to the accumulation of organic matter on the bottom. As this material decomposes, the oxygen concentration in the bottom waters drops. Alternatively, bottom vegetation may be stimulated by excessive nutrients to grow in such dense concentration that tidal circulation near the bottom is reduced or eliminated, thereby inhibiting the growth of bivalves.

Despite the enormous reproductive potential of shellfish, many factors contribute to a very high mortality rate during their life cycle, most particularly during the larval and juvenile stages. Shellfish aquaculture techniques are designed to reduce these losses, by protecting shellfish at early, vulnerable stages from predation and other adverse natural phenomena as long as economically feasible.

Quahogs

The common hard shell clam, or quahog, is well adapted to life in the sea, particularly the sand and mud flats of the subtidal and lower intertidal zone. The northern quahog, *Mercenaria mercenaria*, belongs to the class *Bivalvia*, easily identifiable by two, somewhat rounded, hinged shells, protruding burrowing foot, and the purple or dark blue border found on the inside of the shell. The variety known as *M. Mercenaria notata* is widely grown in Massachusetts. It is distinguished by a chestnut brown zig-zag line of the outside of the shell. Some cultivators prefer this variant because of its faster growth rate and natural identifiability. The name *Mercenaria* comes from the historic use of the shell for making Indian money, or wampum. Beads made from the purple part of the quahog shell were the most valuable form of wampum.

The quahog spends most of its life (which can last for up to 20 years) buried into the sediments of the subtidal and lower intertidal zone, with its two siphons reaching just above the surface to feed and discharge wastes. It feeds by filtering phytoplankton from water that it pulls in over its gills with one siphon and then pumps it back out through the other. Quahogs reproduce in the same manner as most bivalves, by shooting vast quantities of sperm and eggs into the water. Here the eggs are fertilized and dispersed by the currents. Hard clams spawn when the water temperature reaches approximately 60 degrees F. Of the millions of eggs shot out by female clams, only a small percentage survive to maturity in an uncontrolled environment.

Quahogs typically grow up to four inches and sometimes larger. Commercially, there are three names, based on size; the littleneck (48mm valve length or 1.5 inches), the cherrystone (60mm valve length or 2 inches), and the chowder (greater than 75mm or 3 inches or more). Some individuals can attain sizes of up to 130mm or 5 inches.

Quahogs are the preferred food of several predator species, notably green crabs, starfish, moon snails, and horseshoe crabs.

Oysters

Two kinds of oysters are cultured in Massachusetts, the Eastern, or American oyster, *Crassostrea virginica*, and the European oyster, *Ostrea edulis*. Oysters, like other epifauna, live on the sediment surface. The larvae metamorphisize and search out hard clean surfaces (cultch), which may include live oysters, to which they cement themselves. Recently-set oysters are known as spat. Setting oysters, depending upon conditions, may result in heavy local concentrations in the form of bars or reefs, where competition for space is fierce. Once attached, an oyster never moves again, unless dislodged by external forces.

Oyster shells, or valves, differ in size and weight, with the right valve (the top valve) forming flat and the left (bottom valve) being heavier and cupped. The valves are joined by a ligament and the shell shape can vary widely. The size and shape of an oyster's shell is significant in aquaculture; the raw market demands a full, shapely, aesthetically-appealing shell. Shell growth largely depends upon water temperatures and culturing times will vary according to the size to be attained. For example, in Massachusetts, it can take two - four years to attain market size while in Florida, where oysters are grown year round, eighteen months is usually sufficient.

American oysters are divided into separate male and female individuals and spawn by spewing millions of eggs and sperm into surrounding waters, where external fertilization takes place. European oysters are hermaphroditic; each individual possesses male and female germ cells, and fertilization occurs inside the inhalant chamber of the oyster. The larvae then incubate in the chamber for up to ten days prior to being ejected into the surrounding waters. Immediately before setting, both types of oysters develop eye spots and a foot and begin to search out cultch to attach to. Satisfactory cultch includes any clean, hard surface (usually empty bivalve shells).

The color, texture, and quantity of the meat in the shell is very important to the raw oyster market and those qualities will vary with age, water quality, and time of harvest. Oysters will accumulate and/or metabolize almost every element contained in the water around them. The quality of the meat drops during the spawning season. After spawning, oysters build up glycogen, which provides the appearance of a "fattening" or "fat" oyster, the most desirable kind.

Oysters are subject to a variety of natural predators, an environmental hazard that may be substantially reduced by cultivation and predator-control methods. Depending upon salinity, Atlantic oyster drills, thick-lipped oyster drills, rock shells, knobbed whelks, channeled whelks, and starfish all prey on oysters.

Oysters are also subject to a variety of diseases and parasites, the most recently notorious being MSX, discussed infra. More recently, Juvenile Oyster Disease (JOD) has been blamed for some oyster mortalities in the Northeast and mid-Atlantic aquaculture facilities. The severity of impacts by disease and parasites on oyster populations is thought to be related to water quality; higher salinity, high temperatures, and nutrient loading appear to make oysters more susceptible to disease.

Oysters provide a welcome habitat for commensal and competing organisms. Several live in or on the shell; the boring sponge, the boring clam, and the mud worm are examples. Barnacles, tunicates, and mussels (as well as other oysters) will attach themselves to the outside of the shell, as will as several species of algae. One algal species, *Codium fragile*, produces aveoliated branches filled with gas that may actually lift the oyster and carry it off with the tide.

Bay Scallops

Bay scallops, *Aequipecten irradians*, differ from clams and oysters in that they retain the ability to move actively throughout their lives. The juveniles will attach themselves to underwater eel-grass or algae through extruded filaments known as byssal threads. The Eelgrass offers protective isolation from many predators crucial during early life stages, and then settle-out within or adjacent to the vegetation. Their ability to move and remain above the sediment as they mature makes them less prone to bottom predation. Bay scallops eventually lose the tendency to attach themselves; they dwell on the bottom as adults, manipulating themselves through "jet propulsion" by forcefully closing their valves. Scallops less than one year old (determined by the annual growth ring) are considered seed and may not be harvested.

The bay scallop, as with other shellfish, has two shells, or valves, with the "laying" shell (the one the scallop rests on)being lighter in color and having a byssal notch or foot groove. The outer surface of a scallop shell exhibits prominent ridges and furrows, which radiate from the beak to the free margin. During the winter months, the scallop does not grow and a heavy concentric line, similar to that of a tree's annual ring, forms. Growth begins again in the spring and it is this ridge that determines the age of a scallop.

Scallops, unlike quahogs and soft clams, have only one adductor muscle, commonly referred to as the "eye." Bay scallops are hermaphroditic; all individuals possess male and female sex organs and produce both sperm and eggs.

Bay scallops spawn in response to increases in water temperature in the spring, beginning at approximately 61 degrees F., although spawning may be induced artificially in the hatchery by increasing water temperatures; 68 - 84 degrees is the spawning range, with 74 - 76 degrees inducing spawning within fifteen minutes after placement. Bay scallops have the capacity to spawn repeatedly over a period of weeks, depending upon external conditions.

Scallop larvae go through two distinct developmental stages, during which the mortality rate is at the highest point in the life cycle. The embryonic, or sub-veliger stage is the period prior to development of a shell; the post-embryonic, or veliger stage is the period during which the larvae have developed shells but prior to attainment of full development. During this pre-adult stage, the larvae are capable of both digging and swimming.

Once the scallops "set" by way of attachment to an available surface with byssal threads, they have reached the dissoconch ("two shelled") stage and are approximately 1/3 " in size. The scallop does not reach its full internal and shell development until the plicated stage, where the radiating ridges characteristic of the adult scallop develop. Bay scallops have a much shorter life-span than do oysters, clams, or mussels. Most bay scallops do not live beyond two years and they may reach sexual maturity within six months. They also retain their free-swimming (through jet-propulsion, expulsion of water through the "ears" coupled with shell closure) and locomotive abilities, which mandates that cultivation be off-bottom, in enclosed nets, bags, or cages.

Bay scallops, like other shellfish, are filter feeders. Unlike clams, who feed from below the substrate, scallops use their gills to siphon diatoms and other planktonic matter from the surrounding water.

Scallops are not as likely to act as a vector for disease as other shellfish because the adductor muscle is the most common food product. Pathogens are typically transferred through the food chain as the result of eating the whole shellfish, including the gut, where pathogens typically accumulate. However, consumption of whole and roe-on scallops has increased dramatically over the last two years, leading to increased risk of food product contamination.

Mussels

Mussels also initially fasten themselves by byssal threads to substrate or vegetation at metamorphosis. Like scallops, recent evidence has revealed a close relationship between blue mussels and eelgrass during early life stages. Unlike scallops, maturing mussels reattach themselves to a hard substrate, often other mussels, continuously for the remainder of their lives. If stressed, matured mussels can detach themselves and subsequently re-attach their byssal threads after finding a more desirable location.

All stages of mussel development appear to be influenced by water temperature. Mussels will spawn at temperatures between 62- 80 degrees F., but will spawn almost continually when the temperatures remain in the 75 degree vicinity. The larvae are free-swimming, and may attach several times by means of byssal threads until a desirable location (one that is abundant in food and maintains water temperatures above 65 degrees seem to be favored) is located. Mussels grow most quickly when continually immersed in water since they can almost constantly feed.

Once permanently set, the competition for space is vigorous. It is common to find mussels growing in layers of other mussels, both naturally in intertidal and sub-littoral levels, and when cultured on lines. Mussels grown in water temperatures above 65 degrees mature more quickly than those grown in colder waters, maturing in less than a year. Below that range, mussels may take up to two years to reach market size.

12.1 Bottom Culture - Overview

The practice of cultivating bottom-dwelling shellfish (most commonly hard shell clams and oysters) in nursery trays and pens from juvenile stages to maturity is collectively known as bottom culture. Since at least 1974, intensive quahog culture has been ongoing in Barnstable (62 acres), Provincetown (45 acres), Wareham (90 acres), and Wellfleet (80 acres), utilizing bottom culture on the intertidal flats.

a. Species Cultured

Oysters and Quahogs are commonly cultured using bottom culture techniques.

b. Procedure

The practice is conducted in three stages:

1. Production of Seed - very small clams (1 - 25 mm) are obtained from hatcheries (or other sources, including natural collection) where clams are cultured from initial spawning through the larval metamorphosis to the juvenile stage. Once juveniles reach the size of 2mm, they can be marketed as "seed," although the preference is for seed greater than 8 mm, which better resist predation.

2. Field Planting - the seed are "planted" in net-covered boxes measuring approximately 4 feet x 8 feet x 6 inches, that are filled with "clean" sand (sand that does not contain predator species; i.e. green crabs), and are slightly elevated above the intertidal flats on legs. These boxes, known as "nursery boxes" or "cages", may contain up to 10,000 seed clams. Smaller, more manageable boxes sized 4'x 4' are being used more commonly.

3. Grow Out - the seed are allowed to remain in the nursery trays until a size of 19 - 24mm, although all clams between 19 and 176 mm are considered field plant size by the industry. At this point, they are transferred to narrow, net-covered plots ("pens," or sometimes "runways") for grow out. When the clams reach 51 - 63mm (2 - 2.5 inches) they are harvested.

c. Current Bottom Culture Leases

There are approximately 646.5 acres of tidelands currently licensed for shellfish cultivation (commercial and research) in twenty-two Massachusetts cities and towns (Barnstable, Brewster, Chatham, Dennis, Duxbury, Eastham, Edgartown, Essex, Fairhaven, Falmouth, Gosnold, Mashpee, Mattapoisett, Nantucket, Oak Bluffs, Orleans, Plymouth, Provincetown, Truro, Wareham, Wellfleet, and Yarmouth). Cultivated species include, in order of economic importance, (1) quahogs, (2) American oysters, (3) bay scallops, (4) soft shell clams, (5) European oysters, (6) surf clams, and (7) blue mussels.

d. Legal Issues

Due in large part to the extent of privately held tidelands in the state, much of the shellfish culture in Massachusetts is conducted on private property. Often the culturist is not the owner of the flats under cultivation. The recent Massachusetts Supreme Court decision on Pazolt vs. Massachusetts has ruled that culturists must obtain permission from the owners of privately owned tidelands prior to establishing aquaculture facilities. For a discussion of the problems associated with the public use of private property, see Chapter Sixteen.

e. Economics

The cost of hatchery seed (6-8 mm) varies from $25 to $35/100. Gross sales of $25,000 -$35,000/acre have been reported at harvest of mature clams, 2-3 years after field planting. However, severe winters and intense cyclical predation can significantly reduce sales and prolong the maturation period.

According to the reports submitted by municipal shellfish constables, the landed value of cultured shellfish totaled $620,000 in 1988, $1,933,000 in 1989, $906,000 in 1990, and $1,884,000 in 1991. These values are questionable at best. Not all towns with acreage under active cultivation submitted reports and chronic under-reporting is an acknowledged problem. The consensus opinion of the Massachusetts Aquaculture Association and the Massachusetts Shellfish Officers' Association is that the reporting value represents approximately 30-40% of the actual landed value.

f. Environmental Issues

The successful growth and harvesting of food-quality shellfish requires high water quality, quality that is very vulnerable to the effects of competing coastal uses.

Bottom-dwelling shellfish are filter-feeders, obtaining nutrients (phytoplankton, heterotrophic micro-organisms, minerals and dissolved organic particles) by straining them from the surrounding water when ambient temperatures are above 10 degrees C. Conditions that affect either the availability of food (i.e. toxic blooms of certain flagellates, "brown" or "red" tides that repress certain diatom populations) or the quality of the water (i.e. excessive turbidity) affects the set of spat and the growth of seed.

Shellfish are capable of filtering, along with their traditional nutrients, various pollutants and wastes from the surrounding water and substrate. Coastal development and recreational uses supply these pollutants in abundance, either through direct (point-source) discharges or from run-off (non-point source) discharges. The chronic discharge of pollutants systematically degrades the quality of the water. The results of such degradation may vary from death, mutanogenic or teratogenic effects upon shellfish, and sickness and/or death of consumers further up the food chain.

Degradation of water quality (and associated substrate degradation) includes characteristics such as lower dissolved oxygen levels, changes in temperature, changes in salinity, and changes in turbidity. All of these parameters have a direct bearing upon the quality and quantity of shellfish propagated and harvested.

Maintaining and upgrading water quality presents a host of problems. Coastal development, industrial, and recreational use are the primary causes of near-shore water quality degradation. A balance of the competing uses is extremely difficult to achieve and is still evolving.

Culture on tidal flats requires access to work areas that may not be accessible by boat. Off Road Vehicles (ORV) traffic over dunes, coastal banks, tidal flats, and through sensitive resource areas could place endangered species and fragile ecosystems at risk. Use of the intertidal area for bottom culture also raises concern over the potential loss of resting and feeding areas for migratory birds. Some environmentalists see the use of nursery trays, netting, and pens on the flats as developing a "monoculture" that threatens the intertidal ecosystem.

h. <u>Bottom-Culture -- Problems</u>

The following are both real and perceived problems associated with bottom culture techniques:

History/Culture

Shellfishing, both recreational and commercial, is viewed as a Massachusetts' birthright. The notion of "domesticating" it into what is viewed as a form of rather unaesthetic farming, is not popular; it is inconsistent with the way Massachusetts has traditionally perceived itself and its natural resources. Despite some promise as a beneficial alternative to traditional commercial fishing, it also is perceived as a source of competition with wild fisheries (although the limited data available demonstrate little basis for such concern) for the same market.

The reservation of tidelands for shellfish licensed-areas and aquaculture licenses should not, in theory, limit areas used by commercial fishermen engaged in gathering wild stock. The fear of this happening exists. The opposite is true in some areas of the United States where wild stock represents a strong market resource and significant political pressure is employed to limit aquacultural endeavors; i.e. Alaskan salmon fishery. A related conflict is the contamination of wild stocks through the importation of seed from other areas providing a risk to native populations through disease introduction and gene pool homogeneity.

The fear of competition has a long history in the Northeast. Within the last century, violence has erupted over the existence and placement of shellfish licensed-areas. Maine, Massachusetts, New York, and Connecticut have all experienced their own versions of the "Quahog Wars", violent clashes between culturists and commercial fishermen resulting in shootings, boat-burnings, and the seizure and/or destruction of product on both sides of the argument.

The New England states have resolved many of these conflicts in a number of ways. The states of Maine and Connecticut have established procedures designed to limit aquaculture to areas that do not intrude upon the wild fishery. Massachusetts, who has, for the most part, delegated the licensed-area procedure to local authorities, requires that any area proposed for a shellfish licensed-area be a non-productive tideland; a shellfish desert, and some towns have created shellfish management plans that prohibit the siting of licensed-areas in any area where a potential conflict over access to wharves, moorings, or productive bottom may develop. Rhode Island, with its insistence upon a very old and very literal interpretation of the "free and open fishery," has forced most aquacultural activities out of the state.

Financial/Business

Misconceptions exist about bottom culture providing a livelihood or really being a viable business endeavor in Massachusetts, fueled to some extent by the failure on the part of many aquaculturists to conduct their activities in a consistent, businesslike manner. It has been reported to Massachusetts aquaculturists and to various state agencies that coastal aquaculture should not be viewed as a real form of sustainable fishing nor as an industry that justifies or deserves the assistance available to many other small businesses, funded through taxpayer dollars and assisted by state and federal programs and subsidies. The perception exists and persists that the people engaging in bottom culture do it as a hobby, or to pick up a few extra dollars "under the table" or to supplement their "real" jobs. For many serious bottom culturists, this is simply not the case. Given the productivity that can be achieved with a carefully managed licensed-area, bottom culture is engaged in as a serious, full-time occupation.

The nature of the work involved to sustain a profitable licensed-area is not something most people would do to "moonlight." Even those considered part-time aquaculturists typically spend at least a portion of each day on the licensed-areas. For intertidal licensed-areas, all work has to be done on ebb tides, which vary from day-to-day. It means going out to secure the licensed-area in foul weather. During harvest season, it means harvesting every day, no matter what the conditions may be. The work is manual, extremely labor-intensive, and technical assistance and tools are very limited. Immediate responses to emergencies: floods, storms, etc., are necessary if a year to two years' worth of work and investment is going to be saved. Bottom aquaculture is not, nor should it be considered, a hobby.

