NEW JERSEY

AQUACULTURE CONFERENCE

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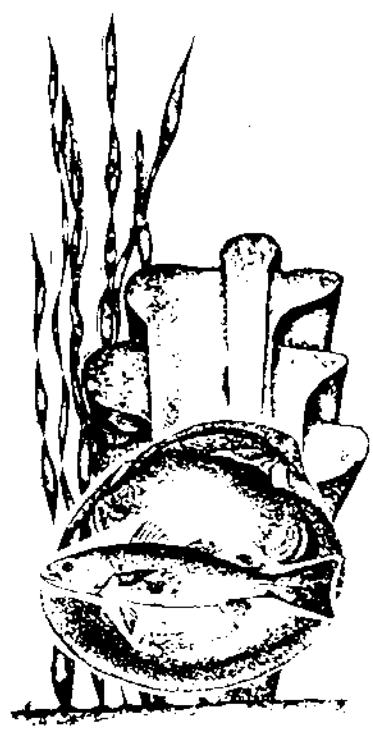

CONFERENCE PROCEEDINGS

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CONTENTS

CHAPTER		PAGE
I.	THE STATE OF AQUACULTURE Clarence Idyll	Idyll - 6
II.	NON-FOOD ASPECTS OF AQUACULTURE John Ryther	Ryther - 16
III.	LIKELY ORGANISMS FOR CULTURE EXPLORATION Michael Castagna	Castagna - 20
IV.	BIOTECHNOLOGY IN MODERN AQUACULTURE Fred Singleton	Singleton - 27
V.	INFRASTRUCTURE FOR AQUACULTURE Robert Wildman	Wildman - 31
VI.	RISKS TO THE AQUACULTURE ENTERPRISE Harold Webber	Webber - 37
VII.	OUTLOOK FOR THE FUTURE Carl Sindermann	Sindermann - 42
VIII.	THE ESSENCE OF AQUALCULTURE: A SUMMATION Harold Goodwin and Robert Abel	Goodwin/Abel - 45

INTRODUCTION

Welcome to Sandy Hook and to the initial New Jersey Aquaculture Development Workshop. I would like first to acknowledge the support of the New Jersey Commission on Science and Technology, Public Service Electric and Gas Company, and our co-hosts, the National Marine Fisheries Service and the New Jersey Marine Sciences Consortium in putting this conference together.

Because of a number of initiatives, and a resurgence in public awareness, New Jersey is currently in a position to bring together an extensive array of services to form an effective aquaculture development program. This workshop is a vital first step in the process.

The workshop participants we have brought together today have been so important to aquaculture development in the United States that they really need no introduction to anyone even slightly familiar with finfish or shellfish farming. We wish to bring their knowledge, their experience, and their insights to bear on New Jersey; to help us decide what direction we should be taking to allow New Jersey to become the strong force it should be as aquaculture starts to mature as an industry in the United States.

Nils E. Stolpe
Conference Chairman

Conference held Sept. 1985

FOREWORD

Aquaculture is not a new subject or interest in New Jersey. In fact, the state has a long history of interest which, until recently, was directed primarily, though not solely, to oysters. Dr. Harold Haskin of Rutgers University is recognized as a world-class oyster and bivalve scientist, and among the bivalve culturists of the world a disproportionately large number were his students.

More recently, a very large utility, Public Service Electric and Gas Company joined forces with university scientists, notably Dr. Albert Eble of Trenton State College, and with today's program chairman Nils Stolpe and Bruce Godfriaux, for the first substantial scale experiment in the use of power plant heated waste water for the culture of organisms. Specifically, the animals were the Giant Malaysian prawn, *Macrobrachium rosenbergii*, and later, the rainbow trout. The extensive reports resulting from this experiment are a substantial contribution to the state of waste water culture technology.

But despite history, interest in aquaculture has revived only recently and grown rapidly in New Jersey, and a new organizational structure which has not yet taken firm outlines and content is being developed. This new interest is the reason for today's workshop, which is hosted jointly by the New Jersey Marine Sciences Consortium and the National Marine Fisheries Service through its laboratory here at Sandy Hook.

Although the mission of the Sandy Hook Laboratory has been development of scientific data leading to the proper preservation and management of the marine environment and naturally occurring stocks, the laboratory consistently has been a supporter of aquaculture through advice and guidance, in some cases the provision of badly needed facilities, and actual participation by individual scientists, sometimes on their own time.

The New Jersey Marine Sciences Consortium, for its part, is a joining together of 29 Universities and other entities, not only in New Jersey but in nearby states. It further acts as expediter and channel for cooperation between member institutions and scientific organizations in other states. As the agency responsible for the operation of the New Jersey Sea Grant Program, the Consortium and its members are also a part of the nationwide Sea Grant network and association—and, as is generally recognized, Sea Grant has been the most consistent and innovative supporter of aquaculture among Federal programs. Of the colleges and universities who are members of the Consortium, at least 15 have received either Sea Grant or Consortium funding for aquaculture ventures or related activities. It may be noted that such ventures are not necessarily the direct growing of organisms, but may be in biochemistry, biophysics, genetics, or sometimes in a pragmatic approach to bioengineering.

In convening this workshop, it was our hope that we could provide a sense of direction and a review of the state of the aquaculture arts that would be useful as New Jersey works to create a coherent, statewide aquaculture program using all competent and interested public and private resources.

To this end, we planned a small workshop of perhaps 20 people with responsibility or mission interest in aquaculture, to hear and discuss aquaculture with a few of the most knowledgeable and experienced aquaculture specialists in the nation.

Despite some losses in mechanics of the meeting, we found that what we had, instead of mere proceedings, was a capsuled summary of the state, methods, prospects, and problems of aquaculture. In effect, the combined words of our invited speakers and following discussions form a primer on how to think about aquaculture, what needs to be realized before planning for a venture—or development of a plan—even begins.

We recommend this report to all who may have any degree of interest or responsibility in aquaculture, including those with good or bad experience. We think it helps to clarify thoughts about this sometimes controversial subject.

Robert B. Abel,
President
New Jersey Marine Sciences
Consortium

CHAPTER I

THE STATE OF AQUACULTURE

An Overview

Clarence Idyll,
Fisheries and Agriculture Consultant

Clarence Idyll has been a major figure in international fisheries and agriculture for over 45 years. Among other positions related to aquaculture, he was Senior Marine Scientist for the National Advisory Committee on Oceans and Atmosphere, Chief of the International Fisheries Development and Services Divisions of the National Marine Fisheries Service, Fisheries Research Advisor of the Department of Fisheries of the United Nations Food and Agriculture Organization, and for over a decade the Chairman of the Gulf and Caribbean Fisheries Institute, an organization for which he was Executive Secretary for nine years before becoming Chairman. From 1953 to 1972 he was Professor and Chairman of the Division of Fishery Sciences, University of Miami, and Chairman of Graduate Studies of the University's Institute of Marine Science from 1956 to 1959. Dr. Idyll was educated at the University of British Columbia, and received his doctorate from the University of Washington at Seattle. Since retirement from Federal Service, he has been a consultant on fisheries management and development.

In addition to a great number of scientific and technical papers on fisheries, aquaculture, and marine science, and articles for such publications as *National Geographic* and *Scientific American*, Dr. Idyll's books include *Abyss: The Deep Sea and the Creatures That Live in It; Exploring the Ocean World, and The Sea Against Hunger.*

The Nature of Aquaculture

Aquaculture is the controlled production and harvest of aquatic animals and plants. In the United States and in most other countries outside of Asia few plants are raised by aquaculture, so we shall be restricting this discussion largely to the culture of animals.

While the word suggests that aquaculture is the watery equivalent of agriculture, in fact in most kinds of aquatic farming the culturist has far less control over the animals he is raising than the land farmer, usually depending on a supply of seed—the young stages of the cultured species—from the wild. Only in a small number of aquaculture operations does the farmer have full control of the life cycle of the animal from brood stock through spawning, larval, juvenile and adult growth, harvest, and back to brood stock.

Examples of this fully controlled aquatic farming include the culture of catfish and trout in the United States, carp and tilapia in China, Israel and elsewhere, and a few operations which grow salmon, oysters and other species in various parts of the world. But the majority of aquaculture businesses over the globe—including a great many which are profitable—depend on the collection of spawn in the wild (mussel culture in Spain, oyster culture virtually worldwide), or on the capture of wild fry (milkfish culture in Indonesia, shrimp farming in Ecuador, yellowtail culture in Japan). This dependence on seed produced in nature can constitute a strong disadvantage since wild production is notoriously variable, leaving the operation with an undependable source of supply. In addition, some species are being depleted by heavy use of the fry, and industries are threatened; examples are the milkfish farming in Asia and some shrimp operations in Latin America. It is because of this weakness in the aquaculture system that strong efforts are being made in many areas to develop techniques for gaining control of the full life cycle of the animal, including maintaining brood stocks and producing young under controlled conditions—operations that are routine in land farming.

Confusion often arises in discussions of aquaculture through lack of understanding of its complexity and diversity. It is commonly treated as though it were a homogeneous activity, and as a consequence mistakes are sometimes made in applying laws and regulations, or in public attitudes. Instead of being a single kind of activity, aquaculture consists of a large number of different ones. It includes culture in fresh water or the sea ("mariculture" is often used to describe sea farming); it includes culture in ponds, raceways, tanks, enclosures, cages; it includes stocking of streams, lakes, reservoirs and the sea with hatchery-produced young; it includes "sea ranching", involving the release of young fish (e.g., salmon) with the expectation that adults will return to the area of release and can be harvested; it includes the farming of a large number of species of animals and plants.

A further level of complexity is imposed by the fact that the amount of sophistication of the culture practice varies widely. In the past, in most parts of the world, "extensive culture" has been practiced for most species, meaning that the density of culture animals is low, supplementary feeding is not employed, and a minimum of care is delivered to the animals. Increasingly, "intensive culture" is being used, involving high densities of animals, supplemental feeding with carefully crafted rations, disease control, and other procedures. This usually results in higher profits, but obviously also involves greater initial and continuing investment, and higher level of skill.

As a final point in this discussion of what aquaculture is—or is not—it is emphasized that it should not be regarded as a solution to the world hunger problem. Some enthusiastic but poorly informed writers have declared that fish farming can raise enormous amounts of cheap food, whereas in fact nearly all aquaculture operations over the whole world are raising products that are moderate, or more commonly, high priced. This is because our technology usually requires relatively expensive seed, feeds, drugs, land, and other inputs. Fish farming is a business and it survives only if it makes a profit, so that its products are usually more expensive than the hungry poor can afford. In the future, there probably will be some kinds of aquaculture operations that will be able to mass-produce food at a low price, but for the present, and in some areas perhaps forever, decisions about investment and public support for fish farming should be based on the expectation that it is a business whose product is designed for the relatively affluent and not for the poor.