Although the work and investment risk are substantial, the returns may be significant, as pointed out elsewhere in this report. However, it is acknowledged by nearly everyone involved with coastal aquaculture: shellfish officers, harbormasters, Division of Marine Fisheries personnel, and several aquaculture trade organizations, that bottom culturists do not, by and large, conduct their operations in a professional manner. Record-keeping is poor and in most cases, insufficient to establish a clear financial picture. Reporting of harvest quantities and prices received is chronically and severely skewered on the low end; average annual reports, required by Massachusetts General Law Chapter 130, contain amounts and prices that are just sufficient for a licensed-area-holder to maintain his/her right to the licensed-area. The under-reporting problem is so generally known that the Division of Marine Fisheries assumes that actual quantities of some species of shellfish harvested and prices obtained are as much as 40 - 60% higher than what is reported.

There has traditionally been little public interest or support for programs that encourage aquacultural development over other uses of highly desirable coastal property. Banks and other lending institutions find little justification for creating small business loan packages for aquaculturists. State and federal government agencies are reluctant to devote thin resources to endeavors which do not appear to provide an adequate return for the investment. In addition, the risk of losing the harvest to disease, predation, destruction by storms, algal blooms, theft or other causes leads to a perception that aquaculture is a high-risk investment, causing banks and lending institutions to proceed carefully.

Public Health

Shellfish have, despite public education and awareness campaign efforts by the industry and the state, a mixed reputation for wholesomeness. Shellfish have in some instances been linked with disease transmission to humans, causing many consumers to avoid any form of shellfish. Aquaculture and public health are discussed in greater detail in Chapter Seventeen.

12.2 Water Column (or Off-Bottom) Culture -- Overview

The use of water column suspension techniques, including enclosures (cages, lantern nets) and lines (longlines and strings attached to rafts or racks anchored on the bottom) for the production of bottom-dwelling and sedentary shellfish, as well as for motile species of shellfish (i.e. scallops) is commonly referred to as water column or off-bottom culture. These techniques are designed to minimize bottom predators, contain mobile species (i.e.scallops) in one place until harvest, and maximize the use of a three-dimensional space for cultivation.

a. Species Cultured

Oysters have been cultivated at least since Roman times, by growing them off of the bottom on rafts and strings. Today, oysters are grown all over the world, using a variety of methods, predominantly off-bottom. In Japan, one of the largest oyster producers, cultivation methods include rafts, lantern nets, and longlines. In Australia, another large oyster-producer, sticks and trays are used. In France and England, oysters are cultivated on off-bottom posts, in mesh nets, and on longlines. Off-bottom cultivation has uniformly produced (1) more oysters than in the same area on the bottom, (2) accelerated growth rates, (3) improvement in meat quality, and (4) significant reductions in predation.

Two different kinds of oysters are cultured in Massachusetts, using off-bottom and bottom methods: the Eastern, or American oyster, *Crassostrea virginica*, and the European oyster, *Ostrea edulis*. In Massachusetts, there are currently seventy-eight oyster cultivation licensed-areas, representing both bottom and off-bottom culture in seventeen cities and towns (Barnstable, Chatham, Eastham, Edgartown, Essex, Falmouth, Gosnold, Mashpee, Mattapoisett, Nantucket, Orleans, Plymouth, Provincetown, Truro, Wareham, Wellfleet, and Yarmouth).

Mussels are one of the easiest species of shellfish to grow. Although extremely popular in Europe, on the U.S. West Coast, and in Maine, mussel culture is limited in Massachusetts. There had been as many as eleven blue mussel cultivators in operation in Massachusetts during the "mussel boom" years of the late 1980's, but there is very little, if any commercial production of mussels today. Recent advances in cleaning and grading wild harvest mussels has resulted in a drop in price for the cultured mussels which had previously been marketed as a superior product (Brooks, 1993).

The blue mussel, *Mytilus edulis*, is simple to culture off-bottom, due to its prodigious reproductive capabilities. The spat is abundant and sets easily on longlines and ropes, precluding the need for hatchery support. Mussel seed in Massachusetts comes entirely from natural populations. Empty mussel strings are placed in the water in June and July (depending upon temperature) to catch seed. Following collection of the seed, the strings may either be left in place or transferred to another growth area. The mussels are grown for 6 - 10 months until reaching harvest size and may remain on the strings for almost two years until the last of a given set is harvested. It is necessary throughout the culture period to lift the strings periodically to remove fouling organisms and to thin the growing mussels.

Cultured mussels produce a shell that is much thinner and flexible than that of a naturally occurring organism, creating some unique harvest problems. Layers of mussels have to be removed from the lines carefully, to avoid damaging the shellfish. Although no one answer can account for the difference in shell structure, the most popular theory has it that mussels react to intertidal pressures and wave action by growing much more rigid, thicker shells than do those suspended in the water column.

Mussels cultured off-bottom do not experience the predation problems of bottom-dwelling mussels, who are a favorite food for many varieties of starfish. Off-bottom culture has been the target of a commensal organism; the pea crab, who is found to co-exist in the shell of mature, cultured mussels. Cultivators have taken two approaches to the pea crab; it is either marketed as a desirable companion product, or it is destroyed by adding extra carbon dioxide to the water around the culture strings.

Although not imported for aquacultural purposes, the zebra mussel provides a interesting lesson on the potential risks associated with farming exotic species. The zebra mussel, *Dreissena polymorpha*, reached the Great Lakes region inadvertently in the bilge water of large ships from Asia. In the Great Lakes, the mussels breed prodigiously and have no natural enemies to keep their populations in check. This mussel has become so prolific that routine maintenance must be employed to clear intake ducts, sewer pipes, drains, and boats.

The bay scallop, *Argopecten irradians*, differs from the soft clam, the quahog, the oyster, and the mussel in several respects of significance to the aquaculturist. It has more rapid growth, a shorter life-span, and is less likely to transmit disease to human consumers if taken from contaminated areas. It is also harder to adapt to cultivation.

Scallops are subject to attack from several predatory bottom species, notably the starfish and the oyster drill, again making off-bottom techniques the culture of choice for scallops.

b. Techniques

Lantern Culture utilizes a cylindrical container fashioned from nylon netting, divided into sections and hung from floats and is used in Massachusetts to culture bay scallops and oysters. As juveniles metamorphosize and attach themselves to a substrate, they are maintained in a hatchery or other natural environment until they attain approximately 3 millimeters in size. At that point, they are transferred to natural growing areas, equipped with fine mesh nets suspended from rafts on the surface and anchored to the bottom. This method utilizes the three dimensional growing space for continuous feeding and limits predation.

Raft culture utilizes strings suspended from a surface raft which is anchored to the bottom. In many places, suspended culture from rafts or longlines has proven to yield the greatest production per unit area of the possible culture methods. Mussels and oysters may be cultured in this manner. In Spain, where mussels are grown suspended from rafts, a maximum production of 500 metric tons per hectare (250 tons per acre) has been achieved. This figure is 1,000 times greater than any other form of aquaculture in which animals are grown without supplemental feeding. Currently there are no raft culture operations in Massachusetts.

Rafts may measure up to approximately 30 x 300 feet, with 180 - 270 ft. longlines, The mussel strings are suspended from the rafts and extend about 21 - 30 feet below the surface. Up to 400 strings may be hung from a single raft or longline and the raft can support up to 9 metric tons of mussels.

The term "**rack**" may be used in several ways. Depending upon what is meant by the word, alternative culture methods are available.

A rack for the growing of scallops and oysters is a device constructed from wood, wood and plastic, and/or various hybrids of non-corroding metals and plastics, that resembles a bureau, complete with pull-out drawers, suspended several feet off of the bottom. Seed shellfish are set out in the drawers and allowed to mature in the water column, safe from bottom-crawling predators.
A rack may also be used in concert with longlines and/or string and lantern culture. When used in this way, a rack is nothing more than a hollow square or rectangular frame, resting on the bottom as an anchor to provide stability and separation for the lines or lanterns suspended in the water column.

c. Current Water Column Culture Leases

There are approximately twenty-eight licensed off-bottom aquaculture operations on 226.5 acres of surface water and water column off of fourteen Massachusetts cities and towns (Barnstable, Chatham, Dennis, Eastham, Edgartown, Essex, Fairhaven, Gosnold, Mashpee, Orleans, Plymouth, Provincetown, Wareham, and Yarmouth). Few of these licensees are operational. Cultivated species include American and European oysters, bay scallops, and blue mussels.

d. Legal Issues

The authority to regulate and maintain near shore areas has traditionally been local; harbormasters and shellfish officers routinely allocate mooring space, issue permission for temporary uses, assign public marina slots, and oversee shellfish licensed-areas.

Water column aquaculture requires greater regulatory involvement than bottom culture generally due to the exclusionary nature of this technique. Off-bottom culture may require a Massachusetts General Law Chapter 91 waterways license, issued by the Department of Environmental Protection or a Chapter 91 permit issued by the municipal harbormaster, because it uses "navigable" area: the water column and/or the surface, as well as the bottom and may conflict with navigation or other uses. Off-bottom culture also requires a license authorized through Massachusetts General Law Chapter 130, Section 57. Local authorities (selectmen, mayor) issue the Section 57 licenses and to some extent, they intrude upon the traditional authority granted to harbormasters to assign moorings and designate areas for scuba diving. Which use takes precedence, how the uses should be distinguished, how the uses may accommodate each other, have the potential for controversy and the procedures employed in the licensing of the various uses are a subject for further legal scrutiny and clarification. Coordination efforts between state and local entities concerning information exchange and reporting requirements also need to be reviewed.

e. Environmental Issues

Off-bottom culture carries with it its own set of demanding water quality requirements, as well as its own effects upon surrounding water, microfauna, macrofauna, submerged vegetation, and sediments.

Phytoplankton: Mussels and oysters feed by filtering suspended particulate matter, both plankton and detritus; the biomass of phytoplankton downcurrent of mollusk culture therefore may be expected to be reduced. Mollusks are effective in removing particulate matter. In one study, particulate concentrations were measured after passage through oyster rafts, each supporting 50,000 - 90,000 oysters. The particulate concentration was reduced 76-95% after passage through 11 rafts (although some of this may be attributed to passive settling rather than removal by the oysters.)

There is also anecdotal evidence of the filtering efficiency of mussels. Growers have found that mussels on the upcurrent side of a raft grow faster than those on the downward side, presumably because of the reduction in food concentration as the water passes through the raft. Divers have reported the water clarity in the midst of mussel strings to be substantially improved over conditions beyond the perimeter of the raft, presumably because the mussels have reduced the concentration of suspended particulates.

Waste Loading: Shellfish culture is associated with nutrient-loading, but nutrition is obtained from indigenous phytoplankton and particulate matter, rather than from any external food source. Thus, the culture operation does not introduce any "new" nutrients into the marine environment, but promotes the recycling of those which are already present. There is actually a net decrease in nutrient levels in the system, since about only 40% of the total nutrients removed by mollusk culture is released directly to the water column; 30% fall to the bottom as particulate material and 30% are removed in the harvest.

Shellfish generate solid waste in the form of feces and pseudofeces. Shells which fall from the culture structure also accumulate on the bottom immediately under the raft or longline. Studies of oyster culture in Japan indicate that the amount of solid waste produced by shellfish culture can be considerable. A raft of oysters in Hiroshima Bay holds 350,000 - 630,000 oysters. During a nine month culture season a single raft will produce 16 metric tons of feces and pseudofeces, with an additional 4.5 tons attributable to feces of fouling organisms growing on the rafts. Approximately 20 - 30% of this material is deposited on the bottom. Additionally, the shading effects of a large raft over an eelgrass bed could lead to considerable degradation.

f. Economics

As noted earlier, off-bottom culture has the potential to provide some of the highest yield figures for shellfish culture, particularly if some of the other problems associated with the growth of the off-bottom industry can be adequately resolved. The actual dollars generated by off-bottom culture are not precise; current figures do not distinguish between culture practices and many figures do not distinguish between cultured product and wild stock.

Most of the traditional oyster grounds in Massachusetts have now either been closed due to pollution or have been harvested to the point of extinction. Significant natural sets still occur in some of the salt ponds on Martha's Vineyard and in the Towns of Wellfleet and Wareham, but much of the current production is aquaculturally-derived, utilizing both naturally produced and hatchery seed. The most favorable growing areas and licensed-areas are found in the waters around lower Cape Cod; virtually no oysters are harvested north of Cape Cod.

Catch statistics from 1889 to the present indicate that oyster production in Massachusetts has steadily declined since the turn of the century. Production fell during the 1950s and has remained relatively constant since that time. The sharp decline in the 1950s occurred during a period of set failures in Long Island Sound that prevented Massachusetts growers from obtaining seed. The brief resurgence in the industry in the 1980s resulted from the increase in the availability of seed from Connecticut in the 1970's.

The importation of seed had to be discontinued in the mid-1980's after the identification of the oyster pathogen - Haplosporidium nelsoni, commonly known as MSX Disease, among the imported oysters. Recently, oysters selectively bred for resistance to MSX at Rutgers University have shown encouraging results and offer considerable hope to the industry. More recently, however, oyster growers have suffered heavy losses among juvenile oysters from a cause other than MSX, presumed to be a pathogen, but as yet unidentified. These recent mortalities, which produced heavy losses in 1990-1991, occurred among hatchery-reared seed in Massachusetts, New York, Rhode Island, and Connecticut.

Reported total landings on Cape Cod in 1989 were approximately 7,000 bushels, of which more than half were cultured on private growing grounds. In 1990, the wholesale price for oysters was slightly over $10.00 per pound (shucked), or more than twice that for quahogs.

Massachusetts has always been a major producer of bay scallops, although predominantly from the harvest of wild, rather than cultured, stock. This species rarely occurs in commercial quantities north of Cape Cod, exceptions being Plymouth and Duxbury Bays, but the comparatively warm water of the numerous and shallow coves and salt ponds of southern Massachusetts have provided an ideal habitat in the past. For many coastal communities, the bay scallop fishery has produced a steady source of income and has been an important contribution to the economy during the winter.

The price for bay scallops varies greatly from year to year, varying indirectly with abundance. In 1990, which was a lean year, the ex-vessel price was $6.61 per pound of shucked meats. In more productive years, the price may be considerably less. A consistent characteristic of the bay scallop fishery has been fluctuations in abundance from year to year, with relatively productive years often immediately followed by general scarcity. The annual bay scallop harvests in Massachusetts near the turn of the century were not much larger than in good years today. However, during the 1970s and 1980s, bay scallops virtually disappeared from many areas in which they were quite abundant, and good years occurred infrequently. It is suspected that the disappearance of the bay scallop in some areas may be linked to increasing boat traffic, as larger amounts of hydrocarbons - a toxin to this species - are released into the water. Some research has linked the loss of eelgrass and eutrophication of coastal waters to the decline in bay scallop productivity through the reduction in preferred scallop habitat. A blight in the 1930's which desroyed much of the eelgrasses on the Atlantic Coast resulted in the total collapse of the bay scallop fishery. Today, a variety of non-point source pollutants have impacted the abundance of eelgrass and therefore poses a threat to bay scallops.

In the past, only the adductor muscle of the bay scallop has been marketed for consumption. Pathogens do not accumulate in the adductor muscle. Therefore, scallops may be taken from areas closed to the harvest of other bivalves if only the adductor muscle is to be marketed. However, increases in whole and roe-on scallop consumption has increased, and these scallops must come from approved areas. The legal proscriptions against the harvesting of scallops less than one year old has provided a practical means for protecting the natural stock. Bay scallops, however, are highly sensitive - particularly in the embryonic and larval stages - to a variety of chemicals frequently associated with industrial and domestic wastes and the adults cannot survive in areas of heavy siltation or reduced oxygen conditions.

Although the bay scallop is readily cultured through its early development in hatcheries, to date it has proven impractical to rear to maturity in large numbers in the wild due to its mobility, as well as its vulnerability to predators. This is where aquacultural techniques such as lantern nets have the potential to become so valuable.

g. Off-bottom Culture -- Problems

The following are problems, both real and perceived which are associated with Off-Bottom Culture.

Historic/Cultural

Water column culture suffers from the same lack of common understanding afflicting bottom culture. The cultural identity of Massachusetts in its wild shellfish industry is at odds with the notion of a domestic shellfishery, particularly one that intrudes upon traditional shore and near-shore activities. Off-bottom culture also intrudes upon the water surface and near-shore bottom, affecting mooring availability, recreational boating, navigation, and commercial fishing activities.

Use Conflicts

Due to the exclusionary nature of this aquaculture technique, other activities (including navigation) in the area of a water column aquaculture facility are displaced. Siting of these facilities is therefore subject to considerable controversy from other users.

Entanglements

There have been reports of marine mammals and reptiles, including endangered species, becoming entangled in off-bottom facilities particularly in Cape Cod Bay. Measures need to be taken to reduce such interactions.

13. FISH FARMS & OTHER TYPES OF AQUACULTURE

13.1. Fish Farms

The rearing of finfish in floating structures: net pens, cages, or enclosures, is a developing industry on both coasts in response to greater demand for a quality, cultured product and diminishing wild fisheries.

Fish farms are not to be confused with ocean ranching. Ocean ranching is the practice of releasing cultured salmon from a designated location into the wild, with the expectation that the salmon will return to the point of release in sufficient numbers to create an economically viable enterprise. There are no ocean ranching facilities presently operating on the east coast of the United States, although the practice is prevalent in the Pacific Northwest and Canada.

The fish farm industry has a longer history in the Pacific Northwest than it does on the East Coast. The commercial culture of salmon in the Puget Sound area of Washington began in the 1960's, but has grown slowly since. In 1994, a total of six growers produced approximately 4,800 metric tons at 12 sites. Atlantic salmon (Salmo salar) was the predominant species grown, followed by coho salmon (Onchorhynchus kisutch) and chinook (Onchorhynchus tshawytscha). Chinook and coho are grown extensively for fishery enhancement purposes in Washington and Alaska.

The only fish farms located in New England are in Maine, where concerted efforts have been made to encourage their development and establish a streamlined, but strict regulatory climate. Such a framework encouraged rapid growth between 1988 and 1993, but total production dropped by 1.5 million pounds in 1994. Currently, there are twenty-three fish farm leases in Maine, predominantly in the Cobscook Bay area. The leases represent approximately two square miles (out of Maine's 2,000 square mile coast). The predominant species reared is Atlantic salmon. Finfish farms have been proposed in Massachusetts offshore of the north shore, in Cape Cod Bay and south of Martha's Vineyard.

a. Potential Marine Species to be Cultured

There are presently no marine fish farms is Massachusetts. Aquafuture is raising hybrid striped bass in Turners Falls. The following species have been proposed for farming in the state.

Atlantic Salmon (*Salmo salar*)
Atlantic Cod (*Gadus morhua*)
Steelhead Trout (*Oncorhynchus mykiss*)

Summer Flounder/fluke - (*Paralichthys dentantus*)
Winter Flounder - (*Pleuronectes americanus*)
Bluefin Tuna - (*Thunnus thynnus*)

b. **Technique**

A fish farm operation consists of distinct components and support arrangements. In addition to the enclosures themselves, boats, ramps, handling equipment, on-and off-loading equipment, and hatchery and/or fry-holding facilities are necessary.

Salmon are normally raised in net-pens, which vary in size and shape depending on the scale of the operation and other factors such as water depth and wave energy. The average dimensions of a typical square pen are 10 meters on a side by 4 meters deep, but circular designs can be up to 30 meters in diameter and 30 meters deep. Pens normally consist of an inner containment net and an outer predator net. Clearance between the predator net and the bottom helps to maintain water circulation, which distributes metabolic waste and excess feed. Pens are usually strung together, connected by walkways, to form a single system. Several systems may exist on one lease site.

Eggs are hatched and fry are obtained from fresh water hatcheries for salmonids. Salmon smolts are generally transferred to net pens off-shore in the spring, where they are held until reaching harvest size. Harvest size will vary depending on the market, the demand, and the regulatory climate. For example, fish meant for the "pan-sized" market would be held until they weighed 0.3 - 0.5 kgs.

Despite being at a competitive disadvantage to wild fish, farm-raised fish do exhibit most of the behavioral traits of an anadromous sepcies. They will migrate to sea if allowed, and return to rivers that are in proximity to their point-of-escapement, and they spawn successfully.

c. **Legal Issues**

There have been a few proposals to operate offshore fish farms in federal waters off the coast of Massachusetts. One such project was proposed by American Norwegian Fish Farms, Inc. in 1987. The plan described 90 circular net-pens to be sited 35 miles east of Cape Ann and a smolt-raising facility located inside the Rockport breakwater. The Corps of Engineers issued a permit for the offshore site in 1990, but suspended it nine months later after the U.S. Navy raised concerns that the site was located in a designated submarine operating area.

In 1994, the applicant again requested a Corps' permit under Section 10 of the Rivers and Harbors Act of 1899, to deploy and maintain fish pens. This time the site was 53 miles east of Cape Ann, in the Wilkinson Basin, and would initially consist of one string of 10 pens. An eventual expansion to 90 pens would be sought if environmental, structural, and conflict-of-use concerns were satisfied by the functioning prototype. Currently, the Corps is concerned that the proposed mooring design would not survive the site's high energy environment, and that the structures could create a navigation hazard if they were set adrift during a storm. Accordingly, the Corps has required the applicant to develop a mooring system that should, by design, survive the offshore environment.

Such proposals are often plagued by insufficient environmental, economic, and engineering information necessary for an adequate review. Once a project is subject to review, it must pass through a myriad of federal and state agency approvals. An evaluation of past projects illustrates the complexity of the legal requirements involved, as well as the need to create a more manageable structure for siting and permitting fish farms if they are to become economically viable in Massachusetts. Needless to say, the Norwegian American project did not pass the permit review and was not implemented, however, other similar types of proposals may be forth coming.

Proposed fish farm in federal waters require permits from the U.S. Army Corps of Engineers for both ocean discharge and dredge and fill activities. The United States Environmental Protection Agency must review and approve an application for a Clean Water Act NPDES permit. The Department of Defense has to issue a waiver on the site as a "non-security" area. Approval by New England Fishery Management Council may also be necessary for any aquaculture facilities located in federal waters (outside of three miles). Additionally, a consistency determination from the state Coastal Zone Management office would be required of any project receiving a federal permit (ACOE, NEFMC). More detail on regulatory requirements can be found in the Legal chapter of this paper.

For any component of the proposed facility to be sited in state waters, the environmental agencies of the Commonwealth of Massachusetts must review a coastal finfish aquaculture permit application, a state clean water act permit application, and a variety of commercial fishing, brokering, storage, transfer, and sale licenses. A Chapter 91 lease (or permit) may be required for leasing state submerged lands, however, no such leases have been executed for aquaculture facilities to date. Bottom culture has thus far been waived from the necessity of applying for a Chapter 91 lease, because it is not an exclusive use of submerged land. Off-bottom culture and fish farms are more exclusive uses and therefore, may require a Chapter 91 lease.

This scenario of regulatory complexity is the same everywhere. Maine has created a separate regulatory structure for the encouragement and development of fish farms, distinct from the wild fishery. The Maine system establishes a "one-stop shopping" office for aquaculture generally, with varying requirements depending on whether the project involves a discharge (e.g. finfish) or structures (e.g. finfish and suspended shellfish) or neither (e.g. bottom shellfish culture). Under the jurisdiction of the Department of Marine Resources, Office of Aquaculture, the environmental, engineering, financial, and technical information necessary to demonstrate permit compliance for the State of Maine and for the federal government is submitted and reviewed. This information is shared among the relevant agencies and after agency review is concluded, a public hearing is conducted on the feasibility of granting the aquaculture lease and the conditions attendant to it.

d. Environmental Issues

Perhaps the most controversial aspects of any analysis of fish farms are the myriad of environmental-impact questions raised. Fish farms influence and are influenced by a very complex set of natural and manipulated forces, including water velocities, water depths, wind and wave action, dissolved oxygen, temperature, salinity, and pollution. The most significant environmental changes addressed (and the changes most likely to create dissension, opposition to the industry, and regulatory chaos) can be summarized as follows:

Sedimentation/Organic Loading

Fish farms generate large amounts of solid wastes in the form of feces and unconsumed feed. These materials are generally deposited in the immediate vicinity of the culture structure. This deposition can result in physical and chemical changes to the natural sediments including decreased redox potential, increased sediment oxygen consumption, and increased concentrations of total volatile solids, total organic carbon, sulfides, nitrogenous compounds and phosphates. While there are profound effects on sediment chemistry and consequently the sediment biota, these effects appear to be localized. Visible accumulation of solids and the alteration of sediment chemistry typically extends no more than 30 meters from the culture structure and benthic community changes observed have been limited to the same thirty meters. Sediment accumulation may be expected to occur beneath any culture facility when less than 15 meters exists between the bottom of the structure and the sea floor. Sediment accumulation is possible at even greater depths, but little data is available since few culture operations have been sited in deeper waters.

The accumulation of organic-rich sediments beneath culture facilities and the consequent depletion of oxygen in the sediment pore waters results in changes in the infaunal invertebrate community. Loss of species intolerant of organic enrichment (typically echinoderms, crustaceans, and mollusks) often occurs. Opportunistic species like polychaete worms may move in and attain numerical dominance in the community. In cases of extreme organic loading, the sediments within the area of greatest impact may reach complete azoic and anaerobic conditions, and form and release methane or hydrogen sulfide gas. These conditions, where they exist at all, tend to be temporally limited to warmer periods of the growing season when feeding and growth rates are high. These impacts may be avoided entirely by modifying the amount of feed used in order to prevent overfeeding and the accumulation of excess feed on the substrate.

Accumulation of organic material in the vicinity of a fish farm may result in the loss of nonmotile megafauna (i.e. surfclams) living in intimate contact with the sediments. However, fish and motile megafauna (e.g. crabs) living on or above the sediment surface are typically found in higher densities around fish farms than in the surrounding area. The attraction of fish and megafauna to the culture area is probably due to increased availability of food in the form of feed unutilized by the cultured fish, the high abundances of opportunistic macroinvertebrates, and the epifaunal organisms living on the culture structure or which fall to the bottom.

Massachusetts' New England Fisheries Development Association is carrying out an interesting polyculture experiment in Maine, in which scallops in bags are being cultured salmon in net pens. In theory, the scallops should be able to use the waste organic material from the salmon for its energy requirements.

Water Circulation

Fish farms may change water circulation and water-quality. The likelihood of these effects and their potential magnitude is highly dependent upon site-specific conditions or the species cultured. A fish farm placed in the marine environment may reduce current velocity in the surrounding area, particularly in the down current direction. This reduction in current velocity will impair dilution and dispersal of wastes downstream of the farm. However, this effect is not likely to be significant except in cases of intensive culturing in an area with very restricted natural circulation.

Water quality

Cultured organisms and culture practices alter the chemistry of the water passing through the fish farm, most notably increasing ammonia concentrations and decreasing dissolved oxygen concentrations. The concentration of nutrients and BOD in the water passing through fish farms are generally very dilute compared to most other discharges to the marine environment.

Phytoplankton

There are no good available data quantifying phytoplankton changes in the Gulf of Maine as the result of the existence of the 23 currently operating fish farms. As many local species are not limited by the addition of nutrients, it is not likely that measurable effects will be imminently detected. Nutrients may periodically be limited in vertically stratified areas and in poorly flushed embayments.

Exotic species

The importation by fish farms of live stock into the state may represent a threat to wild species. Introduced species may establish self-sustaining wild populations, potentially becoming pests or eliminating native species. Future import requests should be carefully evaluated for this potential.

Toxics and Disease

There are several issues for which available data are inadequate for a conclusive determination of significance. These include (1) the environmental and public health effects of antibiotic usage; (2) alteration of the wild gene pool; (3) the capacity for a fish farm to serve as a disease reservoir for the infection of wild organisms; and (4) the proliferation of human pathogens in the vicinity of fish farms.

Concerns over the introduction of disease through fish farms have long been expressed. Recently, outbreaks in fresh water rivers and streams of whirling disease have magnified this concern. The general outbreak of a species-wide disease is usually associated with some form of stress. Within the culture environment, fish may be stressed by overcrowding, undernourishment, poor water quality, and physical damage associated with handling and confinement. An infected hatchery population of trout was released into a Colorado stream and infected the wild population resulting a large scale mortalities. Wild fish in a Utah river were reportedly infected with whirling disease by water discharged from a hatchery. Last year, the state of New York ordered the destruction of 43,000 pounds of fish from four hatcheries because they were infected with whirling disease. These episodes, if they persist, present a clear challenge to all aquaculture projects.

In marine environments, the transmission of parasites from farmed populations to wild ones has been documented. In Norway, the level of sea lice infestation on wild salmon in some areas where salmon farming is concentrated, has been found to be 10 times greater than areas where there are no farms. In 1990, it was estimated that 500 metric tons of wild salmon were lost from various diseases in Norway.

Although salmonid bacterial diseases are not transmissible to human consumers, there has been some question raised about whether the organic enrichment of bottom sediments caused by fish farms could promote the growth of those species pathogenic to humans. Consumption of shellfish collected in the vicinity of a mariculture operation could then serve as a vector for human infection. This is an issue where available scientific evidence is very meager, but experience to date has failed to demonstrate cause for concern. Increased bacterial abundance in sediments beneath fish farms is probable, but it has not been demonstrated that this increased abundance is of any significance in terms of human health.

Genetic Effects

The issue of the genetic effects of fish farms is still somewhat speculative. Cultured organisms may be at a competitive disadvantage with respect to wild stock. If escapes and interbreeding occur, there could be some temporary loss of reproductive capacity in the wild population resulting from the production of less-fit genotypes.

The potential magnitude of this effect is dependent upon the proportion of the breeding population comprised of escaped animals. It should be noted, however, that for years fisheries managers have routinely transferred hatchery-reared salmonids between river systems to improve commercial fisheries.

Recent evidence has shown that more farm raised populations are escaping than was previously thought. In Norway, single incidents resulted in the loss of 1,453,000 and 700,000 fish in 1991. The annual average of escaped fish in Norway between 1988 and 1991 was two million. Scotland has had losses of up to 184,000 in one incident. In New Brunswick, Canada, it is estimated that 33% of the salmon populating their rivers originated from fish farms. In Maine, escapements have been reported to occur from seals breaking through both inner and outer nets in an attempt to prey on the salmon. There is some fear that the return of Atlantic salmon to the Connecticut and Merrimack Rivers are primarily from hatchery stock and thus invading the few wild fish that are left. The potential damage to wild stocks is a real, but not well-understood concern.

Drugs

Fish farms require the use of drugs (antibiotics, hormones, vitamins, parasiticides and fungicides) in order to maintain healthy populations of fish. Public concern about human health and environmental impacts from such drugs has generated an increasingly strict interpretation and enforcement of regulations by the U.S. Food and Drug Administration resulting in a scarcity of federally approved drugs. Consequently, the efficiency of fish farms has been diminished and costs have increased. Furthermore, pharmaceutical companies are reluctant to invest in aquaculture drug research because of the difficulties associated with gaining FDA approval for such drugs reducing their market potential. Only three therapeutic and one anesthetic drugs are currently approved and available for use by hatchery managers. In response to this pressing problem, state fish and wildlife agencies, including Massachusetts, are each contributing $100,000 over the next 5 years to support the certification of a few essential drugs already being used on a pilot basis.

Although potential environmental effects have not been adequately quantified, some drug characteristics can assure a more limited impact. For example, the greater the use of highly water-soluble drugs (i.e. oxytetracycline), the less impact there is anticipated on surrounding waters. However, more research and development with the pharmaceutical industry's backing is necessary for future aquaculture improvements.

Structural Integrity

The structural integrity of fish farm structures and the damage that broken structures could cause on vessels underway and adjacent shoreline facilities is an issue which must be considered when evaluating the effects of offshore fish farms.

Since most offshore sites in Massachusetts are very exposed to storms, the possibility of facility break-up is real.

e. Economics

The prospects for this industry, however, are clear. World demand is consistently outstripping supplies of finfish and states (i.e. Florida, Virginia, California) in which efforts have been made to encourage the industry are demonstrating economic success. In 1991, Puget Sound fish farms produced approximately 1,500 metric tons of salmonids, primarily coho (Onchorhynchus kisutch), chinook (Onchorhynchus tshawytscha), and Atlantic (Salmo salar) salmon. Maine produced 6,100 metric tons of cultured salmon and trout in 1992 and 360 full-time jobs in the fishery with sales of over $30 million.

f. Problems Associated with Fish Farming

The concerns raised about fish farms are similar to those encountered when feedlot management is proposed: pollution, disease, overcrowding, competing uses/abuses and degradation of resources. Traditional uses of this public resource further complicate the siting and promotion of fish farms.

Conflicting Uses

Because fish farms can be an exclusive use of submerged lands, siting fish farms is generally very controversial. Siting problems occur both because other users want to use the same area slated for fish farm development and because shore side landowners and sometimes, communities oppose the locations of fish farms from an aesthetic perspective. Traditional users of the space, such as commercial fishermen and recreational boaters, object to being excluded from the use of public lands. The aesthetic argument has prevailed in some areas of Washington State where aquaculture has basically been shut out by the viewpoint that pristine views are more important (for tourism and lifestyle) than is aquaculture. On the other hand, the argument that aquaculture is a priority use of submerged lands, a means of diversifying the economy in coastal areas and increasing the availability of fresh seafood has resulted in the successful siting of fish farms in several areas of the country.

Fish farms occupy a three-dimensional space; the surface, water column, and bottom. This use effectively forecloses the area of the water column and the bottom from certain other uses; i.e. lobstering, and has been the basis for continuous objection to the siting of fish farms. Currently, this is not a realistic concern. There are no leases in Massachusetts and the leases that exist in Maine obstruct insignificant amounts of the bottom and the water column, relative to their productivity. The Maine Department of Marine Resources (DMR) and the Maine State Planning Office report that, in 1992, lobster production was valued at fifty million dollars, while farmed Atlantic salmon were valued at 88 million dollars.

There is no current, reliable data available to conclude one way or the other whether fish farming depresses lobster take. Maine DMR believes that there is no relation, as fish farms in Maine do not remove significant amounts of productive lobster bottom. Conflicting uses, including lobstering are considered by DMR when making lease determinations.

Competition with Traditional Fisheries

The next objection has effectively foreclosed fish farms in some areas; pressure from commercial wild fishermen who do not want to compete with cultivated stock for the same market. In Alaska, where the wild fishery is an extremely potent legislative force, fish farms are proscribed. Although fish farms represent a potential for tremendous productivity and economy of scale, traditional fishermen are very suspicious of them and many objections have been raised about encouraging their development in New England as well.

Scientific uncertainty about the impacts of fish farms on other species, benthic populations, water quality, wind and wave action, disease, and predation, raise a series of questions about indirect costs of fish farms, with few good answers at this point. In Maine, there has not been any reported negative impact on the wild fishery, despite considerable monitoring. The monitoring, however, has been limited to benthic communities and water quality on site. The threat is real enough that the National Marine Fisheries Service and the U.S. Fish and Wildlife Service are currently considering the need to list the Atlantic salmon as endangered or threatened in seven rivers in Maine. The Status Review for Anadramous Atlantic Salmon in the United States, published in January 1995, identifies salmon aquaculture as a major potential threat to the continued existence of the wild population.

13.2. Seaweed

Seaweed is an important food source in the Far East and portions of Africa; several varieties of seaweed are cultivated as vegetables, among them *Porphyra*, *Ulva lactuca*, *Chondrus crispus*, and *Eucheuma*. Its use in the United States, until very recently, has been limited to phycocolloids, the gelatin-like substance extracted from seaweed that is used as a food and drug additive. The phycocolloids are extracted for use as emulsifying, binding, and smoothing agents in foods and drugs. The primary phycocolloids are carrageenan, agar, and alginate and are commonly found in ice cream, pudding, and toothpaste. Carrageenan is being studied because of its ability to slow, and in some instances, to halt the progress of the AIDS virus. Researchers have found that carrageenan inhibits the genetic replication of the AIDS virus and prevents infected cells from fusing together.

Research into seaweed culture and uses of seaweeds in Massachusetts is being conducted Northeastern University's Marine Science Center. Additional research in the area is being directed at the State University of New York at Stony Brook, the University of Maine at Orono, and the University of Connecticut.

a. Species Cultured in Massachusetts

Although no commercial seaweed culture currently exists in Massachusetts' territorial waters, experimentation and demonstration projects do exist, researching seaweed aquaculture both as a stand-alone operation and as a polyculture with fish farms. The potential exists for production of an economically viable product that utilizes the by-products of fish farm culture.

There is one commercial seaweed farm operating in Maine today that is experimenting with growing two forms of edible seaweeds that use nitrogen- and phosphorus-bearing waste (components of fish wastes) as their food source. The project has not been operating long enough to develop dependable data sets, but the early monitoring results are promising.