Status of World Aquaculture

Aquaculture is a moderately to substantially important method of food production in certain countries of the world, but of insignificant importance in many others. Most of the countries where fish farming makes a large contribution are in Asia, where 65% of aquaculture production takes place. Among the countries where fish farming flourishes are China and India, where 25% of aquatic food consumed is from farms, and Japan where this figure is 10%. Other Asian countries where fish culture is especially important include the Philippines and Korea. In Israel, where aquaculture has reached a high level of technology, half the fishery products used are grown in farms; in Europe, Poland, Romania and Spain grow relatively large amounts of aquatic food by farming.

World production by aquaculture has increased rapidly in recent years, rising from a rough estimate of 1 million metric tons (mmt) in 1966 to 10.5 mmt in 1983 (Table 1). (The figures for 1983 were provided through the kindness of Dr. T. V. R. Pillay.)

But even with the increases that have occurred in recent years, the quantities of food produced by aquaculture are much smaller than those by land farming (less than 1%) or by fishing (about 11%). The importance of aquaculture becomes higher when it is realized that its products are relatively high in nutritional value, being rich in animal protein.

The species produced by aquaculture in the largest quantities are oysters, mussels, seaweeds and fish; shrimp and other crustaceans are far less important quantitatively. In 1975 Pillay reported in Venice that of the 9.4 mmt of aquaculture products fish accounted for 37.1%, molluscs (oysters, mussels, clams) 36.7%, seaweeds 25.4% and crustaceans (shrimp, freshwater crawfish) less than 1%. Over the world about 93 species of fish were cultured, 7 species of shrimp, 6 species of crawfish, and many species of oysters, clams and seaweeds.

The largest aquaculture operations are for growing oysters (e.g., in Japan, Korea, the USA), mussels (Spain), and seaweeds (Japan, China, Korea.) Substantial amounts of fish are grown in China and India; these are mostly freshwater species like carp and tilapia.

The most rapid growth of fish farming has taken place in countries which have severe shortages of animal protein or where the government has made a particular effort to support and promote this industry—or both. Japan, the Philippines, Korea, Poland and Hungary are among such nations. In centrally controlled economies like China, Poland and Hungary fish farming is typically performed on state farms, communes and cooperatives.

Of great importance is the fact that these production units commonly receive substantial government aid in research, extension and information services, and supplies of eggs and fry. In Western nations and other countries where aquaculture is a private enterprise it usually suffers from a lack of aid from the government in services that agriculture takes for granted—especially research and extension services. The dilemma of aquaculture here is that it is not recognized in many countries either as agriculture, animal husbandry or fishing, and consequently has low visibility and rank in the government heirarchy.

There have been some significant advances in aquaculture techniques in the last decades. These include (1) a trend away from "extensive culture", where animals are held in large enclosures at low densities, toward "intensive culture" where they are crowded at high densities in small, more manageable ponds or other enclosures; (2) the use of high technology, involving supplemental feeding, disease control and other modern techniques; (3) the greater use of brackish and salt water areas in which to raise crops; (4) greater control over the environment and the stocks, (e.g., careful monitoring of oxygen content of the water, and the addition of supplemental oxygen when necessary); (5) closing the life cycle of cultured animals by maintainance of brood stock, with artificial stimulation of spawning to produce eggs and fry as they are needed; (6) the production of superior feeds and feeding regimes, to increase the growth rates, viability and market value of the cultured animals; (7) the development of pens and cages, permitting the more efficient use of water areas, including bays, fjords, and other ocean areas; (8) polyculture, where more than one species (sometimes 5 or 6) can be raised in the same pond by using fish that exploit different layers of the water and different populations of the animals and plants living there; (9) integrated culture, where fish are raised along with ducks, chickens, pigs, cattle or land plant crops, employing the waste from these species to increase the fertility of the water; (10) the use of sewage effluent to perform the same function; (11) the use of waste heat from power plants to increase the range of some kinds of fish culture and to improve growth rates.

The Status of Aquaculture in the United States

Aquaculture in the United States is highly advanced or less advanced—depending on what part of the elephant the blind observer is feeling. The United States is highly advanced in many technical areas. These include: (1) Reproductive physiology, where knowledge is already sufficient to exert control over the production and maintenance of brood stock and over spawning in several important species. (2) Nutrition, feed formulation, and feeding regimes, to produce healthy, fast-growing animals. (3) Environmental control, permitting high density farming in smaller areas. (4) Vertically integrated fish farming, where control is maintained by one operating group over all or nearly all phases of the operation, including egg and fry production, larval and juvenile raising, grow-out to market stage, harvesting, and marketing. (5) Disease detection and control. American scientists and commercial operators export these kinds of technology and skills world-wide, including countries often said to be far ahead of the United States in aquaculture—as indeed many are in certain aspects of the activity, including some practical operations and the ability to make a living by fish farming.

The United States is less advanced in aquaculture in other ways: (1) Public acceptance of aquaculture in relation to other food production systems (agriculture, commercial fishing), and to other industrial and recreational activities. (2) Laws, or at least public and societal will to apply legal authorities and rights that aquaculture already has, which would permit these investors to create and maintain viable commercial units. (3) Profitability for many kinds of fish farming, now difficult because of high costs for land, labor, feed and other essentials. (4) Difficulty in satisfying several levels of government regulation and permit requirements. (5) General apathy of the federal government.

Thus, the backwardness of the United States in aquaculture is a consequence of societal, political and economic pressures and not of a lack of scientific and technical skills.

Aquaculture is sometimes regarded as a new activity in the United States, but in fact it is over 100 years old. (Idyll, 1970.) Hatcheries were established in this country before the turn of the century to supplement the natural production of young, for species whose batches had declined. It was recognized then, as now, that the most vulnerable phase of the life history of an aquatic animal is its youth, when lack of food and heavy predation commonly reduce the numbers to a small fraction of one percent of the eggs laid. Hatchery enthusiasts hoped to build up stocks of valuable species by raising them in protected environments and releasing them into the ocean. In 1885 the United States Commission of Fish and Fisheries put the *Fish Hawk* into service as a floating hatchery. Millions of young shad, lobsters, cod, pollock, and other species were distributed.

This activity proved fruitless in increasing commercial catches, because of poor techniques and the inability to release enough young, and marine hatcheries ceased operations in the 1920's. Salmon hatcheries are back in favor now, releasing young fish which increase sport and commercial catches through greatly improved techniques. But modern aquaculture aims at the full control of the species raised: brood stock should be maintained in captivity and spawning controlled, techniques should be available to feed and protect not only the young but the larger animals, right up to the time they are ready for harvest. Natural selection should be possible, so that brood animals can be chosen for size, flavor, rapid growth, hardiness, resistance to disease, and other desirable characteristics. The skills for this have been developed in the United States for some species.

A new enthusiasm for fish farming has been evident in the United States in recent years. This has resulted in some notable successes, with good profits being made raising several species; it has also resulted in the collapse of high hopes in many instances, and some of these failures have hurt subsequent attempts at aquaculture by making it harder to raise capital and to get public and governmental acceptance.

The species raised in greatest quantities in the United States are catfish, freshwater crawfish, oysters, trout and baitfish; clams and salmon are also important, and mussels are showing promise. Most of the catfish and crawfish sold, nearly all the trout, and about 40% of the oysters are raised by culture. Statistics are poor in this country (reflecting weak government interest) and production estimates are available only as recently as 1983 (Table 2). These are presented through the courtesy of Benson Brucker of the National Marine Fisheries Service. Data on the number of commercial aquaculture enterprises are even more scanty; in 1980 the supporting material for the National Aquaculture Act stated that about 1100 catfish farms existed in the United States, along with 250 trout, 400 crawfish, 35 salmon, 30 clam, mussel, and abalone farms, and over 500 oyster culture farms. About 15 United States owned marine shrimp and 20 freshwater prawn farms operated outside the country in areas where physical and economic climates are more amenable to this activity.

Over most of the rest of the world, fish farming is usually a small-scale operation. In many countries one of the chief social attractions of this activity is that it is conducted as a cottage industry, and that it is labor intensive. In the United States, by contrast, fish farming is usually a large-scale, and frequently a vertically-integrated industry. Our economic system favors this mode of operation; there is still an opportunity for United States cottage industry-level aquaculture, but this is minimal.

The strengths of American aquaculture are impressive: first, an excellent scientific and technological foundation and good equipment; secondly, high entrepreneural and operation skills; and, thirdly, high quality products.

The constraints are also impressive: (1) high costs, (2) Official apathy, (3) numerous and sometimes inappropriate laws, (4) lack of research and development assistance, including pilot-scale testing of new systems (5) low availability of capital, (6) the ecological threats posed by the introduction of non-native species.

Aquaculture is a business, and as such must make a profit to survive. Dealing as it does with living organisms, (in the United States, usually with animals), it is beset with many risks, including the possibility of losing the fruits of years of labor. It is a highly technical activity, where knowledge of the results of science is essential for profitability—at least in our economic system. As a latecomer in competition for land and water space it is usually at a strong disadvantage compared with other commercial and recreational activities. As a sometime water polluter and as a frequent victim of water polluted by other activities, it suffers disproportionately from environmental degradation.

Bearing the pressures, aquaculture in our society has little chance of sustaining profitable operations, or indeed, even of getting started, without some government assistance. Action—or lack of action—by a government can have a powerful and even critical effect on the success of attempts to initiate or sustain an aquaculture operation. Such action includes certain essential elements without which the industry can exist only with unnecessary struggle and with diminished chances of success. The essential elements are:

1. An explicit public policy that manifests a positive attitude toward aquaculture.
2. An even-handed system of regulation that gives aquaculture some degree of equity with competing or imposing activities.
3. An administrative infrastructure capable of implementing state policies and regulations concerning aquaculture.
4. Support for research, extension services and training for aquaculture.