The seaweed farm, operating in Passamaquoddy Bay, Eastport, Maine, is culturing two Japanese species of edible seaweed; Porphyra yezoensis and Porphyra nori. The operation grows and distributes its own product and sells pre-seeded nets to other entrepreneurs. Interest in growing seaweed along the east coast is high and many small demonstration projects are being developed by researchers and aquaculturists (the University of Massachusetts at Boston, the University of Maine and the Maine Aquaculture Innovation Center are all experimenting with seaweed culture).

b. Procedure

The culture process is different and less labor-intensive than fish farming. The seaweed growing apparatus, consisting of 60' by 5' nets stretched across PVC frames, are set out in mid-May in Maine and removed by December. Scallop shells are "seeded" with seaweed spores and spread on the sea bottom. The nets are then placed over the shells, to allow the spores to seed onto the nets. Once seeded, the nets are brought to just below the surface of the water and the seaweed grows, primarily by digesting nutrients from the surrounding water. For the first three weeks after seeding, the nets are raised above the water surface daily to dry. The drying process does not affect the cultured species, but effectively destroys microscopic diatoms that attach and compete with the cultured seaweed. After the first three weeks, the drying process is no longer necessary; the porphyra will have grown large enough to resist diatom intrusion. The first crop takes approximately six weeks to mature and subsequently, for the next four - six weeks, can be harvested weekly.

c. **Problems Associated with Seaweed Culture**

Limited markets presently exist for seaweed products on the East Coast. Although the demand for fresh nori and other types of edible seaweed is significant in Japan, quality control, shipping problems and most importantly, trade restrictions, hamper East Coast production. The edible seaweed market in the United States is currently worth approximately thirty million dollars annually. Although the Japanese market, estimated to be worth 1.5 billion dollars annually, is closed to foreign imports, edible seaweed is one of the products currently being negotiated by the United States Trade Representative.

d. **Economic Issues**

The economic advantages of polyculture (combining fish farming and seaweed culture) are clear. Currently, Maine salmon farmers use between 20 - 30% of their total lease area for actual fish culture; seaweed culture could be employed in the fallow areas without obstructing the fish farm operations and maintenance. The seaweed would utilize some of the by-products of the fish culture and the necessary state and federal permits (Maine Dept. of Marine Resources Aquaculture Leases, approvals from the Coast Guard and the United States Army Corps of Engineers for siting, federal NPDES permits) could be obtained contemporaneously, with the submission of similar information for both operations. Additionally, the costs of lease payments, permit fees and marine monitoring could be offset to some extent if polyculture becomes viable.

13.3. AMERICAN LOBSTERS (*Homarus americanus*)

Cultivated lobsters represent theoretically one of the most profitable aquaculture species for Massachusetts. At present, only two commercial lobster culturing facilities exist; one in Monterey, CA and one on Prince Edward Island, Canada. The Massachusetts Division of Marine Fisheries operates a lobster hatchery in Oak Bluffs, Martha's Vineyard for research and enhancement of the natural fishery.

Lobsters have the requisite characteristics to produce a marketable and very profitable commodity; species' toughness for this area, a demand that always exceeds the supply, a (potentially) diminishing wild fishery, a market price that maintains itself at dependably high levels, and little domestic or foreign competition. The primary obstacles to turning lobster aquaculture into an economic realty are the costs of culture and the length of time it takes a lobster to achieve market size.

a. **Procedure**

The Massachusetts State Lobster Hatchery was established in 1949, pursuant to a mandate of the Legislature for a facility designed to promote research into the biology of *Homarus americanus* and to maintain and enhance Massachusetts wild stock.

The hatchery operates two programs; a research and development facility and a hatchery and stocking program. Between May and August, egg-bearing female lobsters ("eggers") are collected by the Division of Marine Fisheries and commercial fishermen and brought to the hatchery, producing an average of 3,500 eggs/year. The eggs hatch out as first stage larvae, which are free-swimming, cannibalistic, and about the size of a mosquito.

The larvae are held at the hatchery for three molts, until they become fourth stage larvae. At fourth stage, rather than remaining in the water column and on the surface, the juveniles gravitate to the bottom and begin developing legs and claws, freeing them from surface predation and allowing their diet to expand to include hard food sources. This first-to-fourth-stage molting period is a critical period in lobster development; DMF biologists estimate that less than 1/10 of 1% of the young lobsters who hatch initially survive in the natural environment through the fourth molt stage. Hatchery survival rates are much higher, up to 75%.

The reasons for such high juvenile mortality arise from the external environment. First-through-fourth-molt lobster larvae are free-swimming with marine plankton in the water column and on the surface. They are subject to predation pressure from a variety of other organisms and are very vulnerable to toxics in their environment, particularly hydrocarbons produced by boats.

b. Problems Associated with Lobster Culture

From hatch-out, lobsters are cannibalistic and will freely feed on each other, creating unique culture problems. In the hatchery, predation is controlled and the juveniles are discouraged from cannibalism by being kept physically separated (through the use of continuous bottom injection of water to keep the lobsters apart in the water column) and by being extremely well-fed. The costs associated with maintaining physical separation and diet requirements, along with the length of time till maturation, have prevented lobster farming from being a viable economic possibility for Massachusetts aquaculture.

c. Economic Issues

The average lobster catch over the past five years (1987 - 1992) has exceeded 14.9 million pounds, at a landing value of over 44.6 million dollars (DMF). Lobsters exceed the value of any other fish or shellfish caught in Massachusetts.

A lobster reaches sexual maturity and approximately one pound in weight in seven years in Massachusetts. Research is being conducted to accelerate growth rates and to breed for larger size and quicker development. It has been observed at the DMF hatchery that lobsters maintained in 70 degree F. temperatures all year long take between five and seven years to mature. At this temperature, diet demands increase. Further research is necessary to develop an economically viable food source for lobster culture. Selective breeding is also being conducted to maximize the edible portions of the lobster. For example, it has been observed that lobsters fed hard shell food earlier into their life cycle develop two larger "crusher"claws, rather than the typical crusher claw and smaller, "ripper" claw.

13.4. Other Potential Species

Sea Urchin Roe (*Strongylocentrotus droebachiensis*) - The sea urchin roe fishery in Maine has been very lucrative in recent years and there is a small scale wild urchin fishery in Massachusetts. The huge demand for urchin roe comes primarily from Japan. Many believe that aquaculture holds great potential for urchin culture. Northeastern University and The Center for Applied Regional Studies received a Fisheries Industry Grant (FIG) in late 1994 to experiment with urchin culture at the Nahant Marine Lab. Initiated by and in collaboration with fishermen in Gloucester, the project will capture and culture urchins for only one to three months, in minimal facilities at sea, in order to increase gonadal content and, thus, ex-vessel value.

Soft Shell Clams (*Mya arenaria*) - Although the market price for soft shell clams is not as high as that for other bivalves, there is increasing interest and technological advancement in the culture of this species perhaps to be used to fund other projects. The primary reason for this is that *Mya arenaria* has a shorter growing period (14 months) than quahogs allowing for a faster and greater return on initial investments. Additionally, the available seed is often free when "steamer tents" are employed to catch a natural set. This scenario could be used to raise initial capital to grow the more valued quahogs. Not only can returns be reinvested more quickly, but "tenting" in effect allows aquaculturalists to use a portion of a grant to fund the purchase of the more reliable but expensive and slower growing quahog seed.

Atlantic clams/surf clams (*Spisula solidissimia*) - Surf clam culture is being experimented with in Maine, CT. and Cape Cod using hatchery seed and hard clam growout technology.

Tautog (*Tautoga onitis*) - Tautog is a native groundfish with white meat which commonly occurs in rocky nearshore waters. Although not cultured commercially at this time, tautog experimentation is occurring at the research level on the Cape.

Striped bass (*Morone saxatilis*), Haddock (*Melanogrammus aeglefinus*), Sea scallops (*Placopecten magellanicus*), Atlantic wolffish (*Anarhichas lupus*), Atlantic cod (*Gadus morhua*), and Atlantic halibut (*Hippoglossus hippoglossus*) are all being cultured in the laboratory in the region and some are beginning to be cultured commercially.

14. SUPPORT SYSTEMS

Hatcheries can be and are used to some degree in Massachusetts to supplement production of fish and shellfish both in the natural environment and for use in aquaculture facilities. Relaying and depuration are two different approaches used in the state for cleansing contaminated shellfish. Neither are presently used for aquacultured shellfish although the possibility exists that they could be.

14.1. Hatcheries

There are several hatcheries in Massachusetts devoted to shellfish production. Although individual variations in diet or equipment may occur, the basic operations are similar.

In the typical hatchery, adult shellfish, selected for broodstock on the basis of desirable attributes such as rapid growth and disease resistance, are conditioned to spawn by being held in trays of circulating seawater at temperatures that stimulate the development of eggs and sperm. During the conditioning period, food in the form of microscopic unicellular algae is added to the seawater. The algal food may consist of several different species that are of proven nutritional value to bivalves and that are maintained in cultures in the hatchery facility.

After the conditioning process, which may last some weeks, the adults are induced to spawn, usually by exposing them to a rapid temperature increase and, if necessary, by adding a suspension of sperm to the holding trays. Eggs that are discharged are collected and thoroughly mixed with sperm to insure fertilization. The fertilized eggs are then transferred to tanks filled with seawater that has been filtered to remove possible predators. The temperature of the water in the larval containers is maintained between 25 - 30 degrees C. The larval density usually ranges from 1,000 to 10,000 per liter (approximately 4,000 - 40,000/gallon of water).

Although hatcheries may vary somewhat in their larval-rearing routine, it is the usual practice to change the water in the larval tanks several times each week. This is accomplished by draining the water from the tanks through fine mesh screens that retain the larvae. The tanks are then cleaned and refilled with warm, filtered seawater to which algal food has been added, and the larvae are returned to the tanks. The duration of the larval period in most hatcheries is between one and two weeks. These methods have been successfully applied to hard clam and oyster larvae in Massachusetts.

Many culturists do not go through the hatchery procedure for oyster seed production; in some areas culturists may rely completely on natural production. For example, on Long Island, NY, areas of natural bottom are dredged to remove oyster predators. Oyster shell is then spread on the bottom during the spawning period to collect seed. After a year of growing in the setting beds, the young oysters are moved to more favorable growing areas, where they grow to maturity. This rather traditional system has worked when conditions are favorable for natural reproduction and when disease and predation can be controlled. In many areas of New England, natural reproduction is too erratic or negligible to provide a reliable basis for culture, making hatchery production an economic necessity.

Aquaculture Research Corp. in Dennis is the state's only commercial shellfish hatchery and produces clam spat for virtually all of Massachusetts' producers.

The Martha's Vineyard Shellfish Group. Five towns on Martha's Vineyard have a cooperative aquaculture agreement for the operation of a non-profit shellfish hatchery which produces seed quahogs, scallops, and oyster spat for distribution to the five Vineyard towns, the Martha's Vineyard Shellfish Group (MVSG). The solar hatchery provides the towns with shellfish seed and uses joint resources for research into improving methods of shellfish propagation. The hatchery has developed its own, genetically-tagged scallops in order to track survival, interbreeding, and population distributions when introduced into the wild shellfish communities. The project also runs public education programs on shellfish enhancement and culture, as well as pollution-abatement programs. The MVSG relies upon support from the state, Dukes County, the towns of Edgartown, Tisbury, Chilmark, Oak Bluffs, and Gay Head, private donations, and the expertise of the local shellfish constables, private aquaculturists, and research facilities at Woods Hole.

The Nantucket Research and Education Foundation is a pilot project for aquaculture training. The program is designed to expand the Town's economic base by enhancing wild shellfish populations through the grow-out of cultured seed and to train fishermen in hatchery techniques, water quality testing and monitoring, and shellfish aquaculture methods.

The Foundation supplies the Town with quahog seed, oyster spat, and eyed larvae and runs a training course in shellfish aquaculture, currently the only one in Massachusetts.

14.2. Shellfish Relaying

Massachusetts, along with most other states with shellfish resources, has vast shellfish beds that cannot be utilized because of contamination. As a result, the practice of relaying: moving contaminated shellfish from restricted areas to clean areas and allowing sufficient time for the shellfish to purge pathogens is monitored by the Massachusetts Division of Marine Fisheries. Shellfish are collected under DMF supervision and re-planted for at least one spawning season (June 15 - September 15). Relaying requirements vary from state to state but must be done according to National Shellfish Sanitation Program guidelines.

Relaying provides several benefits. It allows for the utilization of an otherwise unavailable resource; it works over (cultivates) existing natural beds, usually of benefit to the substrate; it further distributes a local gene pool and may provide some natural spawning enhancement. The most significant benefit may be the depletion of natural stock from polluted areas, which reduces the incentive for illegal harvests. Illegal harvests of contaminated shellfish pose a significant public health hazard.

Relaying is not cheap; careful oversight, testing, and monitoring is required. However, in Massachusetts, it has generally been found that the retail value of relayed shellfish, coupled with the unmet production demands, offsets the costs of relaying.

In Massachusetts relaying has been restricted to municipal propagation and enhancement programs and is generally not regarded as aquaculture. The use of moderately contaminated areas as nurseries and a source of seed for aquaculture has been under consideration for some time, but contaminated shellfish are considered to be a public resource. The relaying of moderately contaminated shellfish from other states has been allowed in the past, but is not presently common. In these circumstances stock must be held for at least 30 days before harvest.

14.3. Depuration Facilities

Depuration is the term applied to the purification of shellfish, harvested from moderately contaminated areas, under controlled conditions. The process generally involves holding the shellfish in tanks of flowing seawater for periods of forty-eight to seventy-two hours. The seawater used is sterilized by ultraviolet light. Shellfish harvested from moderately contaminated areas normally purge themselves of bacterial contaminants within forty-eight hours, but may be held for up to 72 hrs. in some circumstances, after which a decline in quality and shelf life may occur.

Philosophic and practical conflicts surround depuration activities. Like relaying (removing shellfish from moderately contaminated areas and re-planting them in clean substrate), depuration provides the means for utilizing an otherwise unavailable resource. It also represents a way of assuring consumers of a clean and safe product. Depuration is practiced globally: England, France, Spain, and Australia have successfully used it for years with a variety of species. Massachusetts has practiced depuration techniques for over sixty years.

Depuration has been resisted on several fronts. Commercial fishermen fear a loss of economic control over the product. Scientists have retained certain reservations about the process. It has been discovered in soft clams that, if harvested from severely polluted areas; i.e. fecal coliform counts in excess of 88 per 1000 ml, a percentage of the shellfish will fail to purge themselves within the forty-eight to seventy-two hour period. It has also been found that some shellfish, particularly if damaged during harvest, may not siphon during the depuration period at all.

Finally, even if the shellfish can be purged of most of the bacteria contained in their gut, they may not be able to release viruses in their tissues. Others argue that depuration discourages solving the pollution problems which lead to shellfish bed closures. However, given that population models project that by the year 2000 half of the nation's population will be living within the coastal zone, the challenges toward coastal pollution abatement will continue to grow irrespective of practices such as depuration.

Although several eastern states have authorized the operation of depuration facilities by private sector entities (i.e. Virginia and Maine) Massachusetts has no private depuration capacity. The Department of Fisheries, Wildlife, and Environmental Law Enforcement, Division of Marine Fisheries, operates a shellfish depuration facility for soft shelled clams at Plum Island, in Newburyport.

The Massachusetts Plum Island facility is the only depuration operation in the Massachusetts/Rhode Island/New Hampshire area. Only clams harvested from moderately contaminated areas, i.e. with fecal coliform counts ranging between 14 and 88 per 100 ml, are accepted for processing. Any clams brought to the plant by fishermen and found to have fecal coliform concentrations in excess of 1600 per 100 grams of meat prior to treatment are not considered acceptable and are confiscated. This is because many clams having such high initial bacteria counts may fail to purify within the prescribed time period. Clams qualifying for treatment are held in seawater sterilized by ultraviolet light for 24 hours and are again analyzed. Those with fecal coliform concentrations no greater than 500/100 gram sample after the initial 24 hour period may be released for market without further testing after an additional 24 hours of purification. If the initial 24 hour test indicates concentrations higher than 500/100 grams, additional samples from this group are analyzed again after 24 hours. By the end of the total 48 hour treatment, the counts must be less than 230/100 grams. If they are not, the shellfish are retained for further sampling or confiscation. The ultimate objective is to meet the National Shellfish Sanitation Program standard of median concentrations of 50 fecal coliforms/100 grams within a 48 hour period, with no more than 10% of the samples exceeding 130/100 grams.

The Plum Island facility operates year-round and currently processes approximately 50,000 bushels of clams during the year. During its sixty year history, there has been no record of any illness that could be attributed to clams processed at the facility. Shellfish which are depurated at the Plum Island facility are tagged as safe for consumption so as to "certify" their cleanliness for marketing purposes.

Depuration has not proven to be successful in purging shellfish of heavy metals. Although scientific literature suggests that metal depuration is possible, the mechanics of that process have not been adequately addressed. Metal depuration rates vary widely, showing diverse ranges for the same metal within different bivalve species and for different metals within the same species. Laboratory studies have demonstrated that depuration of quahogs of heavy metals was insignificant.

Depuration is not presently used by aquaculturists in Massachusetts but could be under different scenarios. For example, if a shellfish grow-out area became contaminated prior to harvest, an aquaculturist could feasibly bring his harvest to a depuration plant or relay them for cleansing rather than dumping them. Despite warranted concerns, depuration should be evaluated as a potential option while still adequately addressing the public health questions because it makes available to the public natural resources which would otherwise be unutilized.

15. WATER QUALITY

The successful growth, propagation and harvest of aquatic animals, whether freshwater or marine, is heavily dependent uponthe quality of the surrounding water. The presence of toxic chemicals (i.e. metals, petroleum products, etc.), overloading of nutrients (i.e. untreated, partially treated sewage, point source discharges, non-point source discharges), atmospheric deposition (i.e. lead from internal combustion exhaust, acid rain) artificial or uncontrolled temperature variations (i.e. power plant cooling water) and algal decomposition all degrade water quality. Degradation of water quality eventually results in lower concentrations of dissolved oxygen, contamination of fish, shellfish, and substrates with heavy metals, toxic chemicals, and disease-bearing pathogens.

The die-off of indigenous shellfish populations due tocoastal development, shrinking habitats, and pollution through both point- and non-point source discharges, contributes to the descending spiral in water quality. Bivalve filter feeders, such as oysters, clams, quahogs, scallops, and mussels, represent oneof the more efficient, natural, available bio-filtration systems. Filter feeders relative to their size, strain enormous quantities of nutrients and algae from the surrounding water. This process helps to maintain and improve water quality. Once die-off orother forms of population depletion begins, so does an associatedincrease in nutrients and algae and a resulting decrease in water quality.

COASTAL DEVELOPMENT

The effects of coastal development on shellfish-growing areas is indicated by the increasing acreage degraded by anthropogenic pollution sources from 1985 to 1990. Forexample, the largest increases are attributed to urban run-off, impacting 23 to 38 percent of harvestable Massachusetts waters. [Division of Marine Fisheries]. The acreage adversely affected by faulty septic systems increased from 22 percent to 37 percent during the same time period. Pollution from septic systems is associated with continuing residential growth, as well as pressure from the increase in tourism and vacation home development. Also indicative of accelerating pressures from coastal recreation is the increase in waters adversely affected by boating, up from 11 to 18 percent (National Shellfish Register, 1991).

Physical alteration of the coastal environment (dredging and filling; erosion and siltation; damming and/or diversion of streams; constriction of estuary mouths by bridges and causeways; construction of malls, shopping centers and housing developments on the waters' edge) has also had a significant negative impact. Increasing demand for building sites in coastal communities has resulted in destruction of tidal wetlands, an important component of the marine ecosystem that provides a habitat and nutrient source for many species.

Since the late 1950s, disease has taken a heavy toll on shellfish populations already weakened and stressed as the result of degraded water. According to the National

Shellfish Register, "Preliminary findings suggest that the ability of shellfish to withstand such infection is compromised by environmental pollutant stresses."

In Massachusetts, shellfish populations have historically been regarded as a public resource available to all. Under such conditions, municipal and state agencies must manage shellfish with only limited public funds, relying heavily upon nature to sustain or enhance these natural populations.

Dr. David Belding pointed out "In the early days, when thenatural supply was apparently inexhaustible, and practically the entire population resided on or near the seacoast, it was just that all people should have common rights to the shore fisheries. As long as the natural supply was more than sufficient for the demand, no law could have been better adapted for the public good. Now, it is obvious that nature alone cannot be depended upon to sustain these resources."[Profile of the Shellfish Industry in Southeastern Massachusetts, 1930].

SHORT AND LONG-TERM IMPACTS

Acute water quality problems are characterized by sudden,easily recognizable changes in the smell, surface appearance, or turbidity of the water. The most common causes include discharges of chemicals, sudden changes in temperature, the kind of emergency that requires an immediate response; i.e. overturned chemical truck discharging into a receiving stream, an oil spill, etc.

Chronic Water Quality Problems, characterized by low levels of dissolved oxygen, high temperatures, advancing eutrophication, fall-off in indigenous species' populations, are typically caused by frequent, small incidents of water pollution, or "non-point source pollution." The leading probable cause of algal growth, low dissolved oxygen concentrations, salinity and temperature fluctuations, high coliform counts, and resultant lower productivity in coastal shellfish populations are non-point source discharges. [U.S. EPA 1992. The Nation's Water; (OSW No. 24-01-W).

WATER QUALITY IMPACTS ON COASTAL RESOURCE AREAS

Some of the more noticeable effects of degraded water quality are (1) the die-off of eelgrass and other aquatic vegetation, (2) lower levels of dissolved oxygen, (3) contamination of shellfish beds, (4) and the poisoning of fish larvae.

Constant, low-level pollution results in breaking some of the first links in the food chain and killing off organisms upon which small fish feed, thus reducing the quantity of prey available throughout the food chain. Deprived of food and shelter, the populations and species diversity of fish and crustacea decline. Toxic chemicals accumulate, diseases and abnormalities increase. These consequences move up the food chain with more fish, shellfish, birds, and mammals dying or failing to reproduce. These phenomena are not limited to near-shore areas. Many off-shore species spend a portion of their lifetime in the near-shore environment, or depend upon food produced by coastal systems.

Loss of commercial and recreational shellfish catches because of shellfish bed closures due to high coliform counts are directly correlated with human-generated, point source and non- point source discharges. Poorly flushed embayments are particularly susceptible to pollution of shellfish beds. Areas with combined sewer overflows (CSOs) or a high level of recreational boating are also likely to be closed to shellfishing, at least conditionally for portions of the year [Division of Marine Fisheries].

SHELLFISH HABITAT

Quahogs (*Mercenaria mercenaria*), oysters (*Crassostrea virginica*), bay scallops (*Argopecten irradians*), soft shelled clams (*Mya arenaria*), surf clams (*Spisula solidissima*), and blue mussels (*Mytilus edulis*) are culturally and economically the most important species in Massachusetts. The most prolific beds,whether wild or cultured, tend to be established in coves, bays, and similar areas where fresh water flows dilute the seawater, tidal action is regular, there is a constant supply of food, and protection is afforded from storms and surges. These beds are subject to greater risk from bacterial or chemical contamination and consequent degradation due to their proximity to human settlements.

Tidal flats also provide a home to many of the cultivated species in Massachusetts. These are shallow, sloping areas composed of materials ranging from very fine silt and clay to coarse sands. Microscopic algae provide nourishment for tidal flat life, including quahogs, soft-shelled clams, and polycheate worms. It is the combination of salinity, substrate quality, and the character of water movement over the flats that determines the species composition of the plant and animal communities. (Carlozzi, et al. 1975). Contaminants (i.e. TBT anti-fouling bottom paints used on boats) carried to the flats can be taken up by the microscopic algae and worms living in the flat, accumulate in the substrate, accelerate algal growth, lower the dissolved oxygen available, change total salinity, and in turn, impact the shellfish populations by directly killing them or their food sources, or by contaminating them.

PATHOGEN CONTAMINATION

Measurement of fecal coliform is used as an indicator of the possible presence of disease-causing bacteria and viruses. For example, gastroenteritis, hepatitis, and polio are associated with human waste-borne viruses. Shellfishing is prohibited when concentrations reach 14 fecal coliforms per 100 milliliters. Thousands of acres of productive shellfish beds, representing millions of dollars, have been closed to harvesting in recent years because of potential pathogen contamination. Between 1970 and 1990, closed acreage increased by nearly 300% in Massachusetts and Cape Cod Bays. On Cape Cod, over 550 acres are currently closed, a 90% increase from 1980. Closures on the North and South Shores have also been on the rise.

Currently, there are over 7400 acres closed to harvesting on the South Shore, and 56,000 on the North Shore. (Buzzards Bay Project, 1990).

Statewide, out of an approximate 1,800,000 acres of waters under state jurisdiction, 67% (1,199,537) are classified as approved (for direct consumption), 5% (88,887) are classified as prohibited (no harvest of any kind), 28% (498,705) are closed because they are unclassified (lack of sanitary survey) and less than 1% (454 or 1416) are classified as Restricted (harvest with depuration). Unclassified areas are not polluted, but rather areas which have not been surveyed mainly due to lack of shellfish habitat. (Division of Marine Fisheries, 1994)

Shellfish that are not directly killed by the discharge of toxics may take them up, either through exposure to contaminated substrates or through feeding. Many shellfish species have the capacity to bioaccumulate toxics to levels that may kill or damage an organism higher up on the food chain.

For a complete description of public health concerns and shellfish contamination, see Chapter Seventeen, Seafood Safety.

WATER QUALITY STANDARDS

The Federal Water Pollution Control Act, 33 U.S.C. Section 1251 et seq. and the Massachusetts Clean Waters Act, Massachusetts General Law Chapter 21 Sections 26 - 53, require the development and update of water quality standards to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Massachusetts defines "water quality standards" as the criteria necessary to sustain particular uses of various water bodies, as well as to upgrade the water for prospective, designated uses. Water quality standards are developed and evaluated by the Massachusetts Department of Environmental Protection, Division of Water Pollution Control.

314 CMR 4.00: Surface Water Quality Standards, classifies all of the waters of Massachusetts, inland and coastal, into categories based upon the present condition of the water, prescribes minimal water quality criteria to maintain present water quality, and prescribes "antidegradation" requirements to upgrade water quality.

Categories

The regulations divide surface water into Classes in order to maintain or upgrade the uses available when classified; i.e. drinking water, recreation, etc. For coastal and marine waters, the classifications are as follows (314 CMR 4.03):

Class SA - waters designated for the uses of protection and propagation of fish, other aquatic life and wildlife; for primary and secondary contact recreation; and for shellfish harvesting without depuration in approved areas.

Class SB - waters designated for the uses of protection and propagation of fish, other aquatic life and wildlife; for primary and secondary contact recreation; and for shellfish harvesting with depuration (Restricted Shellfish Areas).

Class SC - waters designated for the protection and propagation of fish, other aquatic life and wildlife, and secondary contact recreation.

Parameters and Criteria for Evaluation

The criteria applied to evaluate and classify coastal and marine surface water are (314 CMR 4.03): overall aesthetics, presence and amounts of radioactive substances, presence and amounts of tainting substances, color, turbidity, amount of total suspended solids, presence and amounts of oil and grease, presence and amounts of nutrients, presence and amounts of other constituents, amount of dissolved oxygen, temperature increase, pH level, amount of total coliform bacteria, and amount of fecal coliform bacteria.

Antidegradation

The regulations require that the present quality of surface water be maintained and protected from degradation. To accomplish this, the following requirements are included at 314 CMR 4.04:

(1) Protection of Existing Uses. In all cases, from and after the date these regulations become effective, the quality of the surface waters shall be maintained and protected to sustain existing beneficial uses.

(2) Protection of High Quality Waters. From and after the date these regulations become effective, waters designated by the Division in 314 CMR 4.05(5) whose quality is or becomes consistently higher than that quality necessary to sustain the national goal uses shall be maintained at that higher level of quality unless limited degradation is authorized by the Division.

(3) Protection of Low Flow Waters. Certain waters will be designated...for protection under 314 CMR 4.04 due to their inability to accept pollutant discharges. New or increased discharges of pollutants to waters so designated are prohibited unless a variance is granted by the Division...

(4) National Resource Waters. Waters which constitute an outstanding national resource...shall be preserved. These waters shall be designated for preservation by the Division.... Waters so designated may not be degraded and are not subject to a variance procedure. Existing discharges shall be eliminated unless the discharger is able to demonstrate that:

(a) Alternative means of disposal are not reasonably available or feasible; and

(b) The discharge will not affect the quality of the water as a national resource.

(5) Control of Eutrophication. The discharge of nutrients,primarily phosphorus or nitrogen, to surface waters will be limited or prohibited... as necessary to prevent excessive eutrophication of such waters... . Existing discharges containing nutrients which encourage eutrophication or growth of weeds or algae shall be treated. Activities which may result in non-point source discharges of nutrients shall be conducted in accordance with the best management practices reasonably determined by the Division to be necessary to preclude or minimize such discharges of nutrients.

16. LEGAL/REGULATORY

The utilization of public and private resources in the coastal zone lies at the bottom of a complex, often confusing mix of federal, state, and local requirements and rules governing aquaculture.

There are several federal, state, and local determinations, permits and/or licenses required to engage in coastal aquaculture. The number of agencies and governments involved, and the corollary amount of paperwork required, will vary with the type of aquacultural activity proposed. The system is a three-tiered one (local, state and federal), reflecting the policy positions, general conditions, and specific local requirements for engaging in aquaculture.

For example, local cities and towns are concerned about managing conflicting land and water uses, such as recreational beach use, areas set aside for recreational boating, coastal development, and public access. Local conservation commissions are concerned about natural resource protection, as they must implement the state Wetlands Protection Act. In addition, local economic conditions are significant factors in the determinations of coastal cities and towns when considering the licensing of particular areas for shellfish grants. In Massachusetts, local authorities with a hand in coastal aquaculture include boards of selectmen/ mayors, conservation commissions, shellfish officers, and harbormasters.

The Commonwealth of Massachusetts has additional concerns. Protection, maintenance, and enhancement of the state coastal zone, coastal wetlands, endangered species, ocean sanctuaries and areas of critical environmental concern (ACEC) are all state priorities. Of similar concern is the protection of local species and water quality. The licenses and permits applicable to aquaculture in Massachusetts, including surface water discharge permits, water quality certifications, waterways licenses, state aquaculture permits, reflect the state agenda. In Massachusetts, the agencies relevant to coastal aquaculture are the Executive Office of Environmental Affairs/Coastal Zone Management, the Department of Fisheries, Wildlife, and Environmental Law Enforcement/Division of Marine Fisheries, the Department of Environmental Protection, Department of Environmental Management, Division of Wetlands and Waterways, and the Department of Food and Agriculture.

The federal government, through the U.S. Army Corps of Engineers, the Coast Guard, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service and the U.S. Environmental Protection Agency, implements a broad national agenda: the assurance that United States navigational routes are maintained, that marine mammals and endangered species (and their habitats) are protected, that waters of the United States are not degraded. The permit and review programs that have application to coastal aquaculture, including the National Environmental Policy Act, the Rivers and Harbors Act of 1899, the Clean Water Act, and the

National Pollution Discharge Elimination System permits, protect and advance these policies.

The following overview provides a broad look at the three tiers governing coastal aquaculture.

16.1. Local Permits

Local Issuance of Section 57 Shellfish Licenses

Shellfish licenses are issued by coastal cities and towns under the authority of Massachusetts General Law Chapter 130, Section 57, for a period of ten (10) years, with a right to request renewal. A shellfish license authorizes a named individual a) to plant and grow shellfish, whether bottom or water column culture; b) to place shellfish in or under protective devices affixed directly to the tidal flats or land under coastal waters, such as boxes, trays, pens, bags, or nets; c) to harvest and take legal shellfish; d) to plant cultch for the purpose of catching shellfish seeds; and e) to grow shellfish by means of racks, rafts, or floats.

Section 57 was amended on July, 10 1994 to eliminate the distinction between bottom culture and water column licenses (previously issued under Section 68A); all licenses for shellfish aquaculture will now be issued under the procedures found in Section 57.

In order to obtain a license, an application under Section 57 must be submitted to the municipality. The exact form of a licensing application and the amount of fees payable vary to some extent among municipalities. The Massachusetts Division of Marine Fisheries (DMF) must certify that issuance of the license will have no adverse effect on the shellfish or other natural resources of the town. This is accomplished by conducting an inventory of existing resources by a DMF biologist at the site. The survey will consist of a description of the total size of the proposed area to be licensed, the sediment composition of the proposed area, the number of transects used for sampling of naturally-occurring shellfish, the method used to conduct the sampling, and the number, species, and size of naturally-occurring shellfish found in the sampling area. DMF must also examine the public record to consider other issues raised, which may include other fisheries, endangered species, eelgrass, etc. If DMF concludes that "no adverse effect" will occur, the area will be certified by DMF.

Issuance of the license does not convey any property rights to the aquaculturist. While Massachusetts honors the public trust rights of fishing, fowling, and navigation in the intertidal zone, it is one of the few states in which private property extends to the low water mark. The Massachusetts Supreme Judicial Court has recently ruled, in Pazolt v. Director of the Division of Marine Fisheries, et al., (April 20, 1994) that aquaculture (generally placing structures, such as nursery trays or boxes) is not part of the public trust right of fishing and, therefore, aquaculturists must obtain permission from the private upland property owner in order to practice aquaculture in the intertidal zone.

Local Administration - Massachusetts Wetlands Protection Act

Massachusetts General Law Chapter 131, Section 40, the Wetlands Protection Act (WPA), requires anyone who intends to "remove, fill, dredge, or alter" any coastal resource area, including wetlands, beaches, flats, dunes, land under the ocean, and land subject to tidal action or coastal storm flowage, to file an application called a Notice of Intent with the local conservation commission and receive a permit, called an Order of Conditions, before proceeding.

While some projects for the "normal maintenance or improvement of land in ... aquaculture use" may be exempt from WPA restrictions, the local conservation commission must make this determination. Therefore, all aquacultural activities with a potential impact on resources protected by the WPA must file a Notice of Intent with the conservation commission.

Since conservation commission jurisdiction extends to the limits of offshore municipal jurisdiction (3 miles), any shellfish or finfish operation within that area which impacts land under the ocean is subject to conservation commission review. The placement of nursery trays and boxes for shellfish cultivation typically qualifies as a regulated activity under the WPA. In addition, access (particularly vehicular access) to and from the aquaculture operation may also require the filing of a Notice of Intent if the activity will impact or occur within 100 feet of a wetland resource areas (the buffer zone), such as dunes, banks or beaches.

An applicant who is unsure of the conservation commission's jurisdiction may file a "Request for Determination of Applicability" with the commission for a relatively quick ruling as to whether a full Notice of Intent will be required.

The wetland regulations (310 CMR 10.00) provide all necessary forms. The applicant may also obtain forms from the local conservation commission. Upon submission of a completed Notice of Intent, including a description of the proposed work, resource areas, plans, and payment of a filing fee, the conservation commission will conduct a hearing on the Notice of Intent and either issue the applicant an Order of Conditions authorizing the aquacultural activity and setting forth specific terms and conditions under which the activity (i.e. placement of clean sand) shall be conducted; or deny the application if it cannot be conditioned to protect the interests of the wetlands act.

Appeals, called "Requests for Superseding Orders of Conditions," may be taken to the regional office of the Department of Environmental Protection (DEP).

A number of communities also have their own wetlands protection bylaws that may require additional permits for aquaculture operations in wetland zoning districts. If the project is sited in a local wetland district, a separate application must be filed with the town zoning enforcement officer (usually the building inspector or planning board) according to the procedures of the local zoning ordinance.

16.2. State Pemits

Marine Fisheries

General Law Chapter 130 provides the primary authority for regulation of activities concerning or affecting aquaculture in Massachusetts. The statute is broadly drawn and includes provisions for state agency authority and oversight of coastal and marine fishing, licensing and permitting, coastal pollution, riparian rights, reporting requirements, specific coastal and marine species, commercial and business activities, wetlands protection, and shellfish activities. The Chapter also vests the authority to promulgate rules and regulations for its implementation in the Division of Marine Fisheries (DMF) within the Department of Fisheries, Wildlife, and Environmental Law Enforcement.

Section 57 of Chapter 130, governing the licensing of shellfish areas for aquaculture, is discussed in the paragraphs above on local permits. Additional sections of Chapter 130 that may be of interest to the coastal aquaculturist include Section 17B aquacultural enterprise permits. Application may be made to the DMF for a permit to possess, take, or harvest any fish out of season and outside of the size limitations if it is (1) for use in aquaculture, and (2) kept separate from natural stock of the same species. This permit would not apply where shellfish seed is re-planted on flats and not held separately from whatever limited natural stock might exist, but is applicable to the sale of seed shellfish.

In addition, DMF issues Section 69 Permits (under the authority of 322 CMR 7.01, 3.03) for possessing or importing seed quahogs, clams, oysters, and scallops.

The Massachusetts Waterways Licensing Statute

Massachusetts General Law Chapter 91 protects and manages Massachusetts tidelands and waterways promoting a balance among the many competing public and private uses of the coast. Specific circumstances, provisions, obligations, and requirements are articulated in the regulations promulgated under c. 91 at 310 CMR 9.00 et seq.: Administration of Waterways Licenses.