TABLE 1

WORLD AQUACULTURE PRODUCTION
(In metric tons)

1983

Region	Finfish	Molluscs	Crustaceans	Seaweeds	Total
Africa	43,553	286	26		43,865
Asia & Pacific	3,575,084	2,589,151	86,095	2,392,047	8,842,377
Europe & N.E.	729,200	548,380	167	100	1,277,853
Latin America	167,801	30,953	20,087	1,637	220,478
North America	155,800	133,178	27,425		316,203
Total	4,671,244	3,301,948	133,800	2,393,784	10,500,776

Source: Food and Agriculture Organization, Rome

TABLE 2

ESTIMATED U.S. AQUACULTURE PRODUCTION FOR 1983

SPECIES	VALUE ($1000)	WEIGHT (Metric tons)	(1000 lbs.)
Baitfish	100,000	15,000	33,000
Catfish	132,000	100,000	220,000
Clams	9,500	4,300	9,460 (1,689)*
Crawfish	30,000	27,300	60,000
Freshwater prawns	1,500	125	275
Mussels	1,500	1,680	3,700 (775)*
Oysters	31,500	125,000	275,000 (23,300)*
Pacific Salmon	6,800	9,400	20,600
Trout	50,000	20,000	50,000
Other	7,000	3,200	7,000
TOTAL	369,800	308,005	679,035

*Meat Weight

Source: National Marine Fisheries Service

Before describing the government role in aquaculture development, it should be emphasized that careful examination should be made by government groups to determine whether aquaculture is an appropriate activity for the political unit considering it. Climatic, environmental, ecological, political, economic, and legal characteristics of a region may well make fish farming an unsuitable industry there. Thus, in spite of the manifest promise of aquaculture generally, officials of a particular region should not be dazzled by this promise, but should carefully weigh the costs—monetary, political and social—of encouraging aquaculture against the returns that can realistically be expected. If the results of such a study are promising, the government can increase the chances of success of a fish farming industry by considering its role, including the four essential elements previously mentioned.

The Government's Role in Aquaculture Development

1. A favorable attitude toward aquaculture by the state can be most clearly manifested by explicit public policy stating that the activity is in the public interest. This is most logically located in an aquaculture act which the legislature should probably pass for this and other purposes. The passage of such an act is in itself a statement of a positive attitude. But obviously, the attitude will most effectively be shown in the actions of state officials in dealing with the industry.

2. An even-handed system of regulation can be centered in an aquaculture act. As a latecomer among the many activities using the water and shoreline environment, aquaculture has been laden with a confusing and burdensome array of regulations, many of which were designed for other activities and are inappropriate to fish farming. There are 120 federal laws, scores of state and municipal laws and hundreds of regulations that impact on fish culture in this country (Aspen Systems Corp.). These are designed to keep peace between aquaculture and activities on which it impinges, to protect the environment, to protect public health, to control disease, and to accomplish many other tasks which are in the public interest. Aquaculture should not be given exemption from necessary environmental regulations, but by the nature of this new activity and the history of many of the laws in existence, it has transpired that fish farming is sometimes unnecessarily and unfairly burdened by laws intended for other activities.

Appropriate regulations and laws include those which establish clear property rights in the organisms being cultured and in the subaquatic lands and the water column where the culture is taking place, through provisions for leasing land and water areas. To quote from a paper prepared for the World Conference on Aquaculture held in Venice, Italy, in 1981 (Idyll, in press): "A major problem faced by fish farmers is the difficulty of establishing ownership or legal control over a water area. This is especially hard in coastal regions where rights to use and traverse water have already been vested in uses which may be incompatible with aquaculture. These uses include commercial and sport fishing, recreational boating, navigation, waste disposal, mineral extraction, and aesthetics. Aquaculture usually appears on the scene long after the other uses have been established and accepted, and there may be no room for a new contender. Whereas in Japan, the existence of forests of stakes supporting seaweed culture or crowds of rafts covering coastal bays is accepted as a matter of course, in the United States, rafts for suspended oyster culture or pens for salmon raising have caused strong opposition from residents on the adjacent shoreline."

3. In the process of establishing regulations, a state government should ensure that it creates the infrastructure necessary to make it work efficiently. Regulations should not impose a crushing administrative and bureaucratic burden on the fish farmer—as is unfortunately very frequently the case. To quote from the paper cited above, "In the U.S.A. the states have the primary authority and responsibility for developing and supervising aquaculture, although the federal government has a substantial role (and one that many in government and industry think is too substantial.). But most of the laws that specifically authorize or control aquaculture business operations are at the state level, and state laws and regulations often have greater impact than federal actions on the daily operations and on the end of the year profit or loss sheets."

Compliance with regulations has sometimes been so burdensome to fish farmers that their enterprises have failed for this reason alone. Water laws and regulations are among the most troublesome. As one of many examples, the United States Army Corps of Engineers requires permits for the disposal of dredge and fill, based on requirements developed by the Environmental Protection Agency. "The law also requires that the Fish and Wildlife Service of Interior and the National Marine Service of Commerce have opportunity to review applications." Then, one or more state agencies may also review them. "One of the commonest complaints of fish farmers concerns the length of time and the expense of securing dredge and fill and other permits. Delays due to reviews of several agencies may take one to two years. Most states have not developed the machinery, staffs and skills to implement their regulations. For example, Maine growers are handicapped by the lack of government inspectors to certify the health of oysters shipped from their state. In Virginia, the Marine Resources Commission lacks adequate personnel to survey grounds for oyster leases, and the state is five to six years and 700 applications behind in this task; an applicant may take seven to eight years to have a lease approved." The situation in these states may have improved since this was written, but it is likely that there and elsewhere administrative machinery is not fully up to the task.

Quoting again from the paper presented at the Venice Conference in 1981: "Many and perhaps most states have not made serious efforts to promote aquaculture, but others have. Florida has a special Mariculture Act, and has made official pronouncements of policy support. This has not been fully effective yet since the state has retained a cumbersome bureaucracy involving 32 agencies without a clear central authority. Oregon has established a State Permit Center and a Regulations Service Program whose objective is to simplify permit requirements and to make their results more certain."

"Hawaii has been the most aggressive in the official encouragement and practical assistance to aquaculture. In 1977, the Hawaii Coastal Zone Management Program published a *Register of Government Permits Required for Development*, '. . . to encourage Government agencies and the public to consolidate and streamline the development review process so that Government red tape can be eliminated without compromising Hawaii's environmental quality.' That same year the Department of Planning and Economic Development issued *Permits and Environmental Requirements for Aquaculture in Hawaii*, which 'provided an analysis of the redundant and overlapping Federal, State, and county laws . . . This document . . . provided the impetus for a major regulatory reform in Hawaii that has vastly simplified certain permit and review procedures.' It proved so useful that a revised edition was issued in 1980.

In the latter document, an introductory statement by the Governor of the State summarized the problem faced by prospective aquaculture operators in the United States: 'It is often the complexity of today's society which discourages citizens from becoming entrepreneurs. . . very often the anticipated gains are simply not worth the cost in time and effort to overcome institutional barriers. The growth in government red tape—permits and approvals required, officials to see, hearings to be held, forms to be filled out, studies to be done, statements to be filed—has been discouraging to everyone who confronts the tangle. Red tape is often the result of society's laudable desire to protect its citizens and environment, and we pass laws and regulations to prevent similar crimes. In the process, we handcuff desirable activities.

A special act in Hawaii sets forth policy and specifies the kinds of available aids and the controls imposed. The aquaculture Planning Office provides a consulting service for active or would-be farmers. State offices work with applicants before the permit process begins, substantially reducing delays from about two years to as little as two months.

4. Agriculture in the United States is acknowledged to be the best in the world. It has gained this eminence to a significant degree through the information and techniques provided by research in the universities and government institutions. It is taken for granted that agricultural research must be done, and that it must be continued indefinitely since new problems are constantly being encountered. Aquaculture has the same needs. Research on a complex array of problems facing the industry is necessary; life history and biology of the species being raised; genetics and reproduction; growth and behavior; nutrition and diet; environmental requirements; engineering, construction, and operation of hatcheries, ponds and other facilities; disease and parasite control; production of seed stock; predation and mortality; harvesting and processing; introduction of non-indigenous species. Agriculture receives this kind of research and more, continuously and as a matter of course, from the federal and state governments the attitude of the United States federal government is that aquaculture, although it is a food producing industry, must stand on its own in providing research support. This leads to a catch-22 situation since there is no aquaculture industry, in the sense of large companies or cohesive consortia of companies, raising one crop, which could afford to maintain support for the necessary research. After a certain stage of development, such strength might be attained by industry. But any political unit with serious intent to develop aquaculture should expect to support some level of research and pilotscale studies. Some of this could be provided by support to university and other scientific groups. Support for extension services and training could be handled similarly.

Summary

In summary, aquaculture can be an activity of considerable economic and social value, providing food, jobs and profit, and using water and land resources that might otherwise be under-utilized. But while this substantial promise exists, it should not be assumed that aquaculture is appropriate everywhere. There are places and times where environmental, economic, political, or administrative conditions prevent aquaculture from being successful.

Aquaculture in the United States is a relatively small industry compared to this activity in some other parts of the world, and compared to agriculture. This is partly because it is a relatively new activity as a science-based food industry and partly because the United States is not short of food. But the products of aquaculture are in demand and can be of especially high quality, and with catches of seafood facing a fixed upper limit, fish farming deserves careful scrutiny.

Aquaculture in the United States is backed by good technical information, but it is constrained by high costs of labor, land and other requirements, and by social and legal barriers. To be successful, an aquaculture enterprise should have the explicit support of government. If a state determines after careful weighing of probable benefits compared to monetary and social costs that aquaculture would be an appropriate local activity, the government should be prepared to commit the legal and financial backing required for profitable operations.

Questions and comments following Dr. Idyll's presentation

The first question to Dr. Idyll was: Considering the success of catfish, crayfish, rainbow trout and oyster aquaculture in the United States, have they successfully overcome the constraints you discussed? Are they fairly old industries that were there before the regulatory morass was created and so did not have to be confronted with it? Second, has government support been significant in their present success, and if so, to what extent?

Dr. Idyll pointed out that catfish and trout aquaculture are very different in their history and both have surmounted problems, creating successful and profitable activities to some degree despite the government. The trout industry exists, of course, because of highly favorable environmental circumstances, namely the availability of good water. As to the catfish industry, Dr. Idyll said he really did not know to what to attribute its success; catfish farmers continually have fought with the government, and have sought its support. Certainly catfish farming has had state government support, notably in Mississippi. The trout industry received no financial government support or encouragement, but profited from research conducted for the trout sport fishery.

Dr. Idyll alluded several times to the importance of public acceptance. Because the organisms most under culture are those the public likes—such as oysters—was the reference to public acceptance of the product, or of aquaculture as a business?

In answering, Dr. Idyll contrasted the general attitude in the United States toward aquaculture with what he has seen in other parts of the world, in Asia for example. "I was deeply impressed in Japan by the fact that in bay after bay along the coast there are forests of stakes and multitudes of cages where aquaculture is being carried out. This kind of occupation of the shallow water closest to the coast would not be tolerated in the United States. In fact, there were some attempts on the West Coast where oyster farms were created and other places where salmon cages were set up and the operations had to be stopped because the public would not permit the operations to continue. Thus, the attitude I allude to is one where aquaculture is given some kind of preference, or at least equity, in operations along the coasts.

Of course there are many opposing interests . . . recreational fishing, boating, swimming, and so on, and many laws. Laws depend on the will of society and the attitudes of the public, and many of these laws make aquaculture very hard to sustain. I think the reason that catfish and crayfish farming have boomed so fast is that they are on privately owned farmland. That is in sharp contrast to oyster production in coastal areas where there are multiple use conflicts.

A listener commented that the cages and stakes in the bays of Japan are specifically related to a partnership between cooperatives—the fishermen's associations—and the government. Such cooperation exists in other parts of the world where aquaculture has been successful in paternalistic societies, as in the case of carps in Poland and China, and for other species in a large part of India. In free enterprise worlds there is just not much aquaculture; even the great efforts in Norway are small compared to those where public and private efforts are integrated.

A floor commentator discussed the essentially two types of aquaculture now on-going in the United States. One type is small proprietorships, partnerships, or small corporations which have the advantage that they have no large overhead to support, generally not a large capital base to carry, and a general lack of built-in corporate bureaucracy or procedural requirements. The other type is the large corporation, and most such corporations in the United States today are not production-oriented in the aquaculture sense. They may process food, but don't farm it. Large corporations have the advantage of strength and power and experienced staff to fight through procedures and regulations, and they can sustain losses for a long time. But after creating the aquaculture subsidiary and carrying it, they find it does not produce sufficient return on investment and they get rid of it.

There is much evidence that large corporations have a hard time making it, but on the other hand, there aren't many small operations that have succeeded, either, and those which have succeeded—trout and catfish—are marginal. But listen to what the land farmers have to say and it becomes clear that traditional agriculture is marginal, too.

A number of comments were directed to government regulations, especially state regulations. One point in regard to the small aquaculturist is that he would profit most from what might be termed benign neglect of freedom from some restraints which often make no sense. However, a related point is that the aquaculture industry such as it is, has been of little or no help to the government in formulating sensible and useful regulations, and in establishing guidelines that will protect the public interest while aiding the culturist.

Comments critical of government regulation were balanced to some extent by other comments pointing out that state agencies have been very helpful, within their ability, to give assistance, but are often bound by laws which they must carry out even if counterproductive. A New Jersey Department of Health person added that too often persons approach the agency resentful over the fact of being regulated at all instead of discussing specific problems and seeking solutions together.

A final comment to close Dr. Idyll's portion of the program was from a person who said that his experience with government people was pretty positive; he had come to realize that there is only one way the image of the bureaucrat can go, and that is down, because all the helpful and useful actions go unnoticed while mistakes or unpopular actions are given wide publicity and comment . . . yet, on balance, agency people, whether Federal or State, are very dedicated and helpful.

CHAPTER II

THE NON-FOOD ASPECTS OF AQUACULTURE

John H. Ryther
Director, Division of Applied Biology
Harbor Branch Foundation, Fort Pierce, Florida

John Ryther was associated for over thirty years with the Woods Hole Oceanographic Institution as a research associate, marine biologist, senior scientist, Chairman of the Department of Biology, and Director of the Coastal Research Center. He continues his association with Woods Hole Oceanographic Institution as a guest investigator although his focus of activity is now the Harbor Branch Foundation at Fort Pierce where he moved in 1983. He has been professor of aquaculture at the University of Florida, Gainsville, where he continues as Adjunct Professor of Agriculture, and he is Adjunct Professor of Oceanography at the Florida Institute of Technology at Melbourne. Dr. Ryther was educated at Harvard, where he earned his doctorate; in addition, he holds an honorary doctorate of science from the University of New Hampshire. Included among his many honors and activities are Directorship of the United States Biological Program for the Indian Ocean Expedition, Chairmanship of the Tropical Laboratory Study Committee of the Associated Universities, membership in a number of commissions and committees of the National Academy of Sciences-Research Council, including head of the Commission on National Resources; membership on the Biological Oceanography Panel of the President's Science Advisory Committee, Commissioner on the United States Marine Mammal Commission, and member of the editorial board of several scientific publications, including Aquaculture.

We begin with a bit of history about waste water treatment, which is a non-food use of aquaculture. Shortly after World Was II, a method was developed for treating waste water by dumping it into ponds, called sewage oxidation ponds. The concept was that organic matter would decompose and produce nitrogen, phosphorous, and other nutrients needed to support the growth of algae, the algae would produce oxygen for bacteria to decompose the sewage, and the bacteria would produce CO2 needed by the algae. With all parts of the system working together, the organic matter would be converted from something not very pleasant to nice, clean aglae.

The problem with the system is that if waste organic matter is converted to algae and then the algae is disposed of in a river, lake, or ocean, the organic loading is not reduced at all; there is just as much suspended solid, and just as much BOD (biological oxygen demand) in the algae as there were in the wastes. The next step, then, is to run the algae through some kind of process which will de-water, grind up and sack the residue, which may then be used for cattle feed, fertilizer or mulch.

At this stage, that horrid word "economics" emerges. It costs a lot of money to extract the algae from the water, far more money than any use of the algae could bring. So the system has never proved to be economically feasible.

People around the world who tried to raise single-cell algae as a high protein food, always ran into the same economic constraint. In attempts to improve the economics, the concept was then taken in two directions.

Growing Higher Plants in Waste Water

A number of higher plants have been grown in waste water with varying degrees of success, and perhaps the best example is in the South, especially in Florida. Water hyacinths are grown in waste water in a number of places and are very effective in cleaning up the water. The plants are big enough for relatively easy harvesting, but once harvested, what's to be done with them? It's costly to haul them around and the final product of any kind of processing isn't worth much. The plants can be composted and used locally, and this is done to a limited extent.

Another approach can be seen at Disney World: A big hyacinth farm produces plants that are digested to produce methane gas for fuel. The system is neat, effective, and economical.

A related process not strictly aquaculture, is what EPA and others are calling Nutrient Film Technology.

There seems to be considerable interest in the technique, which has been known for years as hydroponics. Terrestrial plants grow huge root masses in gravel or some other substrate through which a thin film of waste water flows. This technique probably is worth additional examination.

Animals to Harvest Waste Water Plants

Instead of paying the mechanical and energy costs of getting algae and other plants out of the waste water, why not get an animal to do it for you? The Chinese have done this for centuries, using Chinese Carps which eat plankton and detritus directly. A number of animals are available which feed low on the food chain, either eating the algae or feeding on the small plankton animals which feed on the phytoplankton.

The method has produced very large fish production in a number of places. Again, the problem is one of economics. The kinds of fish which feed at the proper trophic levels are not much prized by the American fish food eater. While carp has an ethnic market, which is very seasonal, the price remains low or the market non-existent except for a few days a year. Other species similarly face low demand and low price, and if production is in waste water, that fact deals the final blow to marketability.

Mixing Waste Water and Sea Water

At Woods Hole we conducted a similar marine-based project to see if we could grow single-cell algae in a mixture of waste and sea water and feed the algae to such marine animals as clams, oysters, mussels, and scallops. We got good conversion and good growth of oysters and clams, but we did run into some problems. One was that we couldn't control the species of algae in the big, open ponds, so we ended up with weed species which would not support the growth of local oysters and clams, although the weed algae did well in supporting exotic species like European and Japanese oysters and Philippines hard clams. We don't understand why. We grew a pretty good crop of the exotics, and then ran into a basic ecological problem: animals do not eat their food with 100% efficiency. We had efficient nutrient removal from the sewage by the single-cell algae, then the oysters ate the algae and put all the nutrients back into the water again. So, as a final polishing step, we used seaweeds as an excellent filter which took out all the nutrients the shellfish had put back into the water again. We ended up with clean waste water and a crop of seaweed.

The next problem was with the Food and Drug Administration. We hired a virologist and added polio vaccine virus to our system in huge quantities as a tracer. We found that if we depurated the oysters and clams for a couple of weeks we couldn't find any traces of virus left in the system. But the FDA people asked if we could prove there wasn't a single virus present in the oysters. Of course we couldn't. They claimed that one hepatitis virus can produce hepatitis. That may or may not be true, but it appears as though the health implications of growing a crop like oysters and clams in waste water eliminate the possibility of doing it commercially.

Seaweed and Biomass

Finally, we questioned why we should go through the laborious process of treating waste water to grow phytoplankton, feed it to molluscs, and then grow seaweeds; why not just run it through seaweeds in the first place? We started working with seaweed, and that turned out to be very satisfactory.

As we ran into the first oil crises, the Department of Energy began hunting for new energy sources, and among these was biomass. The idea was to grow biomass, convert it to methane by anaerobic digestion and so produce a nice, clean fuel. Department of Energy wanted scientists to devise ways of producing quantities of biomass. We applied for and received a grant to grow seaweeds for biomass, and moved our operations from Woods Hole, Massachusetts, to Florida because we could grow about twice as much seaweed in the warmer climate.

We became quite proficient in growing seaweeds in a highly intensive system. We aerated the flow so that the seaweed is continually suspended in the water and got tremendous yields. Although the green alga *ulva* was one of the most successful, the fastest grower was a red seaweed, *Gracilaria*, which is found up and down the East Coast of this country, and all over the world. The yields of *Gracilaria* were as high as 50 dry tons per acre per year, and if you know about crop yields, you know that such an amount is tremendous production, about as high as any plant on earth. It compares with the impressive yields of sugar cane and some of the other grass-type land plants.

To get such yields, we had to pump great quantities of water, and in terms of energy, the system was just not energy efficient. Then the oil shortage ended and there turned out to be a glut of natural gas, so the whole idea of growing biomass for energy no longer looked exciting. We're still getting a little support, due to government inertia, but our hearts really are not in biomass production any more.

There is however, another fascinating aspect to seaweed growth, and especially to our work with *Gracilaria*. Like other red seaweeds, *Gracilaria* contains a valuable marine colloid, in this case, agar, the gel material put on bacteriological plates to grow cultures. There is a huge industrial and medical demand for agar, as there is for the other marine colloids, carrageenan and alginate. The demand for food grade agar is especially high. Every MacDonald's hamburger has some agar in it, in the sauce.

Much of the agar we use come from Japan, produced from a red seaweed called *Gelidium* harvested from their coastal waters. But pollution is depleting the Japanese crop, so the Japanese are searching around the world for new sources. There is a lot of *Gracilaria* that grows in Florida's Indian River and other places up and down our East Coast, but unfortunately, it is a poor source of agar. On the other hand, *Gracilaria* grows vegetatively; it is a sterile plant which does not go through a reproductive cycle at all, and one of the interesting things about it is that it mutates freely. Not only the color, but the shape and everything else changes.

Some of the mutants are not red, but green. Some have no agar at all, and others have a lot. We now have 27 varieties of *Gracilaria* and have hired a biochemist to begin looking at their chemical content. One that is an excellent agar source, better than the Chilean agar which has been used commercially and exploited by the Japanese. Ours are all natural mutations, but a Canadian scientist working with *Gracilaria* has been using chemical mutagens and has produced hundreds of varieties.