Chapter 91 also protects the public's property rights in coastal (as well as in many inland) waterways. Below the low water mark in tidal areas, the state owns all land and water outright, while in the intertidal zone, the public has an easement to enter for the purposes of fishing, fowling, navigation, and free passage. The Commonwealth also owns the state's Great Ponds, and protects the public right of navigation on most inland rivers and streams.

In addition to direct ownership rights, the Commonwealth regulates and licenses water-dependent uses such as maritime commerce and transportation, fishing (including shellfishing), recreational boating and swimming, and other activities which enable the public to use and enjoy the waterfront.

Certain aquaculture activities, including bottom, off-bottom culture and fish farms could be required to submit applications for waterways permits or licenses.

Permits under Chapter 91 must be obtained from the local harbormaster for the placement on a temporary basis of moorings, floats or rafts held by bottom-anchor. If the aquaculture activity fits this description, no additional permit is needed from DEP under Chapter 91.

A Chapter 91 license is required for fill or structures in tidelands; the definition of "structure" includes any weir, boom, breakwater, line, or wire, plus any pile-held or permanently fixed float or aquaculture gear. Structure does not include any mooring, float or raft which has received an annual permit from the harbormaster, nor does it include any weir, pound net, or fish trap that has been approved by DMF.

If a license is required, the applicant must provided detailed information on the project, including plans prepared by a registered professional engineer or a land surveyor; must pay occupation and tidewater displacement fees; and must comply with all substantive standards for environmental protection, water-related public rights (navigation, fishing, fowling, free passage), protection of existing water dependent uses, and engineering and construction standards. If the project is located in an Ocean Sanctuary, the applicant must demonstrate during the Chapter 91 process, that the project meets the "public necessity and convenience" requirement of the Ocean Sanctuary Act. Once approved, the applicant is given a long-term, recordable license for exclusive use of the area.

The Massachusetts Environmental Policy Act

Prior to the issuance of many state permits, the requirements of the Massachusetts Environmental Policy Act, General Law Chapter 30, Sections 61-62H, (MEPA), must be satisfied. MEPA is administered by the Executive Office of Environmental Affairs, MEPA Unit, with regulations at 301 CMR 11.00. MEPA requires the state to review, for environmental impacts many direct state activities, plus many projects that use state funding, or projects that require issuance of a state permit or license. The need for review is typically triggered by the size of the project and type of state activity (permitting, funding, etc.) involved; specific thresholds are listed in the regulations and should be consulted for each proposed project. A request for a determination can be made to MEPA to conclude whether or not the specified project surpasses MEPA thresholds and requires further review. Aquaculture projects are likely not to require MEPA review unless the site is located in an ACEC and the project action is appealed to DEP. Other examples of MEPA thresholds that may be of concern to the coastal aquaculturist include:

* any project resulting in the dredging, filling, alteration or removal of one or more acres of bordering vegetated wetland or salt marsh, or ten or more acres of any other resource area protected by the wetlands regulations;

* any project needing a Superseding Order of Conditions from the DEP that includes: any fill or structure within a regulatory floodway of rivers or streams delineated under the National Flood Insurance Program; alteration of a primary dune; construction in a velocity zone on a barrier beach; new, expanded, or reconstructed armoring of a coastal bank; the alteration of 1,000 square feet or more of salt marsh, or 5,000 square feet or more of bordering vegetated wetland, or 500 feet or more of bank, or 1/2 acre or more of any other area subject to the wetlands protection act;

* licensing under Chapter 91 of any solid fill structure of 1,000 square feet or more base area, or pile-supported structures of 2,000 square feet or more; and

* any project located in an area of critical environmental concern that needs a state permit or license listed in the thresholds (301 CMR 11.26).

If a listed threshold is met, an Environmental Notification Form (ENF) must be filed, describing the proposed project, the potential for environmental impacts, and the alternatives available that would avoid or minimize damage to the environment. The Executive Office of Environmental Affairs, through its MEPA Unit, will publish and review the ENF in the Environmental Monitor, hold a meeting with state and local agencies, and the public, to identify environmental issues, review any written comments received about the ENF and make a determination about whether further environmental information in the form of an Environmental Impact Report (EIR) is required.

If no EIR is required, there is no further obligation under MEPA and the appropriate state permits may be issued. If an EIR is determined to be necessary, the applicant will have to file the EIR, describing in detail the proposed project, alternatives to the proposed project, a description of the existing environment, an analysis of environmental impacts and the mitigation measure(s) that may be employed to avoid, or if not possible, to minimize negative impacts. The EIR, as was the ENF, will be published and reviewed by the public, state, local agencies and MEPA. Once the Final EIR has been reviewed and certified as complete, the permitting agencies are free to act on the project; each permitting decision must contain a finding (called a Section 61 finding) that all feasible measures have been taken to avoid or minimize damage to the environment.

Surface Water Quality Discharge Program

The Massachusetts Clean Water Act, General Law Chapter 21 Sections 26 - 53, establishes a management structure for the protection and maintenance of the quality of the waters of the Commonwealth.

Section 43 of the Act establishes a program, implemented through the regulations promulgated at 314 CMR 3.00: Surface Water Discharge Permit Program, regulating the discharge of pollutants into the waters of the Commonwealth. These permits are issued jointly with EPA's National Pollution Discharge Elimination System (NPDES) permits described below.

Any activity resulting in a discharge into Commonwealth waters may be subject to the requirements of the surface water permit program and an anti-degradation demonstration. As an example, an aquaculturist establishing a shellfish hatchery might utilize one influent line and one effluent line. Whatever is discharged from the effluent line, such as circulating water, water used to carry nutrients and wastes from seed trays, etc., would be subject to the effluent limits established under the NPDES permit.

Other Permits or Requirements

The above permits and licenses are generally required of all aquaculture projects located in state waters. Other state agencies may review many aquaculture proposals via MEPA and ACOE interagency reviews. For example, the Department of Environmental Management reviews MEPA, Chapter 91 and ACOE applications with an eye for projects located in Massachusetts Ocean Sanctuaries (generally speaking, all state waters (below mean low water) with the exception of the area between Lynn and Marshfield. The Ocean Sanctuaries Act derives its authority under Massachusetts General Laws, Chapter 132 A, Sections 13-16 and 18 and regulations 302 CMR 5.00. This Act is designed to protect coastal waters by prohibiting activities that could be environmentally or aesthetically damaging. To date, DEM has not taken jurisdiction over any aquaculture project.

STATE CERTIFICATION OF FEDERAL PERMITS OR LICENSES

Water Quality Certification

Section 401 of the federal Clean Water Act (33 U.S.C. 1344), requires states to certify that federal actions, such as the issuance of federal permits or licenses that allow discharges to state waters, comply with state water quality standards. Typically, DEP issues a water quality certification for 1) point-source discharges allowed by federal

NPDES permits; and 2) the discharge of dredged or fill materials allowed under federal Section 404 or Section 10 permits. These federal programs are discussed more fully below. DEP is in the process of promulgating new regulations for the 401 program that are compatible with the Army Corps of Engineers Programmatic General Permit (also discussed below). Aquaculture projects that meet certain criteria identified in the new regulations will not need individual water quality certification.

Massachusetts Coastal Zone Management Federal Consistency Certification

Similarly, the Massachusetts Coastal Zone Management Office must certify federal actions, including the issuance of licenses and permits, to ensure they are consistent with the state Coastal Zone Management Program. The Massachusetts Coastal Zone Management Program contains 27 broad policies that can be found in 301 CMR 20.00. These policies provide the state with an important tool, as they are often the only state standards and review applicable to aquaculture operations in federal waters (i.e. any project beyond the 3 mile limit or the bay closure lines). Federal permits relating to aquaculture which could trigger the Consistency requirement include ACOE Section 10/404 permits, New England Fisheries Management Council actions and NPDES permits.

16.3. Federal Permits

Permits For Dredged or Fill Materials and Permits For Affecting or Obstructing Navigation

Section 404 of the federal Clean Water Act (33 U.S.C. 1344), requires a permit for the discharge of dredged or fill material into the navigable waters at specified disposal sites.

Section 10 of the Rivers and Harbors Act of 1899 requires a permit for any activity affecting or obstructing navigable waters.

On August 24, 1993, the Army Corps of Engineers issued a Programmatic General Permit (PGP) to administer both of these programs in Massachusetts. The PGP will be in effect for five years before being reevaluated.

The PGP provides a simplified review process for minimal-impact projects that fall within the Corps' permitting jurisdiction. Most shellfish aquaculture activities will fall under "Category II - Screened PGP" activities. Category II Projects will be screened by the Corps of Engineers and the federal resource agencies (Environmental Protection Agency, U.S. Fish and Wildlife Service, and National Marine Fisheries Service) for a case-by-case determination of the applicability under this general permit.

Substantively, the Corps will look to its previously issued "Letter of Permission" for guidance in determining whether to issue the PGP or to require an individual permit for shellfish operations. The Letter of Permission (dated August 21, 1991) established information requirements (i.e. the proposed work, the location of the proposed license, a description of fill activities (importation of clean sand for nursery trays and subsequent discharge of naturally-occurring dredged sand to the surrounding substrate) and a description of the natural resources and bottom sediments in the grant) and a series of universal conditions that must be satisfied by an applicant.

In order for an aquaculture applicant to receive a PGP, all other state and local permitting conditions must be satisfied; i.e. Order of Conditions, a Section 57 license, Chapter 91 permit, etc. For these projects, applicants should submit a permit application to the Corps; applicants filing a Notice of Intent (NOI) with their local Conservation Commission should submit a copy of their NOI materials to the Corps at the same time they apply to their Commission, along with additional information concerning the work within Corps jurisdiction.

Screened projects may not proceed until written notification is received by the ACOE and the applicable certifications or waivers concerning water quality and coastal zone management are received by the applicant.

National Pollution Discharge Elimination System Permit

Section 402 of the federal Clean Water Act, (33 U.S.C. 1342) requires a permit for any activity resulting in the discharge of any pollutant, or combination of pollutants into navigable waters. These permits, called NDPES permits, are issued jointly with the state. As an example, an aquaculturist establishing a shellfish hatchery might utilize one influent line and one effluent line. Whatever is discharged from the effluent line, such as circulating water, water used to carry nutrients and wastes from seed trays, etc., would be subject to the effluent limits established under the NPDES permit.

National Environmental Policy Act

In some cases, particularly for large projects or those expected to have significant environmental impacts, the requirements of the National Environmental Policy Act, 42 U.S.C. 4321, (NEPA) may need to be satisfied. The burden is on the federal agency proposing the action (such as permit or license issuance) to identify environmental impacts, to avoid and minimize those impacts, and to explore alternatives that may be less environmentally damaging. An environmental assessment, or if the project is significant and controversial, an Environmental Impact Statement (EIS) is prepared by the permitting agency.

The New England Fisheries Management Council (NEFMC)

Aquaculture projects located in federal waters could be required to obtain an authorization from the NEFMC to site facilities. No precedent exists for this type of authorization off of Massachusetts state waters although a proposal for sea scallop aquaculture is now before the Council.

17. SEAFOOD SAFETY/PUBLIC HEALTH

Public health issues surrounding the quality and safety of wild and cultured shellfish have been a source of general concern throughout the industry. Much negative information and publicity, especially concerning water pollution and contaminated shellfish areas, has increased public awareness about the potential dangers of eating shellfish, particularly shellfish that has not been adequately stored or cooked. As discussed earlier, bivalve mollusks are filter feeders, straining particulate food from surrounding water (and absorbing elements through substrate). The particulates are caught on the gill surfaces and are transported to the digestive tract. Because of their ability to filter significant quantities of water in relation to their size and the ability to retain microorganisms in the size range of bacteria and viruses, shellfish may ingest and concentrate undesirable pathogens, as well as toxic pollutants and heavy metals, during the filtering process. Some bivalves are so efficient that they may concentrate and/or exceed 1000 times the ambient contaminant concentration. (Chang, 1991) Many of these pathogens may have little effect upon the shellfish, but could be devastating to a consumer.

HISTORY

It has been known for years that shellfish harvested from polluted areas can cause illness, particularly if eaten undercooked or raw. Toxins such as pesticides, hydrocarbons, heavy metals, radioisotopes, and marine biotoxins all may be successfully concentrated by shellfish. The major public health concern historically however, has been with the pathogenic bacteria like Salmonellae and viruses capable of causing hepatitis-a, gastroenteritis, and polio.

PATHOGENS

Fecal coliform bacteria, which lives in the intestines of warm-blooded animals, has traditionally been used as an indicator of sewage pollution. Evidence of fecal contamination in turn, indicates at least the potential presence of pathogens. Therefore, classification of shellfishing is based upon the concentration of fecal coliform bacteria in overlying waters.

According to the National Shellfish Sanitation Program, shellfish growing areas may be approved if, on the basis of fifteen sets of samples taken under adverse pollution conditions as described by the sanitary survey, they meet the following criteria:

1) the median number of total coliform bacteria in the water does not exceed 70 per 100 ml of water sampled, and not more than 10 percent of the samples have a count in excess of 230 per 100 ml, or

2) the median number of fecal coliform bacteria - bacteria associated with the feces of warm-blooded animals - do not exceed 14 per 100 ml, and not more than 10 percent of the samples have a count in excess of 43 per 100 ml.

The methodology is not by any means foolproof. There are problems associated with the use of total coliforms or fecal coliforms being relied upon as the indicators of the level of sewage contamination. The actual degree of risk of infection posed by human pathogens is also uncertain. Coliform counts may mislead, as follows:

1) sewage treatment plants generally use chlorine to sterilize effluent. Although chlorine does reduce bacterial contamination, it may have little effect upon virus populations. In that circumstance, the lack of coliform bacteria in a sample may not indicate the absence of viruses;

2) *Escherichia coli* (primary fecal coliform component) has a lower survival rate in seawater than other organisms, including viruses. Therefore, concentrations of *E. coli* may lead to an underestimate about the risk of other pathogens;

3) *E. coli* in seawater may assume other, non-detectible forms, resulting in false (low) numbers of indicators reported;

4) there are many pathogens that flourish in water that are not associated with fecal contamination and may not be tested for or detected.

NATURALLY OCCURRING PATHOGENS

Vibrio

Concern has been expressed that fish farms could lead to increased numbers of bacteria that cause disease in humans. Sedimentation and organic-loading of finfish waste products could result in uptake, accumulation, and transmission of human pathogens through vectoring shellfish. These concerns have been directed specifically towards the bacteria genus *Vibrio*, since the genus is common in marine systems and includes fish, shellfish, and human pathogens.

The genus *Vibrio* contains approximately 20 species. Five of the species, *V. cholorae*, *V. parahaemolyticus*, *V. vulnificus*, *V. alginolyticus*, and *V. mimicus*, are known human pathogens, and the pathogenicity of two other species, *V. fluvialis* and *V. metschnikovii*, is unclear. *V. anguillarum* and *V. ordalii* infect salmonids, but there is no evidence to suggest that these species are human pathogens.

In humans, *Vibrio* infections most frequently cause gastroenteritis. The clinical symptoms include diarrhea, abdominal cramps, nausea, and vomiting. The disease is normally mild to moderate in severity, and symptoms typically persist for a few days. Exposure to *Vibrio* suspended in seawater can also cause earaches and wound infections. Primary sepsis, caused by *V. vulnificus*, is the most serious of the *Vibrio* diseases. Infection occurs most frequently in persons with chronic liver disease. The *V. vulnificus* infection causes fever, chills, and nausea, and results in death in about one half of the cases. (NSSP Operations Manual, 1992 Revision).

Vibrio bacteria, including pathogenic and nonpathogenic species, are common members of the microbial community in estuarine environments throughout the world. They play significant roles in nutrient recycling and are probably the principle bacterial group responsible for the mineralization of refractory organic materials like chitin. (Cabrizzi, 1990)

The fact that potentially pathogenic *Vibrio* species are widespread but the incidence of infection is relatively low is probably attributable to three factors. First, not all strains of a pathogenic species are virulent. Second, many pathogenic *Vibrios* require water temperatures above 15 degrees C. Finally, the incidence of *Vibrio* infection is minimized by cooking seafood and killing the bacteria. *Vibrio* infections are contracted by eating raw seafood, inadequately cooked seafood, or cooked seafood which is subsequently left in contact with raw seafood.

Concerns that aquaculture could lead to increased incidence of *Vibrio* infections are based on two facts. First, *Vibrio* suspensions have been found in greatest abundance in areas characterized by high inputs of organic matter and/or particulate material. Such conditions may exist in the vicinity of fish farms. Second, filter-feeding mollusks concentrate bacteria through normal feeding activities. Thus, there is a potential route for human infection if a fish farm promotes increased Vibrio suspensions in the vicinity of harvestable shellfish. Shellfish in these circumstances could not be harvested for direct human consumption.

There is no current evidence to conclude that fish farms contribute to the proliferation of bacteria species and strains pathogenic to humans.

NATURALLY OCCURRING BIOTOXINS

Shellfish contaminants can take the form of naturally- occurring toxins, such as certain phytoplanktons that tend to bioaccumulate in warm weather, microbiological contamination where the shellfish acts as a vector for disease transport to humans, and bioaccumulation of toxics, such as heavy metals and polycyclic aromatic hydrocarbons (PAHs).

Paralytic Shellfish Poisoning (PSP)

Quahogs, soft shell clams, oysters, and mussels may act as transmission vectors for paralytic shellfish poison (PSP) to humans. PSP results from the ingestion of saxitoxin, an extremely potent toxin produced by the dinoflagellate *Alexandrium tamarensis*.

Anyone who has lived in a coastal area has experienced the phenomenon known as "red tide." Under certain conditions; high water temperatures, calm seas, low salinity, and high-nutrient content, certain naturally occurring plankton will experience population explosions, resulting in tremendous quantities of planktonic organisms reproducing at a massive rate in a very short period of time. It should be noted that all such population explosions may not be toxic and may not discolor sea water; this is dependent upon the kind of organism experiencing the rapid growth, or "bloom." Toxic red tides on the east coast are primarily caused by the dinoflagellate *Alexandrium tamarensis*. Shellfish ingest this organism and accumulate toxins in their bodies. This accumulation has no ill effect on the health of the shellfish directly, but if consumed by humans, can result in PSP. This toxin is particularly dangerous because it will not be eliminated by cooking and does not change the appearance of a contaminated mollusk. (Northeastern Marine Advisory Council, 1987)

PSP acts quickly. The onset of symptoms will usually occur within thirty minutes of ingestion, causing tingling in the lips, face, neck, and extremities. This is followed by headache, dizziness, nausea, and occasionally vertigo. In cases of severe poisoning, muscular paralysis and respiratory failure may occur, which can be fatal.