You can see the potential. If you can grow 50 dry tons per acre year and produce good quality agar which sells for about a thousand dollars per ton, that is pretty good farming.

The possibilities of *Gracilaria* mutations does not stop with a good agar producer. One mutant, a really deep red one, contains about three percent of its weight as phycoerythin, the red pigment. Those of you who are up to date on biotechnology are aware that phycoerythin is very much in demand because it is conjugated with monoclonal antibodies for detection by laser. The pigment flouresces at just the proper wavelength. Now, phycoerythin is worth about $2500 per gram—and these plants contain three percent of the pigment. It isn't easy to extract, but perhaps the technique can be improved.

The potential of seaweed for useful active substances has not really been investigated enough, but even the little we know tells us more effort would pay off. For instance, another of our seaweeds contains a substance useful in medicine and agriculture; a nematologist at the University of Florida, who tested some of our seaweed extracts against nematodes under a small Sea Grant, found one that was extremely active. Extract from the seaweed not only controls the growth of nematodes, but stimulates the growth of the host plant—tomatoes, in this case. We're beginning to try to grow that seaweed as an agriculture materials source.

Finally, the common temperate zone seaweed, *Ascophyllum*, which grows in the New England intertidal areas and in Europe, contains fairly high concentration of a growth hormone particularly good for root crops like potatoes. It's obvious that there are a lot of such useful natural products which could be utilized.

We found another use for our *Gracilaria* mutations, by the way, which leads me into another non-food use of aquaculture. People from the tropical fish industry came by and they happened to look into our tanks, and they said, "Wow! Where did you get that stuff?" We told them we grow it all the time, so they asked for some to take back for market testing for a aquarium use. A few weeks later we got a big order from them, and they asked how much we would sell it for. We figure that the stuff was worth about 10 cents a pound for methane, but worth more than that to them, so we decided to charge a lot—$1.50 a pound. They said they'd take a large quantity, and we've been shipping to them regularly. I just found out a couple of weeks ago that they've been selling it for $10.00 a bunch. I think our price will go up next year.

Aquariums and tropical fish are big business. Florida is the leading United States producer of ornamental fish, a 50 to 100 million dollar business annually, mostly of a "mom and pop" type. Only a very few species are bred and grown in captivity. The most valuable ones are imported from Hong Kong, Thailand, Singapore, and the

Philippines. The fish are collected from coral reefs with cyanide which kills three-fourths of the population. The other fourth is shipped to the United States and three-fourths of those are dead by the time they get here. So the price is very high per fish, and the sizeable market is expanding. Decimation of the natural reef populations has become a very serious problem.

There is no reason why exotic fish from the Tropics should not be bred and grown. We're working with about a dozen species in our laboratories, trying to develop a breeding technology that will make us independent of foreigh shipments with their huge losses. If profit is your motive, look at it this way: price to the grower for a food fish—catfish—is about 70 cents per pound. Some of the ornamentals are worth about $400 per pound.

I think my principal point in all of this is that the non-food uses of aquaculture have considerable value and promise.

Questions and comments following Dr. Ryther's presentation

Carrageenan is a marine colloid much like agar which also is obtained from red seaweeds. Dr. Ryther noted that carrageenan happens to be plentiful at the moment compared with agar and hence does not have the same value. He does have a few tropical species which do produce carrageenan. While there is a bit of research on red seaweeds going on in Canada, Maine, the traditional United States source, is devoting itself to harvesting only (Canada and Maine have been principal suppliers of Irish Moss, *C. crispus*, valuable for its carrageenan content).

A questioner astonished at the news that water hyacinths are being cultivated on purpose after all the efforts to get rid of them in Southern waterways, asked what products could be made from the pests. Dr. Ryther replied that mulch could be made from hyacinths or they could be fermented for methane, but the value is very low. They are grown only because they are so effective in waste water treatment.

In answer to another question, Dr. Ryther said he thought there probably were fresh or salt water seaweed or algae species that could be used in New Jersey for waste treatment, and efforts should be made to key the species to the kind of waste, e.g. agricultural waste, human waste, or industrial waste.

Following up on his comments about tropical fish in answer to queries, Dr. Ryther noted that ornamental fish is the second most popular hobby in terms of money spent, with the winter months as the big market season. Tropical fish breeding can be done with modern closed system technology; his own systems are semi-closed for the fish and open for the seaweeds. For the future, as breeding succeeds, prices will probably drop and companies will set up in the Caribbean where they can work more profitably.

Finally, on the reason for open systems and high pumping rates for seaweed, a new supply of CO_2 must be introduced constantly to get high yields. If one could set up next to an industrial plant, with CO_2 output, pumping costs would be less.

For New Jersey, Dr. Ryther recommended serious consideration of aquatic plants as sources of high value materials and for their ability to clean waste water.

CHAPTER III

CANDIDATE SPECIES FOR AQUACULTURE IN NEW JERSEY

Michael Castagna

Scientist-in-Charge, Virginia Institute of Marine Science
Eastern Shore Laboratory, Wachapreague

Michael Castagna became a Virginia Institute of Marine Sciences Division Director in 1979 after a career which carried him around the United States and to a number of countries abroad as a planner, designer, and consultant on aquaculture business and academic aquaculture ventures. He is an internationally recognized authority on the culture of molluscs and had held offices ranging from Executive Committee membership to the Presidency of the National Shellfisheries Association. He is Assistant Director of VIMS and Professor, College of William and Mary.

After completing graduate work with an MS at Florida State University in 1955, Michael Castagna spent two years as an assistant curator at Marineland, Florida, before joining the Bureau of Commercial Fisheries where he became a research biologist. During this period he became a diver and underwater cameraman, working on fisheries investigations between mollusc culture activities. Starting in 1958, he became known as a practical expert in mollusc culture and was called as consultant to commercial growers and several universities for which he planned and developed marine culture facilities, among them the University Del Norte in Chile. Mr. Castagna has written widely on the basic biology and applied culture of marine oragnisms, and an indication of the regard of the aquaculture community is, when a problem in mollusc culture arises, "ask Mike."

Aquaculture as a business in the United States is fairly new, but it has been used as a management tool for many years, as in providing cultch for oyster set, or operating trout hatcheries for sport fisheries. Back in the early 1950's, aquaculture became an extremely popular field for investment, and a lot of damaging things were done in the name of aquaculture that set the industry back many years.

Very often, candidate species were chosen that had no chance of making it. The culturists would say, "I'm in an aquaculture business," only they ignored the meaning of "business." One basic thing about a business is that the product has to sell at a profit, and aquaculturists were slow to learn this. In fact, we had a man in our area who grew a product to just below market size, at which point he had 25 cents per item invested, and he sold the product for a nickel. The sooner this man got out of business, the better off he would be. Obviously, in a case like this, increasing production was not the answer.

Originally, more often than not, species were selected because they were easy to grow. There was no real concern about marketability. For instance, a well-known millionaire in the fishing business supported a lot of research in Florida for pond culture of menhaden. He thought if he could grow menhaden under controlled conditions, he would escape all the other problems of the fishery, such as a tempermental fish captain and it would be the happiest day of his life. When you realize that even in today's market menhaden are worth only a few cents per pound and were worth even less then, it was not a viable business choice of species. However, the menhaden were easy to grow--easy, but not cheap.

The next species to be tried were mullet--and mullet brought 10 cents a fish in a good year in Florida. Finally, there was a switch from low value to high demand fish like pompano and red snapper, and crustaceans like white shrimp. This was the right way to go--except that the species, though they had high marketability, were being farmed in a poor area of the country for their culture. For instance, pompano leave Florida every winter because temperatures drop to a lethal level. White shrimp weren't ready for culture except perhaps on a labortatory scale, and red snapper had to compete with a pretty good fishery, and the technology wasn't established to grow them.

During this period, we went through the idea of feeding the world through aquaculture. It's a high ideal, but the third world which needs the aquaculture product are going to have to produce for themselves--and quite a few are doing so. As for the United States producing the aquaculture products, when we consider our high labor costs, the high costs of water and land, and even higher costs for engineering, plus the strong dollar, the countries that need aquaculture products, the most can't afford them. So a lot of the good, easily grown fish most useful for protein had to be abandoned as prospective specimens. On the other hand, the technology we developed for some of the species which have little or no market in the U.S. was applied and even improved in other countries. So projects that didn't pan out economically here did some good elsewhere.

One species did work out--catfish. It's a hard business to understand in some ways. Originally catfish farmers just started as pay-to-fish ponds and made money doing it. A few trout farmers, incidentally, have made a little money the same way. Well, the catfish people kept producing more and more catfish, and the technology improved with some good university research, and the farmers went out and found markets for their catfish. They banded together and started promoting, and today farmed catfish are a staple. We even have fast food catfish outlets. So that industry is booming.

For a while there were many trial projects with polyculture, catfish, bass, and bluegills all together in the same pond. If the ponds were in the right geographic area from the standpoint of climate, the ponds eventually converted to just catfish. Carp were grown, too, and looked promising for a while. Carp sell for a high price in New York and other places were there's an ethnic demand at the right time of year--but at other times you can't give them away.

Finally, looking at aquaculture as a business led people to the only economically sound conclusion: to grow species for which there is high market demand and a good price, species which can be produced at a cost that will allow a return on investment and a reasonable profit. Today, the aquaculture business is growing shrimp, prawns, clams, oysters, abalone, and a few high priced finfish like red drum.

Some of the good high-value species have problems, too. Often our climate isn't really well suited, and aquaculture businesses have moved to other places, usually south in more tropical areas.

The regulatory climate also offers plenty of problems. We have so many regulations that people who might otherwise develop a profitable business simply give up, or grow broke paying lawyers. Part of the social problem is that culture of many species may compete with a traditional fishery, and a lot of fishing associations do their best to block aquaculture because of the possibility of competition.

With this background, let us try to set up some criteria for choosing candidate species for aquaculture---and this applies not only in New Jersey, but anywhere people are thinking about going into the aquaculture business.

First, the selected species should have good market demand and a good market price.

If these two factors are not present, the task of marketing becomes so overwhelming that no entrepreneurial outfit could make it. A major company with plenty of capital resources and plenty of patience would be needed.

Interestingly enough, in the early days some of the biggest money made by aquaculturists was in selling their little outfits to big corporations. For one thing, the economic structure of the country is such that a big company could pick up a little one and write off virtually the entire costs of the R&D and market development. If the enterprise failed---and a lot of them did---there were further tax write-offs. In essence, the big outfit had a choice: give it to the IRS or put it in aquaculture.

Second, with a good market and a good price, is species compatibility. The geography must fit the candidate species. Temperature is of primary importance. Now, it is true we can improve on nature's temperatures with power plant effluent, or with the big inflatable greenhouses used in Florida in recent years by ornamental fish culturists, or through other engineering means, but keep in mind we are talking about business. If too much money has to be put into engineering and energy, those who provide the energy and engineering make the money, not the aquaculturist.

The chosen species also must be compatible with native aquatic and terrestrial species, and with the environment. A species which might prove antagonistic, or might bring disease or parasites into an area must be avoided. If the very idea has all the residents of the area and their associations up in arms, the species is incompatible with the social environment. These are not minor matters. There are species which have escaped into the wild and caused difficulties; for instance, the famous "walking catfish" case in Florida. There have been several cases of aquaculture projects which were sound in every way---except that the pens, nets, trays, or whatever were considered to be "visual pollution" by people who owned waterfront property, and the owners won out.

Third, it is a good idea to look into the history of native species for possible aquaculture candidates. In too many regions some of the fine and highly prized species that used to be plentiful are no longer around in commercial quantities. The reason may be degradation of the water, or it may be pollution combined with habitat destruction or even over-harvesting. But, the waters still are polluted and the habitats changed, you say, so that door is closed--but that isn't necessarily so. Often the weak link in the life cycle of some species is the embryo stage. For instance, oysters are very vulnerable to relatively minor changes in water quality from the time they are eggs until they become larvae.

In this and similar cases, if you can control the early stages in a hatchery, treating or selecting the hatchery water of siting the hatcheries in good water, the species can be brought safely to a useful seed stage and planted in areas less than optimum for hatching but good for growth. Those of you familiar with aquaculture history can recite lists of operations of both shellfish and finfish species that are hatchery based. Some are publicly supported and some are successful commercially.

Fourth, it is important to select a species for which the technology of culture exists. If the technoloty isn't there and it is necessary to spend a couple of years on research and development your entire capital can be eaten up and bankruptcy is just around the corner. This used to happed quite often in the early days, and those who are going into the aquaculture business to make a profit should take this very seriously, and select species we know how to grow.

Fifth, there are many factors which add up to economic feasibility. There is the cost of space. If the species requires lots of room, the costs go up, so you are better off choosing an animal which can be grown in a tight, efficient little culture facility. Then, there are time constraints. If growth to market size takes a year, more or less, you perhaps can live with that, but if it takes six years, you're in trouble. It isn't enough to say, "I can get six times as much for this product, so I can take six times as long to grow it." In six years a lot can happen: storms, flooding, extensive power failures, drought, a polluting industry setting up next door, a change in political climate which affects the degree of protection you get, or even a change that imposes a whole new set of regulations you cannot meet and stay in business.

Sixth, and last, an aquaculture business has to be managed like any other business. Without going into all the elements which constitute good management, let me sum up a lot of them in one sentence: *If it costs a dime to grow a thing you can only sell for a nickel, don't grow it.*

Now, let's look at species which might be considered for aquaculture.

We start by defining our purpose, because there is a different mix of species from which to choose for each purpose. If the aquaculturist is primarily a hobbyist who is satisfied if he makes only a small profit or just breaks even, he has a wide spectrum to choose from. If the culturists are running a "Mom and Pop" operation and have another major source of income they hope to supplement, that's another, smaller selection But if the objective in an honest make-a-profit type of business, the real constraints set in, and that's the only type of aquaculture.

The first division of species is between fresh and salt water. Among the fresh water species, it's clear you could do all right with any kind of trout in New Jersey, assuming good water quality. Perhaps catfish might make it in the southern parts of the state--but not in the north because the growing season is too short. Other fresh water species that might be looked at are bass, pike, carp, tilapia and so on, but none are really good candidates either because New Jersey is too far north, or, because the state has fresh water problems; there simply would not be an adequate supply of high quality water. Except for very small operations, it would be prudent to ignore most of the fresh water species. You can probably cite exceptions, and I'm sure there are some. For instance, fresh water prawns in power plant effluent have a substantial history, as Al Eble and Bruce Godfriaux can relate But in discussing a real business operation with growth potential and genuine return on investment, I don't believe fresh water animals are the choice.

That leaves us with estuarine and marine species. We don't have time for an exhaustive examination, so let's take a few examples. To begin with, one historically excellent species which is now practically missing is the sturgeon. Work done in recent years shows that they grow rapidly, either to pan size or a size which can be smoked--and smoked sturgeon is thought by many to be one of the great gourmet delicacies. So, naturally, is caviar. The sturgeons can be grown to proper size then taken into the laboratory, operated on and the gonads removed. After that the fish are put back into the water to grow new gonads for the next year. In California they've been doing this with the same group of sturgeon for five years, so the technology does exist. The fish probably don't like it but it can be done.

Another species which might be considered for this area is the rockfish. There are some very successful rockfish hatcheries on Long Island, and in North Carolina for instance. I think you could grow both rockfish and the rockfish-perch hybrids. Now, having grown these desirable animals, what do you do with them? At present, you could sell the rockfish to various state and federal agencies to be put back in the environment to help rehabilitate the species, which is in serious trouble. As to selling them for a profit...the regulations would be simply an unbelievable mass of barriers. More about this in a moment.

One species you could grow here--which I do not advise you to grow--is eels. The market for eels is primarily export, and it's too "iffy." The history of eel culture in this country is one of boom or bust. If the Japanese have a severe shortage of young eels, they'll pay anything to get them; but the next year they may have plenty of their own and they don't want yours. The Europeans like a somewhat larger eel, and raising them to the proper size for the Scandinavians, for instance, just isn't profitable.

We haven't done very much in this country with a family of finfish with which the Europeans have done very well--the flatfish. The English have major production going,so the technology already exists and is well-proven.

But as we look over the range of possibilities, it seems to me the natural choices for New Jersey are the shellfish. The have a lot of advantages, like staying where you put them, and feeding very low on the food chain so expensive pelletized foods are not needed. Of course the market already exists.

I think a careful cost assessment would show that a method being used on the West coast would not only work in New Jersey, but would be a real stimulus to oyster culture. I know you already are culturing oysters by traditional methods and that you have some very highly skilled and qualified oyster people in the state, and to them I recommend consideration of the remote setting technique. The oysters are taken into a hatchery where they are fertilized and spawned. Then the larvae are grown through the various stages until somewhere around the 16th day they develop a red spot, visible under a microscope, which is called the eye spot. Once the eyed larvae stage is reached, they can be shipped to oyster growers.

To ship the eyed larvae you just drain them down, wrap them in wet paper towels and pack them in an ice chest. They can be shipped for up to seven days, though that's a little long to hold them. Once the larvae are put in warm sea water, they start swimming, and finish the next 72 hours of their metamorphosing and setting. There are even drugs to enhance the process.

What I'm suggesting, is the possibility of either a commercial or a state-sponsored hatchery which produces great quantities of eyed larvae for shipment to growers with setting tanks--and these setting tanks, by the way, are backyard swimming pools bought pretty cheaply off the shelf from Montgomery Ward or Sears. You fill them with sea water which you heat, and aerate. An aerator which works well is the anti-pollution device off a wrecked General Motors car.

This system works. In Virginia, we found we could carry our larvae around in an ice chest in the back of a truck, and after 36 hours we put them in sea water at about 24 degrees Celsius with high setting rates. We use automotive anti-pollution blowers to demonstrate they aerate satisfactorily. On the West Coast growers get between 11 and 40 percent setting rates, moving toward the higher numbers as they get better at it. Our setting rate is between 14 and 28 percent, so we're doing pretty well,too. We leave the larvae in the tanks for three days until the setting is done, then we suspend them off piers for a hardening period. At that point the seed can be moved to a growing area.

A good possibility for New Jersey is the hard clam, *M. mercenaria*. This is an excellent candidate species because it reaches its highest market demand at its smallest saleable size. As soon as they reach littleneck size, they are worth the most. There already are three or four successful clam farms here in New Jersey.

One clam that may surprise you as a good possibility is the surf clam. I know you're remembering that these clams take from four to six years to reach market size, but surf clams can be bred in a hatchery and then put in natural waters where they will grow to steamer size in about a year. They are excellent as steamer clams, so much so that a company in Delaware is selling them at 22 cents each, wholesale.

I know some of you have thought about the edible mussel,*Mytilis edulis*, and it's one that deserves a brief look. It does occur in these waters year around, but there are periods when the temperature goes high enough so the mussels do poorly. Even though the market is growing, it's good to keep in mind that New Jersey is right on the southern edge of the mussels' range. As the price goes up, the risk may be worth it, but I'm not sure the time has come.

The soft clam, *Mya arenaria*, simply isn't worth growing. The highest price I could find in the green sheets over the last 10 years--they're the reports that give market prices, published by National Marine Fisheries Service--was $80 a bushel. It takes about 2100 to 2400 clams to make a bushel, and when you figure out the price per animal, it's simply too low. Over the past decade while you were selling littleneck size hard clams for an average 10 cents each, the average price for soft clams would have been less than four cents. Think of it this way: it takes as much space, as much pumping of water, and as much cost to grow the soft clam as it does littlenecks, and that makes them a comparatively poor candidate.

My own pride and joy was the bay scallop. A delicious animal. It's pretty, it has blue eyes, and it's a perfect aquatic animal which can be grown in seven to nine months. There isn't a better species--until you look over the green sheets and find the highest price in the last ten years was $48 for an eight pound gallon, which is how they are sold. Part of the cost to you is shucking the scallops and disposing of the shells. It takes 450 scallops to make the saleable gallon, which means you are getting just four and a half cents each.

A species that looked promising was the American lobster. The technology for growing lobsters is pretty much in place, but the profit picture is shaky, so I think I would say better wait a few years on those.

That sums up a brief overview of candidate species for New Jersey as I see it from my particular vantage point. I'm sure you have both arguments and questions, but at least you know now what I think.

Questions and comments following Dr. Castagna's presentation

In response to a question about oyster culture on PVC pipe, Mr. Castagna replied that the French have turned recently to PVC pipe for setting oysters. For years the French used different kinds of materials while in the United States we stayed pretty much with oyster shell cultch. The French, especially on the coast of Brittany, set their socalled plate or Belon oysters--*Ostrea edulis*--on tiles. Later they changed to a kind of grout made of sand and crushed oyster shells; after the oysters reached a certain size, they could be knocked loose and sold as single oysters. Then they turned to plastics and developed a gadget called the French venetian blind, because that's what it looked like. The blinds were promising, but expensive, and in getting the oysters loose they sometimes broke. Then the French went to a device that looked like a Chinese hat which could be flexed by machine so the oysters would just pop off. Now the choice is PVC pipe with external grooves which can be placed first horizontally and then vertically to get best growth, after which it is simply flexed and the oysters drop right off. The French are delighted with it, and the Canadians are making the pipes in British Columbia. Recently the Coast Oyster Company, which is the General Motors of the oyster industry, began experimenting with the pipes and they like the system. They will make their own pipes because it costs too much to import them. Eventually they will quit using cultch and go 100 percent with the French pipes.