All shellfish-producing states have monitoring programs for PSP. In Massachusetts, the Department of Fisheries, Wildlife and Environmental Law Enforcement maintains a testing and monitoring program. DMF, with laboratory assistance from DEP, conducts a monitoring program in shellfish growing areas while DPH monitors shellfish in the marketplace. In the event that tolerance levels for saxitoxin are exceeded in tested shellfish or shellfish growing areas, the shellfish are seized and destroyed, the growing areas are posted and closed, and local cities and towns are notified.

THE NATIONAL SHELLFISH SANITATION PROGRAM

In 1925, the National Shellfish Sanitation Program ("NSSP") was created, the result of a cooperative effort between the shellfish industry, the U.S. Public Health Service (now the Food and Drug Administration) and cooperating states. The goal of the program was to design uniform standards, applied to all participating states, for the maintenance and oversight of shellfish sanitation in growing areas, in harvesting, and in processing. Uniformity was critical; all participating states embraced the same standards to assure consumers of a uniformly healthful product and to eliminate any competitive advantage a state could obtain by not adhering to the same sanitary requirements. Participation in the program is not mandated by law, but a state who does not participate cannot engage in interstate shipment or distribution of shellfish.

The basic obligations of all participating states are as follows:

1. All states shipping shellfish have to adopt adequate laws and regulations for the sanitary control of the industry; complete and maintain sanitary surveys of growing areas, delineate and patrol restricted areas, inspect shellfish plants and laboratories, and implement measures to insure that all shellfish reaching consumers have been grown, harvested, and processed in a sanitary manner. The state agrees to issue numbered certificates to shellfish dealers complying with the sanitary standards and copies of the certificates are then forwarded to the Food and Drug Administration ("FDA").

2. The FDA makes an annual inspection of each state shellfish control program, including the inspection of a representative number of shellfish processing plants. Based upon this information, the FDA determines the degree of conformity the State program has with the NSSP. Based upon this information, a monthly list is generated of the valid interstate shellfish shipping certificates.

3. The private sector has adopted and augmented this management structure and created its own, additional sanitary standards, including tracking mechanisms to record the shipping and final disposition of the shellfish.

In 1982, the NSSP created an organizational structure utilizing the expertise of shellfish control officers, the FDA, cooperating state representatives, and industry officials; the Interstate Shellfish Sanitation Conference ("ISSC"). The ISSC adopted the NSSP Operations Manual in 1983, as well as a process to revise and amend the provisions of the manual.

In 1983, the ISSC adopted the NSSP Operations Manual as the formal statement of standards for shellfish sanitation. In 1984, the FDA entered into a Memorandum of Understanding with the ISSC as the basis for a continuing, cooperative relationship between the states, private industry, and the federal government.

In 1985, the NSSP Manual was formally codified by the FDA and published as regulations in the Federal Register (50 FR 7797, February 26, 1985).

The NSSP Manual is divided into two parts, reflecting the awareness that the growing and processing of shellfish are two distinct processes. Part I: Sanitation of Shellfish Growing Areas is a guide for preparing state shellfish laws and regulations pertaining to the sanitary control of shellfish growing area classification, laboratory procedures, relaying, patrol operations, and marine biotoxins. Part II: Sanitation of the Harvesting, Processing and Distribution of Shellfish is a guide for operating, inspecting, and certifying shellfish shippers, processors and depuration facilities and for controlling interstate shipments of shellfish.

The Manual also provides specific protocols for Reviewing Classification of Areas Implicated in Shellfish Related Illnesses, Reviewing Classification of Areas Implicated by Pathogens in Shellfish Meat Samples, and Approved National Shellfish Sanitation Program Laboratory Tests.

Part I, Section G of the Manual addresses aquaculture. The section is divided into three categories:

Administrative Procedures - state laws and regulations designed to provide an adequate legal basis for sanitary control of aquaculture;

Open Water Aquaculture - the cultivation of molluscan shellfish in natural shellfish growing areas; and

Shellfish Polyculture and Land-Based Monoculture - the establishment of procedures for issuing permits for shellfish aquaculture, approving culturing sites and boundaries, keeping records, imposing quarantine measures, and developing other control measures as may be necessary, recognizing that the potential for pathogens in land-based monoculture facilities is greater than natural areas and prudent control measures must be used. Further, the use of indicator microorganisms may not be related to their use in natural settings. There are also increased public health concerns related to polyculture, as the potential is greater for contamination of molluscan shellfish with pathogens and animal drugs than in monoculture.

Massachusetts is a participant in the ISSC and subscribes to the standards promulgated by the NSSP. As part of its Coastal Zone Management Program, Massachusetts is developing a protocol for the siting of wastewater treatment plants, using as a condition to be evaluated in the siting process the existence and classification of shellfish growing areas.

The process employed by the NSSP to classify shellfish growing areas assumes the existence of treatment plants in the proximity of shellfish growing areas and assumes the potential for shellfish contamination. This assumption has been a necessary operating premise, as waste water treatment plants have historically been sited near shellfish beds without giving due consideration to the need for clean water.

In Massachusetts, the protection of shellfish resources is one of the factors to be evaluated in determining water quality standards and the consequent uses allowed in that particular body of water. The state Coastal Zone Management Program Policies require the preservation of shellfish beds and encourage the development of aquaculture. A siting process that considers preserving the water quality necessary to maintain and enhance existing shellfish resources prior to running the risk of degrading that water quality preserves water quality and forwards achievement of coastal resource management goals.

18. ECONOMICS OF AQUACULTURE

UNITED STATES

Aquaculture is the fastest growing "agricultural" industry in the United States. In 1990, there were over 100 species cultured; eight species accounted for approximately 70% of total culture, with over 3400 aquaculture operations in the United States. This trend is driven by increased demand for fisheries product and reduced yield from traditional fisheries landings (National Research Council, 1982). Given the increased demand, there is a significant potential for job creation in an expanded aquacultural industry.

The estimated U.S. Total Aquaculture Production (including freshwater) has more than doubled from 139,887 metric tons with a total value of over $260 million in 1983 to an estimated 313,518 metric tons with a total value of over $724 million in 1992. (NMFS Statistics Division) The aquaculture industry supports an infrastructure of hatcheries, feed mills, processing plants, equipment manufacturers, and suppliers of specialty services and products, as well as enhancing the natural fishery with juvenile finfish and shellfish seed and spat.

U.S. annual per capita consumption of fish and shellfish has increased since estimates were first made in 1909. At that time the per capita estimate was 11 lbs., in the 1950 and 60's it was well below 5 lbs., and in 1993 it was 15 lbs. (U.S. Department of Commerce, 1993). Most remarkable was the sharp rise in consumption from 1970 (about 4 lbs.) to 1990 (about 5 lbs.) The domestic seafood industry has identified a goal of increasing domestic seafood consumption to 20 lbs/per capita by the year 2000 although this appears unlikely.

It is estimated that 10% - 14% of the fishery products currently consumed in the United States are aquaculturally derived. Changing consumer preferences combined with the reduction in the wild fishery appear to be the dominant factor in the growth of aquaculture. (FDA, 1990)

Most of the United States' demand for seafood is met by imports. The value of imported fisheries products more than doubled during the 1980's, to $9.6 billion in 1989. This resulted in a significant trade deficit - $4.9 billion for all fisheries products and $3.1 billion for edible fish and shellfish in 1989. Imported fisheries products contribute more to the United States' trade imbalance than any other food or agricultural commodity. After petroleum products, imported seafood contributes more to the United States trade deficit than any other natural resources product. (Joint Subcommittee on Aquaculture, 1992)

Despite the trade imbalance, some aquacultured fish products are exported. There has been significant growth in U.S. exports of ornamental fish with exports of $17 million in 1993 and over $10 million in the first half of 1994. (US Department of Agriculture, 1994)

NORTHEAST REGION

The Northeast Region, as covered by the Northeastern Regional Aquaculture Center (NRAC), includes the states of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, and West Virginia. NRAC estimates the total 1992 farm gate value of aquacultured products in the northeastern United States to be $146,409,000. Cultured shellfish comprises approximately 53 percent of the 1992 regional farm gate value, with oyster production being the single largest segment of the regional industry accounting for roughly 42 percent of the total. Net pen culture of Atlantic salmon and steelhead trout was the second largest category contributing 29 percent to the regional value. (Northeastern Regional Aquaculture Center, 1993)

The state of Connecticut is the largest aquaculture producing state in the region with estimated farm gate sales of $61.7 million, primarily from oyster sales. Maine is the second largest aquaculture producing state in the region with farm gate sales of $42.9 million, largely from pen-reared salmonid. Pennsylvania is the third largest aquaculture producing state, with farm gate sales totaling $11,926,000, dominated by trout culture. New York is the forth largest aquaculture producer, with $9,637,000 in sales, primarily from the Long Island oyster farms. (NRAC, 1993)

Massachusetts follows as the fifth largest aquaculture producer with $8,020,000 in sales. The dominant species in Massachusetts, in order of economic value are: Northern Quahog, oyster, trout, hybrid striped bass, scallops, baitfish/other fish and tilapia. (NRAC, 1993) Trout, striped bass, baitfish/other fish and tilapia are all grown in inland facilities in Massachusetts.

When comparing the aquaculture industries from state to state, it should be kept in mind that the potential for aquaculture to succeed is dependent on several considerations. While some of these considerations are flexible and can be made more accommodating for aquaculture (laws, regulations, policy, business climate, private and public initiatives) others, (tidal range, exposure, biological parameters, flushing rates, temperature, native species) cannot be easily overcome.

Economic success of aquaculture requires maintenance of a high price in the market to offset basic investments and rearing costs per organism and to assure a good profit margin. Price per organism however, is insufficient to insure economic viability. Maintenance of consistently high sales volume is also required.

MASSACHUSETTS

The reported (landing) value of aquacultured shellfish in Massachusetts is difficult to calculate. The Division of Marine Fisheries and municipalities collects annual landing data from aquaculture producers as a part of their reporting requirements under Section 35 of Massachusetts General Law Chapter 130. Precise reporting to DMF is not required of aquaculturists and thus the information received and summarized by DMF reflects only the producers who self-reported. As has been mentioned previously in this report, aquaculturists have also historically underreported their landings for various reasons. Due to both the chronic under-reporting that exists within the industry and the lack of any sophisticated, consistent calculation of true value, shellfish aquaculture is both undervalued and overlooked in Massachusetts.

If the real values were consistently reported, the significance of this industry to Massachusetts would become apparent. Although the shellfish aquaculture industry in Massachusetts is not large when compared to other industries in the state, it is important to consider that the industry is located in small Cape Cod towns which have few other year-round industries. To the municipalities where shellfish culture is practiced, this industry is increasingly desirable for economic development.

Total Estimated Values for Cultured Shellfish; 1986 - 1993

The following estimated values are derived from DMF landing data. For the year 1992 estimated values from the Northeast Region Aquaculture Industry Situation and Outlook Report are also provided for the sake of comparison. NRAC compiled its data via individual grower surveys and is likely to be more realistic, but still not precise. The NRAC figure includes production of inland cultured striped bass, trout, baitfish and tilapia. Comparison of the two estimated values of aquacultured products for 1992 reveals the significant problem Massachusetts has with accurate reporting of aquacultural production.

1986 =		$ 2,114,026
1987 =		$ 318,584
1988 =		$ 620,058
1989 =		$ 1,933,145
1990 =		$ 906,815
1991 =		$ 1,884,017
1992 =	(DMF)	$ 863,418
	(NRAC)	$ 4,000,000 (approx. value of quahogs & oysters)
		$ 8,020,000 (all aquacultured products)
1993 =		$ 1,753,192

An additional 4.5 market multiplier is utilized by NMFS to conservatively account for the additional value of spin-off jobs, support industries and employment-related benefits.

FUNDING SOURCES

The common constraint shared by almost all aquaculturists is the lack of dependable funding sources, both for start-up and for operational costs. Most federal funding sources are geared toward traditional agriculture and the programs that include aquaculture generally limit it to finfish and inland endeavors. Most private lending institutions in Massachusetts either do not recognize aquaculture as a commercial venture or recognize the high risk of "crop failure" inherent to aquaculture. This financing vacuum forces most aquaculturists to apply for personal loans to get the venture and operating capital they need.

One of the essential keys to success in any industry is its access to reliable sources of funding. Traditional agriculture has relied upon three sources to provide many of its capital needs: the farm credit system, the Farmers Home Administration, and private lenders. Aquaculturists, particularly shellfish culturists, need the same access and the same opportunities.

DISTRIBUTION/MARKETING

Shrewd marketing is important to the livelihood of any industry, particularly aquaculture. Concurrently, an effective marketing campaign can expand the distribution of aquaculture products outside of the local area. At present, however, local growers are providing product to a limited market which has forced down the unit price. Through aggressive marketing efforts, the market for local aquaculture products could be expanded to other regions of the country, which would increase product output forcing up the unit price. Unfortunately, the industry is not currently capable of funding such a marketing initiative.

Similarly, financial obstacles to aquaculture projects including start-up costs and marketing initiatives, as well as those inherent to the complicated permitting process, exclude all willing participants from entering the aquaculture industry other than large corporations. In order to open the industry up to small scale operations and provide any chance of an alternative to traditional fishing, governments might need to create a framework whereby small scale projects could obtain permits more easily. Additionally, states would need to provide assistance in the form of funding start-up costs and marketing initiatives if such projects are to have a chance of maintaining viability.

19. SUMMARY \ RECOMMENDATIONS

19.1. Inland Aquaculture

1. Several state and federal agencies have direct roles in regulating inland aquaculture. Because each agency has different authorities and mandates, the development a "one stop shop" for an aquaculture permit will be difficult. However, as a first step, developing a "user friendly", easy to read brochure on what agencies need to be contacted and who specifically to contact along with telephone numbers, would help substantially with the entire permitting process.

2. Establish an aquaculture extension position. This should be filled by an individual that possesses strong biological as well as technical capabilities in the field of aquaculture.

3. Private aquaculture needs to assist in funding the registration of critical drugs needed in fish culture. It is in the industry's own best self-interest to work directly with the states and federal government in accomplishing this huge task.

19.2. Marine Aquaculture

The following conclusions incorporate both issues relating to the aquaculture industry as a whole and to specific types of aquaculture practiced or proposed for Massachusetts. The conclusions summarized here can be characterized as problems which warrant further attention and action.

MARINE MONITORING/ENVIRONMENTAL REVIEW

Protection of coastal water quality is essential to a sustainable wild and aquaculturally derived seafood industry. Shellfish beds closed due to point or non-point pollution sources represent an underutilized resource and lost revenue for coastal Massachusetts.

The state must move forward to remediate and reopen closed wild shellfish beds while at the same time, promoting marine aquaculture for non-productive intertidal and subtidal areas. Marine aquaculture development should not be promoted at the expense of our wild fishery.

The siting of wastewater treatment plant outfalls historically was done without consideration of adjacent shellfish beds. As a result, shellfish beds located adjacent to outfalls are often restricted or closed due to excessive fecal coliform counts.

Fecal coliform may not be the best indicator for pathogens and viruses but is uniformly used as the indicator species for shellfish safety.

The full extent of environmental impacts from aquaculture are uncertain. While it appears from limited studies and experience that aquaculture, if properly sited, does not cause noticeable degradation, the public often has the belief that aquaculture is a polluting industry.

Despite the numerous permits required to undertake aquaculture, environmental review of aquaculture proposals is fragmented. If MEPA thresholds are not met and a Chapter 91 license not required (which is generally the case), the only opportunity for state level environmental review is at DMF which has limited staff resources dedicated to environmental review of such proposals. The other state environmental agencies would have a back-door role in reviewing Section 404/10 permits.

There are concerns that the use of Off-Road Vehicles (ORV's) utilized by shellfish culturists to access the intertidal area may be detrimental to wetlands and oftentimes, endangered species such as piping plovers.

Financial and staff resources necessary for environmental review, marine monitoring, technical assistance, administration, and enforcement of aquaculture leases are not adequate at the state or municipal levels of government. Funding for aquaculture, however, does exist under NMFS' Fishing Industry Grants (FIG) program and the Saltonstall-Kennedy (SK) program.

ECONOMIC REVIEW/MARKETING

Bivalve mollusk culture has historically been and is presently, the dominant form of aquaculture in the state. No other type of marine aquaculture is currently under commercial cultivation.

The lack of an accurate reporting mechanism for marine aquaculture production has resulted in unreliable economic information on this small, but growing industry.

Aquaculturists are oftentimes not viewed as business people but rather "hobbyists" due to inconsistent reporting of profit and poor record-keeping. This perception that aquaculture is a hobby and not a viable business has led to difficulties in obtaining technical assistance, bank loans, small business assistance, etc.

Press coverage of shellfish disease has led to widespread consumer concern or fear over the safety of shellfish. Overcoming this largely erroneous fear has become a marketing hurdle for the aquaculture industry.

There is no state agency which is explicitly responsible for promoting aquaculture. This stems largely from aquaculture having aspects relating to both agriculture and fisheries. Aquacultural practices do not easily fit within one existing agency mandate. There is presently minimal state involvement in aquaculture marketing, small business development and financing.

Privatization of traditionally government functions (i.e., hatcheries, marine monitoring, depuration) could be considered as a means to minimize government costs and encourage private investment in aquaculture.

The majority of aquaculture research and development is done by the private sector or the academic community in Massachusetts. The role of state and federal research and development is extremely limited. Research and development needs relating to production technology, disease control, quality control, environmental impacts, and species specific information are holding back the economic potential of aquaculture in Massachusetts.

Opportunities for aquaculture training and education is extremely limited in the state. Most private aquaculturists are reliant on limited technical assistance from Sea Grant, U-Mass Extension, and other aquaculturists. There are no degree granting institutions with aquaculture programs in the state.

REGULATORY REFORM

Shellfish culture, fish farms and aquaculture in general, are poorly understood industries in coastal towns. This misunderstanding has sometimes led to distrust and conflict over private and public tideland and submerged land use.

The aquaculture industry in Massachusetts operates using a mix of private tidelands, public tidelands, state-owned submerged lands (from mean low water to three miles seaward) and probably sometime soon, federally owned submerged land in the Exclusive Economic Zone (EEZ). Multiple use conflicts of these lands are numerous. Wild fisheries, navigation, recreation, aesthetics and environmental protection are some of the competing uses of this land.

The regulatory requirements for aquaculture are complex and somewhat redundant. It is often unclear to proponents which permits and approvals are necessary from what authorities for different types of aquaculture located in different jurisdictions.