When single oysters are popped off any substrate, there is a soft spot where the oyster set. It would be an advantage to dip these spots in grout, because crabs, which are natural oyster predators, pinch that soft spot to get at the meat. The Coast Oyster Company is working the proper engineering to solve the soft spot problem at their location in Bremerton, Washington. The company actually owns 22 thousand acres in California, Oregon, and Washington, with the largest holdings in Washington.

In regard to market demand for hard shell clams: When Mr. Castagna and colleagues began experimenting with clams, they went to every clam shipper that they could find, and were told the same story, that the shippers could handle between four and 10 times the number of littlenecks they could put their hands on. They could also ship double the number of cherrystones, but chowder clams were a glut on the market.

To manage a clam industry, it would be well to put a restriction on the number of large chowder clams that can be brought in, because the big ones are the best spawners and the best survivors.

At a conservative estimate, the market can handle at least four times the present volume, even with present method of selling the clams only in the shell. With application of a little seafood technology and some minimal processing of the clams--maybe popping off one shell, putting them in aluminum pans and freezing for ease of handling, or with a sauce and a plastic container for microwave cooling, the demand might be increased a very great deal. Marketing is perhaps the most important thing to be done in aquaculture.

A question on harvesting--only raking and treading are acceptable harvesting methods in New Jersey--led to a discussion of law as it affects aquaculture, and Mr. Castagna had these comments.

"Every state on the Atlantic Coast has had an independent study on harvesting by dredge and has found that the hydraulic dredge, even including the hydraulic box dredge, do far less damage than the standard dredges that are now allowed--and the hydraulic dredge has been turned down repeatedly as a harvesting tool. In Virginia, an oyster dredge can be used to dredge clams. The breakage rate for animals brought aboard is 30 percent, and the breakage rate on the bottom probably is even higher. The breakage that is seen on a hydraulic dredge is less than one percent. Yet, efforts have so far failed to change the law."

"The states must come up with a model aquaculture law that takes aquaculture out of the existing complex of legal structures and strictures. Aquaculture needs its own laws and regulations, and these should have nothing to do with wild harvesting of fish or shellfish."

"It makes no sense for aquaculturists to be hemmed in with restrictions that have little or no bearing on aquaculture. For instance, a farmer who is leasing farming land is not told by the leasing agency that he can plant anything he wants to within limits, but when he harvests it he must use a John Deere tractor. He should be able to use whatever the crop and situation call for, whether he is farming the land or an estuary. If he does it wrong and loses money through inefficiency, that's his problem, not the leasing agency's."

"Sometimes we get hung up on definitions. I think the simplest definition for aquaculture is that seed planted for aquaculture is hatchery-produced. That immediately makes it different from wild harvesting."

"Where conflict comes in very often is in multiple use of water areas. The same area might be useful for commercial or recreational fishing, boating, swimming, SCUBA diving, water skiing, or aquaculture--and sometimes all of these. In the National Aquaculture Bill, for every species considered in the bill the greatest constraint given was lack of suitable areas. I don't know what you do about that. One suggestion is that some areas be zoned for aquaculture, and all other competitive users stay out."

"In Virginia, which is one of the more enlightened states for aquaculture but still a long way from ideal, we use oyster leases. There is nothing in the state law that allows for clam leases, but the state allows us to take up an oyster lease and use it for clams. Anyway, there's no doubt that water column and sub aqueous bottom must be leased to the aqua-culturist for his exclusive use if we are serious about this industry.

An attendee noted the appearance in some of our markets of the so-called green mussel. Dr. Castagna commented that this mussel (Perna) is imported primarily from Australia and is available in both fresh and dehydrated form. It is claimed--although not publicly advertised in this country--that the green mussel is good for arthritis, and it is finding a big market in Europe. Although quite a bit of good culture research has been done on the West Coast, the species does not appear promising for aquaculturists in this country. Green mussels probably will continue to be imported, perhaps in increasing numbers, from Australia.

Speaking of mussels, I believe this is a good example of species who have possibilities and the kind of questions that need to be addressed: "There are a few little isolated places where mussel growing is dependable, but the farthest south location I know of is at Wachapreague Inlet. If you're not familiar with the geography, Wachapreague is on the Atlantic side of the Delmarva Peninsula, about halfway between the Maryland line and Cape Charles at the mouth of Chesapeake Bay. Mussels can be found dependably at the Wachapreague Inlet, but inshore they are wiped out every August. South of Chesapeake Bay, there is no place where mussels can be obtained dependably even if you need only a handful every month.

"The pertinence of all this about mussels is that the species is possible for New Jersey--if the price goes high enough to warrant a high risk industry. For a high risk industry there had better be a high enough profit so that, if you have a wipe out, the company will not be wiped out with the mussels.

No matter what you are growing, a return on investment of at least 20 percent is a must, I believe. When you are growing a species which may be wiped out one year in there from climatic variations, from disease, or anything else, your return on investment had better be closer to 40 or 50 percent. And make no mistake about it, and believe no ironclad guarantees, everything that is grown, whether on land or sea, or in the air, has occasional disasters. Farmers are gamblers, and aquaculturists are even more so. But, with sense and good planning, the gamble is sometimes worth it."

CHAPTER IV

BIOTECHNOLOGY IN MODERN AQUACULTURE

Fred L. Singleton
Acting Director, Center of Marine Biotechnology, University of Maryland

Dr. Singleton's current research emphasis is directed to evaluating interactions between populations in the bacterial communities of aquatic systems and between the bacterial populations and various elements of their physico-chemical environments. In an ecosystem, co-existing species often are in competition for available resources. To succeed, a competing species must either be more efficient in sequestering resources or must negatively influence competitors. Dr. Singleton's research will yield information which can be employed to control survival and growth of foreign or disease-causing species. Further, determining the manner by which populations of bacteria interact can be a means of discovering novel bioactive compounds. By evaluating the interaction between organisms and components of their environment, it will be possible to determine the mechanisms of survival of human pathogens in the marine environment.

Dr. Singleton received his baccalaureate degree in microbiology at Clemson University, his MS in medical ecology at the University of Texas School of Public Health, and his doctorate in microbiology from Texas A&M University. Before joining the University of Maryland faculty, he held teaching and research positions at Old Dominion University, and the University of West Florida. Earlier, he held visiting assistant professor, research associate, and postdoctoral positions at Maryland.

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Decades of research on the fundamental structure and function of nucleic acids and proteins have yielded a technology which is so fundamental to the life sciences that we are seeing the beginnings of a scientific revolution. The tools of the modern molecular biologist can be employed to excise selected genes from an organism, transfer that gene (or set of genes) into another organism, and have the substance (e.g., protein) encoded by that gene produced in the recipient organism. Thus, we can now employ microorganisms as a source of a variety of important substances. For example, medically-important substances such as human growth hormone, insulin, and interleukins, among many others, can now be produced in this manner.

As a result of many well-publicized achievements in biology and medicine, biotechnology has become a familiar term in most segments of society. It is obvious that biotechnology may have a significant impact on all aspects of our lives. Indeed, the potential of biotechnology is unlimited. However, I stress the word "potential" because of the need to understand that, although this technology is advancing rapidly, much of what may result from biotechnology is, at the moment, only in the experimental stage. Therefore, even though the general public has become aware of the "new" science of biotechnology, a great deal of work must be accomplished before the potential of this technology can be realized.

The role of biotechnology in modern aquaculture can be significant. The extent of the impact of biotechnology on aquaculture will depend on a number of factors, including future advancements in molecular biology and molecular genetics, as well as resolving the legal and bioethical questions concerning developing and exploiting genetically-engineered strains of fish, shellfish, and other aquatic organisms, including microalgae and macroalgae.

Biotechnology is not a new science. For centuries society has benefited from biotechnology. The production of bread, beer and wine, practiced for many centuries, are but a few examples of biotechnology. However, only in recent years has technology progressed to allow us to manipulate selected genes of an organism. The ability to manipulate and transfer functional genes has significant potential for the aquaculture industry. However, even such powerful techniques can be of limited use unless basic biological, ecological, physiological processes of a species are understood.

In many cases it may be possible to employ biotechnology in aquaculture in the absence of any genetic modification of the species being grown. As an example, I will use ongoing studies of Drs. Ron Weiner and Rita

Colwell (Department of Microbiology, University of Maryland) and Dr. Dale Bonar (Department of Zoology, University of Maryland) who have isolated a bacterium, referred to as LST. This bacterial isolate represents a new genus. LST was originally isolated from a mariculture facility in Delaware and, subsequently, has been isolated from numerous other marine and estuarine systems. This microorganism's natural habitat is the surface of submerged materials. A metabolic product of LST is involved with induction of settlement and metamorphosis of oyster larvae. Studies have demonstrated that the melanin pigment, or one of its biosynthetic precursors, produced by LST acts as a chemoattractant and/or metamorphosis-inducing agent for oyster larvae. It is believed that LST and oysters have a symbiotic relationship. Such relationships between invertebrates and microorganisms are common in the marine environment. Furthermore, laboratory studies have demonstrated that LST can increase the number of oyster larvae which set and begin metamorphosis. Field studies are underway to test the hypothesis that LST or some of its metabolic products can be employed on a commercial scale to increase productivity in oyster-growing facilities.

Understanding the fundamental physiology of a species can also be important for adapting a species to aquaculture. Dr. D. E. Morse and his colleagues at the University of California at Santa Barbara have demonstrated that spawning in a number of molluscs is regulated by certain prostaglandins. Interestingly, prostaglandins are known to regulate reproduction in humans as well as a number of other types of organisms. In their studies on the reproductive physiology of abalone, a commercially valuable mollusc, it was discovered that hydrogen peroxide was formed as a metobolic byproduct. Subsequent studies demonstrated that hydrogen peroxide stimulated the natural enzymatic systhesis of prostaglandins. Therefore, spawning of abalone (and other molluscs) can be induced by adding a small amount of hydrogen peroxide to the sea water in culture facilities.

Obviously, the ability to induce spawning in molluscs is important to aquaculture of these species. However, of equal importance to the success of a culture system is the ability of the larvae to grow and metamorphose. Basic ecological and physiological studies have demonstrated that external biotic and abiotic influences are important in the development of invertebrate larvae. I have already mentioned the studies of Dr. Weiner regarding the effect of metabolites of LST on the behavior and development of oyster larvae. The symbiotic relationship between oysters and LST is typical of symbiotic relationships between other invertebrate species and organisms of other trophic levels. For example, abalone larvae have been demonstrated to settle and begin metamorphosis in response to the amino acid, gamma-amino butyric acid (GABA). GABA is a simple amino acid and a powerful neurotransmitter in higher animals. Numerous other chemical compounds have been indentified to induce settlement or affect development in marine invertebrates.