For the purposes of regulation, aquaculture does not fit precisely into any existing state agency. Instead, it has been fragmented between the Department of Fisheries, Wildlife, and Environmental Law Enforcement and the Department of Environmental Protection. At times, aquaculture is considered an industrial venture, while at other times it is considered fishing or agriculture. As a result, aquaculture is currently faced with regulatory constraints from several directions, but without benefitting from a direct association with any of the administrative agencies.

Should the New England Fisheries Management Council exercise its jurisdiction over aquaculture projects in the Exclusive Economic Zone (EEZ), the state's role in reviewing such proposals is limited to Consistency review through CZM. CZM has no enforceable policies directly relating to aquaculture.

There are concerns that the use of Off-Road Vehicles (ORV's) utilized by some shellfish culturists to access the intertidal area may be detrimental to wetlands and oftentimes, endangered species such as piping plovers. Generally, there use is not standard procedure throughout the industry.

Financial and staff resources necessary for environmental review, marine monitoring, technical assistance, administration, and enforcement of aquaculture leases is not adequate at the state or municipal levels of government.

The Chapter 91 program does not currently consider shellfish trays to be "structures" and therefore they do not require any license or permit. Additionally, floating pens are handled like moorings and are generally approved by local harbormasters under Section 10A. To date, DEP has not required a license for any intertidal or subtidal aquaculture facility because most operate with mooring systems rather than with fixed structures. Therefore, aquaculturists are permitted to use year to year Chapter 91 permits obtained by local harbormasters to use public lands at no cost. Some large aquaculture operations may choose to obtain a long term license for financing or to reserve the rights for a longer period of time because the annual 10A permits may not offer long term security that is usually needed for these projects.

Aquaculture leases issued by municipalities are limited to ten year periods with no guarantee of renewal.

Aquaculturists perceive regulating agencies, both state and federal, as having an adversarial approach to aquaculture review rather than being cooperative or encouraging. Aquaculturists see the need for a gubernatorial policy which supports aquaculture in the state.

There may be a need for the regulatory structure to differentiate between commercial aquaculture and resource preservation, enhancement of wild fisheries, and experimental endeavors.

GLOSSARY

Applicant - any individual, partnership, corporation, firm, business, club, organization, association, municipality, or any other commercial or non-commercial entity.

Aquaculture -the propagation, culture, and maintenance of fish under a Class 1, 2, or 3 permit.

Bait fish -the following fish are considered bait fish in Massachusetts and may be captured for personal use: American eel, white sucker, creek chubsucker, banded killifish, mummichog, pumpkinseed, golden shiner, emerald shiner, spottail shiner, rainbow smelt, yellow perch, fallfish.

Commercial bait fish - the following fish are considered commercial bait fish in Massachusetts: white sucker, mummichog, golden shiner, emerald shiner, spottail shiner, fallfish.

Culch -Hard material (usually broken oyster/clam/scallop shells) laid down in intertidal area to attract spat.

Culture -to use an artificial environment or an altered or enhanced natural environment in order to induce fish growth, development through life stages, or reproduction.

Director -the Director of the Division of Fisheries and Wildlife or his agent.

Discharge - (Clean Water Act, 33 U.S.C. Section 1362) The addition of any pollutant to navigable waters from any point source, (or) the addition of any pollutant to the waters of the contiguous zone or the ocean from any point source other than a vessel or other floating craft.

Division - the Massachusetts Division of Fisheries and Wildlife.

Expansion - an increase in the area of an aquaculture facility used to hold fish during culture or maintenance.

Ex-vessel price - Price that fishermen receive for their catch. "Off the boat price"

Farm gate value - Price that aquaculturists receive for their products. "off the farm price"

Fish -any vertebrate of the class Cyclostomata or Osteichthyes or parts, spawn, or viable eggs thereof inhabiting freshwater.

Great Pond -a natural pond the area of which is twenty (20) acres or more.

Maintain - to keep fish in indoor or outdoor confinement or otherwise hold them under artificial conditions that allow the person exclusive control over the fish. Fish that are maintained may be supplied with food or otherwise cared for to sustain life but not to induce growth or allow reproduction.

Native -a species that either occurs, or has occurred within Massachusetts, provided that the original occurrence of such species is not the result of deliberate or accidental introductions by humans.

Naturalized - fish species that were introduced by humans and have established self-sustaining, reproducing populations.

Navigable Waters - all waters, creeks, coves, inlets, and arms of the sea or rivers that are: 1) under tidal influence; or 2) defined as navigable by the U. S. Army Corps of Engineers under the Rivers and Harbors Act.

Non-point Source - Pollution source not confined to a discrete conveyance (i.e. agricultural runoff, return flows from irrigation, and stormwater discharges.)

NPDES - National Pollution Discharge Elimination System. Permit issued by the federal Environmental Protection Agency (EPA) for point sources of pollution (i.e., outfalls, drains).

Point Source - Any discernable, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants may be discharged.

Propagate - to take specific measures to encourage the natural or artificial reproduction of fish.

Stock - to release fish into the waters of the Commonwealth. A liberation permit is required for all releases that are not specifically allowed by other aquaculture permits.

Toxics - Heavy metals such as lead, copper, and mercury as well as a broad class of pollutants known as organics. Organic pollutants include such petroleum based compounds as polycyclic aromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's) and pesticides. Filter feeding bivalves tend to accumulate cadmium and mercury as well as PCB's.

Wildlife - amphibians, reptiles, birds, and mammals.

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APPENDIX: MDFW Aquaculture Regulations Summary

DIVISION OF FISHERIES AND WILDLIFE

SUMMARY OF AQUACULTURE REGULATIONS

Approved by the Fish and Wildlife Board
August 25, 1994

INTRODUCTION

The Division of Fisheries and Wildlife (DFW) has a mandate to conserve, restore, and manage the biological resources of the Commonwealth. The DFW, through its statutory authority, oversees activities such as fishing, hunting, trapping, and aquaculture. Each of these activities is regulated through a license/permit system and is subject to certain restrictions.

The DFW aquaculture permit process has not been significantly revised since 1968. Since that time, a burgeoning aquaculture industry and changing sportfishing demands have generated many new fish and wildlife issues. In keeping with these changes, the DFW has developed a clear, concise, and standard process for issuing aquaculture permits in the Commonwealth. These regulatory changes simplify and clarify the permit process and enhance resource protection.

The following is a summary of the regulations found in 321 CMR 4.09. This summary is intended only as a guide to permit requirements. The official regulations, available from the Statehouse Bookstore (Room 116, Statehouse, Boston, MA 02133), should be read before any final decisions about aquaculture are made.

There is a glossary in the Appendix that defines the terms found in this review. Although it defines some terms that might be considered common knowledge, a review of the glossary is necessary to fully understand this document.

AQUACULTURE - 321 CMR 4.09

This section is entitled "Propagation, Culture, Maintenance, and Sale of Protected Freshwater Fish." These regulations are designed to create a clear, concise process for issuing permits for the culture and sale of fish while protecting the Commonwealth's existing fisheries resources from over-exploitation, uncontrolled and unintentional introductions, and disease infestations.

Aquaculture Permits

Except in situations specifically allowed by fish and wildlife laws, it is illegal to possess, maintain, propagate, culture, or sell any fish without having a valid permit in one of four classes:

1) Class 1 private waters permit;
2) Class 2 public waters stocking permit;
3) Class 3 aquaculture permit;
4) Class 6 dealer's permit.

Harvest of fish from the wild is not allowed under any aquaculture permit. These classes are provided for in general law and defined by fish and wildlife regulations. Fish cultured under an aquaculture permit may be harvested without regard to existing fishing regulations (321 CMR 4.01).

All permit applicants must submit information regarding their intent to culture fish (Table 1). The DFW will review the information and issue or deny the appropriate permit. The DFW may also revoke permits that have been issued if the permit holder violates any of the terms of the permit or any DFW fish and wildlife laws and regulations. Permits are good for one (1) year and renewal applications must be filed before January 1. Renewal applications should be submitted at least 15 days before this deadline to ensure that the paperwork can be handled quickly.

Table 1. Information required on all aquaculture permit applications.

1. applicant's name, address, and telephone number
2. applicant's date of birth
3. in the event the applicant is a corporation, firm, partnership, institution, or agency, the name, address,and telephone number, of the president, director, head, or principal officer
4. the location or locations where the permitted activity will be conducted
5. the species or types of fish or parts thereof which are to be propagated, cultured, maintained, or sold
6. the specific source or sources from which the fish are to be obtained
7. the date of the application
8. the applicant's signature
9. for a Class 3 permit, accurate diagrams, models or drawings in scale or pictures depicting the precise physical conditions under which the fish will be maintained
10. for a Class 6 permit, or for a Class 3 permit issued for commercial purposes, a signed affidavit certifying that the applicant has to the best of his knowledge paid all state taxes as required by the Massachusetts Department of Revenue
11. a written plan detailing the intended activity for which the fish are to be maintained, the disposition of the fish, if relevant, and other information pertinent to a full explanation and justification for the possession of the fish
12. for a Class 3C aquaculture permit, a waste management plan as provided for in 321 CMR 4.09 (4)(a).

Class 1 Private Waters Permit

A Class 1 private waters permit is issued for non-commercial aquaculture. Fish may not be sold under a Class 1 private waters permit. This permit authorizes the permit holder (i.e. individual, club, or association) to buy, possess, propagate, culture, and maintain fish for personal use only. People may fish in a waterbody licensed as a Class 1 without a Massachusetts fishing license as long as they have written permission from the permittee.

Each waterbody permitted under a Class 1 private waters permit must meet all of the following criteria: 1) it may not be located on a great pond or navigable water; 2) it must be designed to allow the passage of anadromous fish that naturally or historically occur in that body of water; 3) it must be conspicuously posted; and 4) it must be exclusively controlled by the permittee. It is important to stress that a stream or pond can not be permitted under a Class 1 private waters permit unless the applicant (i.e. individual, club or association) owns all of the shoreline of the pond or both banks of the stream.

The waterbody used to culture fish under a Class 1 permit is required to have screened intake and outflow conduits to prevent the escape of the smallest life stage being cultured or maintained. For example, if 9 to 12 inch trout are placed in a pond for fishing under a Class 1 permit, the pond must have the appropriate mesh screening to prevent the escape of trout 9 inches or larger. Class 1 permittees are authorized to grow only those fish species that are either: 1) native or naturalized in Massachusetts and found in most (approximately 95%) of the Commonwealth's watersheds; or 2) are listed as commercial bait species as approved by the Fish and Wildlife Board (Table 2). **Live fish may not be taken from the premises of Class 1 permittees unless they are to be stocked under a valid liberation permit or transferred to a facility with a valid permit to culture those fish.**

Class 2 Public Waters Stocking Permit

A Class 2 public waters stocking permit authorizes the permit holder to purchase, possess, propagate, culture, and maintain fish that are going to be stocked into public waters. The terms and conditions of this permit will be determined on a case by case basis. Fish may not be sold under a Class 2 public waters stocking permit.

Class 3 Aquaculture Permit

A Class 3 aquaculture permit authorizes the permit holder to propagate, culture, maintain, purchase and sell fish. Class 3 aquaculture permits may be issued for three different types of facilities:

1) **Type A aquaculture facilities** are those facilities with the fewest requirements to prevent the escape of cultured fish. However, they are also the most limited of the facilities in terms of the species that may be cultured;

Table 2: Fish species allowed for culture under a Class 1 permit or a Class 3 Type Aquaculture Facility.

bluegill	Lepomis macrochirus
brook trout	Salvelinus fontinalis
brown bullhead	Ameiurus nebulosus
brown trout	Salmo trutta
chain pickerel	Esox niger
emerald shiner	Notropis atherinoides
fallfish	Semotilus corporalis
golden shiner	Notemigonus crysoleucas
largemouth bass	Micropterus salmoides
mummichog	Fundulus heteroclitus
pumpkinseed	Lepomis gibbosus
rainbow trout	Oncorhynchus mykiss
spottail shiner	Notropis hudsonius
white sucker	Catostomus commersoni
yellow perch	Perca flavescens

2) **Type B aquaculture facilities** are intermediate in their requirements to prevent the escape of cultured fish and are allowed to grow more species than Type A aquaculture systems;

3) **Type C aquaculture facilities** have the most requirements to prevent the escape of cultured fish and are allowed to grow the largest number of fish species.
Type A, B, and C, aquaculture facilities have four criteria in common: 1) they may not be located on great ponds or navigable waters; 2) they must be designed to allow the passage of anadromous fish that naturally or historically occur in that body of water; 3) they must be conspicuously posted; and 4) they must be exclusively controlled by the permittee.

Live fish may not be removed from any Class 3 facility without a valid permit to stock or culture those fish. The seller must keep a record of the name, address, and permit number of the buyer.

Although all aquaculture facilities are authorized to propagate, culture, and maintain fish, each type has different criteria to which it must adhere.

AQUACULTURE FACILITY CRITERIA:

Type A Aquaculture Facilities

Type A aquaculture facilities are required to have screened intake and outflow conduits to prevent the escape of the smallest life stage being cultured. Type A aquaculture facilities are authorized to grow only those fish species that are either: 1) native or naturalized in Massachusetts and found in most (approximately 95%) of Massachusetts' watersheds; or 2) are listed as commercial bait species (Table 2).

Type B Aquaculture Facilities

Type B aquaculture facilities are required to have screened intake and outflow conduits to prevent the escape of cultured fish and also must be enclosed by a fence or similar barrier to prevent unauthorized access, theft and vandalism. Type B aquaculture facilities are authorized to culture any species found in Table 2 and additional species that already exist, as determined by the DFW, in the watershed in which the facility is located.

Type C Aquaculture Facilities

Type C aquaculture facilities require the most restrictive measures to prevent the escape of cultured fish and protect aquatic resources. These facilities must be designed to ensure the separation of cultured fish from the Commonwealth's natural aquatic environment both physically and biologically. Type C aquaculture facilities must be located and operated outside the 100 year flood plain as defined by the Federal Emergency Management Agency (FEMA). Type C facilities must be located within a secure, permanent, and enclosed building designed to prevent predation from birds and mammals, escape of cultured fish, trespass, theft, and vandalism. These facilities must also be designed, constructed and operated in such a way as to prevent the discharge of biological effluent and diseases into the environment and have a non-polluting waste disposal plan to dispose of solid waste such as fish carcasses. Lastly, to ensure continual water quality maintenance, Type C facilities need to: a) have a functional backup electrical system; or b) discharge all of their effluent into a municipal waste treatment facility.

Fish species that may be cultured in this type of facility include the following: a) all species listed in Table 2; b) all species found, as determined by the DFW, in Massachusetts watersheds; and c) tilapia, white bass, and white bass X striped bass hybrids. Other species may be allowed, at the discretion of the Director, for culture in Type C aquaculture facilities and will be considered on a case by case basis.

Amendments to Class 3 Permits

Class 3 permittees must submit written amendments to the DFW permit office to propose any changes in the species held at their facility or any expansion of the facility. The amendments must be submitted and approved before the changes may take place.

Class 6 Dealer's Permit

A Class 6 dealer's permit allows the permit holder to possess, maintain and sell live or dead fish that were harvested or cultured legally. There are two common situations where this permit is typically issued. First, this permit will allow bait store owners to hold commercial bait species for sale. Second, grocery stores or restaurants that have a live tank of fish, often trout, will be able to operate under this permit rather than having to obtain a Class 3 aquaculture permit. A Class 6 dealer's permit is not needed to sell carcasses that have already been processed and packaged legally.

If fish are to be maintained alive under a Class 6 dealer's permit, the facility must meet the established requirements for holding that species. For example, in order to maintain rainbow trout, the premises of the Class 6 dealer would have to meet the requirements for a Type A aquaculture facility. Live fish, except for commercial bait fish species sold as bait, may not be taken from the premises of Class 6 licensees unless they are to be stocked or cultured under a valid permit. **The seller must keep a record of the name, address, and permit number of the buyer when selling live fish.**

<u>Special Circumstances Concerning Aquaculture Permits</u>

Recreational Fishing

Fishing in aquaculture facilities (for example fee fishing areas or sportsmen club ponds) is an activity that has gained in popularity over the past decade. DFW regulations do allow for this activity with certain restrictions and when certain guidelines are followed. Class 1 and 3 permit holders may allow fishing in waters under their control. In these situations, the permittee must keep a log book to record the date, number and species of fish removed by angling, and the name(s) and signature(s) of angler(s) who removed fish. This log book must be used for the purposes of recording removal of any fish for which the DFW has set length or creel limits. A dated receipt from a Class 3 permittee with the name of the permittee, number, and species of fish removed will also be acceptable proof of lawful possession. The purpose of the log book or receipt becomes clear in the following example: If an individual is stopped by an Environmental Police Officer and is in possession of four trout, when the limit is three, a receipt from a licensed aquaculturist is necessary to demonstrate that those fish were taken legally. The permittee must keep a record of these receipts for a minimum of two years. State law also allows that, as an alternative to the log book, metal tags may be placed on each fish that leaves the premises.

The Sale of Bait Fish

The sale of bait fish in Massachusetts is an important addition to the income of many tackle shop owners. Recent DFW regulation changes have stipulated which species may be sold as bait and which species may be captured by licensed anglers for their own use as bait (321 CMR 4.01). A Class 6 dealers permit may allow the maintenance and sale of commercial bait species but **not** the capture of baitfish from the wild. A Class 3 aquaculture permit may also allow the permittee to culture, maintain, and sell commercial bait species, but again does **not** allow capture from the wild. A shiner permit (321 CMR 4.01) is required to capture designated commercial baitfish species from the wild for purposes of sale.

Scientific and Educational Permits

Scientific, educational, and captive breeding permits will be issued only as Class 3 permits. Fish must be held in indoor facilities that meet the aquaculture facility requirements appropriate to the species being cultured or maintained.

Selling Fish as Food

Class 3 permittees and Class 6 dealers need to meet some additional criteria in order to sell fish as food. They must have a Class 3 or Class 6 permit for each place of business; they must conspicuously post their permit in their business in full public view; and they must meet the packaging, marking and tagging requirements as follows: the fish, once killed, must be wrapped or packaged in containers that are labelled with the name and address of the permittee, and the species name, number, and the net weight of fish in each package.

SUMMARY

The DFW has the authority to regulate aquaculture in the Commonwealth. A process and decision criteria have been established under these regulations to ensure a consistent, fair approach to issuing permits to aquaculturists while protecting the Commonwealth's aquatic resources.

The end result is a permit system that protects the resource and can be more easily implemented and applied to the multitude of modern aquaculture interests.

Massachusetts **Coastal Zone Management**

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