The ability to transfer functional genes from one species to another may have a significant impact on traditional approaches to aquaculture. Many genes of fish and shellfish have been cloned in bacteria. Dr. Dennis Powers (Department of Biology, The John Hopkins University) and colleagues have cloned the genes which code for metallothionein proteins in some fish and shellfish. Metallothionein proteins are produced by organisms, in part, in response to heavy metal stress. Metallothioneins bind metals as a means of protecting the organism from toxic effects of metal ions. Although not directly related to aquaculture per se, the cloning of metallothionein genes in bacteria allows us the ability to produce large quantities of these metal-binding proteins. This may be the basis of developing a technology to remove toxic metal ions from industrial effluents, and possibly to recover valuable metals from aquatic systems.

Studies are ongoing at The John Hopkins University under the auspices of Dr. Powers to clone other selected genes from various fish species. For example, the gene which encodes the "antifreeze" protein produced by flounder inhabiting cold ocean waters was first cloned by Dr. DeVries and colleagues at the University of Illinois. Efforts are now being directed to transferring the antifreeze gene into striped bass and trout. Likewise, other ongoing projects are designed to transfer growth hormone genes into selected species of fish. The objectives of these, and other related studies, is to produce hybrid strains of fish that will grow under conditions not tolerated by the native (non-engineered) fish. This technology may provide the aquaculture industry with hybrid strains of fish and/or shellfish more amenable to culture.

Scientists have succeeded in cloning mammalian growth hormone genes and transferring them into fish. Although this technique increases the rate of growth, presently the technique cannot be used commercially due to the method of introducing the gene into the fish; fertilized eggs must be individually microinjected with the gene. However, the potential of this technology for the aquaculture industry is obvious and is virtually unlimited.

When, or if, this potential will be realized depends on our ability to continue rapid advancements in molecular biology and molecular genetics as well as our ability to resolve the technical problems of introducing genes into thousands of eggs simultaneously. Furthermore, the ecological and bioethical questions of using genetic engineering to develop hybrid strains of fish, shellfish, and other organisms must be resolved.

One aspect of biotechnology in aquaculture which has immediate application and significant potential for the future concerns developing methods of controlling fish and shellfish diseases. Genetic engineering and hybridoma (monoclonal antibody) technology may result in the development of vaccines as well as disease resistant strains of fish and shellfish. In addition, an ecological approach to controlling disease-causing microorganisms is under investigation in my laboratory. Briefly, this approach involved the use of naturally occuring aquatic bacteria that either produce a bioactive metabolite which is inhibitory to pathogenic bacteria or are competitors of these pathogens. The systems we are investigating involves *Vibria anquillarum*, a pathogen of many fish and shellfish larvae. Chromogenic bacteria isolated from estuarine waters of Chesapeake Bay are grown in laboratory microecosystems (microcosms) and tested for the ability to restrict the growth of *V. anquillarum* in these systems. Chromogenic strains which cause significant reductions in the population size of *V. anquillarum* are then assayed to determine if the populations reduction is the result of production of a bioactive metabolite, e.g., antibiotic-like substance, or if the two species are competing for limited resources. Several chromogenic strains have been isolated which cause statistically-significant reductions in *V. anquillarum* population's. Preliminary results from bioassays employing oyster larvae have indicated that selected strains of aquatic bacteria can be effective in reducing disease in populations of oyster larvae.

There is a need for additional studies on the molecular biology and molecular genetics of fish, shellfish, and other aquatic animals. Likewise, additional study is needed on adapting aquatic plants (microalgae and macroalgae) to aquaculture. Methods of modern molecular biology are being employed for developing hybrid strains of algae with desired characteristics. One of the more exciting programs being carried out in this field is that by Dr. Donald Cheney (Department of Biology, Northeastern University). Dr. Cheney is developing hybrid strains of marine macroalgae (seaweeds) which produced increased quantities of phycocolloids (e.g., agar, carrageenan, alginate).

Decades of intensive breeding programs for terrestrial plants have resulted in highly productive crops. Although this traditional approach could be employed for developing hybrid strains of seaweeds with desired characteristics, a more practical approach is to employ techniques of modern molecular biology. Dr. Cheney has developed tissue culture systems for growing cells of certain seaweeds and is employing techniques such as protoplast fusion to form hybrid seaweeds. Seaweeds represent a major food source for many countries, especially in the Far East. Mariculture of seaweeds has been developed in China, Japan, and Korea, as well as other countries to a lesser extent. A great deal of the potential of seaweed culture will be realized only after strains of seaweeds are developed for the production of specialty chemicals.

To conclude this brief overview of the potential impact of biotechnology on modern aquaculture, I will re-emphasize the point that the tools of genetic engineering represent incredible potential for the aquaculture industry; however, most of the potential of biotechnology has yet to be realized. This potential will be capitalized on only by continuing basic research on the fundamental ecological, biological and physiological processes of organisms amenable to aquaculture. The tools of biotechnology cannot be employed to develop hybrid strains of selected species without understanding the basic physiology of these species.

Questions and comments following Dr. Singleton's presentation

The leading question to Dr. Singleton was what this "good science" means to the practical problems of the aquaculture industry. Dr. Singleton pointed out that, although his training is in microbiology and his exposure to practical aquaculture is limited, "good science" is needed to solve problems of aquaculture operations and the most effective means of applying that science is "to establish open lines of communication with the bench scientist." As to the cost of bringing research to the point of useful application, it will be expensive, and the time required to reach that point is dependent on availability of funds, among other factors.

A questioner asked, "Do you mean to tell me that one day I could walk into the lab and tell a genetic engineer to put a red spot on the nose of a fish?"

Although the example was extreme, Dr. Singleton commented that technology is advancing to the point that we can transfer to a species genes which encode particular characteristics, and in some cases, we already have reached that point.

In regard to the use of growth hormones in increasing the growth rate of fish, several groups of scientists have succeeded experimentally, but in response to a question about potential and reaching a 100 percent increase in size, Dr. Singleton pointed out that there are limiting factors regardless of what is done to increase the growth rate, so 100 percent is too much to ask of an organism.

On the question of whether the technology could be used to adapt species to grow in areas not typically inhabited by that species, the possibility exists, but whether it is practical must be determined by evaluating the impact of the species on the ecosystem. Dr. Singleton mentioned earlier the anti-freeze protein of flounder and suggested that it might be possible to transfer the anti-freeze gene to a warm water species so it would grow in colder water. He stressed that it "may be possible" because, while technically possible, the effect of the gene product on other physiological processes of the warm water species would be unknown.

A listener asked, "what are the stumbling blocks which prevent us from using super fish and shellfish?" Dr. Singleton pointed out that going from the experimental stage to commercial production is never easy, and "a great deal of work remains before much of the potential of biotechnology is realized. With regard to the stumbling blocks, even if we develop a 'super fish' many legal and bioethical questions remain concerning release of genetically-engineered organisms into the environment. That question will be answered in the future, probably by the Supreme Court.

A practical roadblock to success is that time and money are required. There has to be more funding for basic biological and ecological studies of organisms amenable to aquaculture, and more funding to provide molecular biologists with the means of accomplishing many of the things that are possible. Dr. Singleton: 'You can never ask a scientist how much money it will require to do something—there is never enough.' "

A final comment was that some of the discussion was a bit naive in the sense that genetic manipulation and hybrid formation is "about three billion years old. The ideas of creating a super fish that can take over the world is absurd . . . if we take a native species and genetically modify it, we are creating a weakened organism: nature has an effective way of ensuring survival of the fittest. Therefore we have to continue with efforts to develop hybrid strains for aquaculture." Dr. Singleton agreed: "organisms exist under a tremendous selective pressure and if a particular trait would be an advantage for a species, in all probability that trait would have been selected for during the past couple of billion years."

CHAPTER V
INFRASTRUCTURE FOR AQUACULTURE

Robert D. Wildman
Deputy Director, National Sea Grant Program

In addition to his responsibilities as Deputy Director of the National Sea Grant Program, National Oceanic and Atmospheric Administration, Robert Wildman is the program's Living Resources Division Head and Program Director for Plans and Aquaculture. His involvement with aquaculture also takes him into international affairs. He is Vice Chairman of the U.S./Japan Natural Resources Program's Aquaculture Panel, Co-Chairman of the Living Resources Panel of the U.S./France Cooperation in Oceanography, and Co-Leader for the Living Marine Resources Investigation Section of the U.S./People's Republic of China Cooperation in Marine and Fisheries Science and Technology Program. Mr. Wildman also has served as the U.S. Department of Commerce representative on the Board for International Food and Agriculture Development's Joint Committee for Research and Development. He was one of eight members of the Advisory Board for Disney's new Living Seas Pavilion at the Epcot Center. Mr. Wildman was educated at Upper Iowa University and did graduate work in marine biology, oceanography and plant sciences at Scripps Institute of Oceanography, UCLA, and the University of California at Berkeley. He was awarded a National Institute of Public Affairs Fellowship for graduate study in science, technology and public policy at Indiana University after service with the Atomic Energy Commission Richland Operations Office as a biologist and Chairman of the Working Group for the Columbia River. He was a charter member of the World Mariculture Society, and had been a member of the WMS Board and its Vice President.

Drs. Ryther, Castagna and Singleton have provided a substantial base of information on aquaculture. I'd like to build on that base and touch on just a few points with respect to aquaculture development in New Jersey, where it appears to stand at this point, and what changes might be helpful at the state level for the future. Also, I will discuss Federal sources of assistance and some existing aquaculture programs which may provide information of use of New Jersey aquaculturists.

In 1979 the New Jersey legislature made a decision to expand the programs in fisheries and aquaculture to try to get the state back into a preeminent position in the seafood business. It established task forces to study the situation. Now some of the studies have been completed and they contain findings, conclusions and recommendations. It is probable that some of the recommendations have been acted upon—and it is probable that some of them never will be; that is the way such processes go.

As I see it, the question is not what New Jersey really needs in order to make itself a real success in aquaculture, but what *more* it needs. We have had three new organizations introduced to us here at this workshop. These are groups that should have a positive impact on aquaculture development. You may have about all the organizations you need, though there may still be a need for specific state aquaculture legislation. Also, there may still need to be a group to conduct promotional activities; the kinds of things that help facilitate permitting, licensing, leasing, arranging financing, etc. It's these legal/regulatory constraints that appear to have the most inhibitory effect on commercial aquaculture development in the United States at this time.

New Jersey is proceeding at a steady pace, and not too hastily. The number of mistakes that could be made here in New Jersey should be reduced considerably by taking advantage of the experience in some of the states like Hawaii, California, Washington, Maine, and others that have taken an active and promotional role in aquaculture development. A careful analysis of what these states have done would be prudent: how they have succeeded and, recognizing that some failures have occurred, what those failures were and at what cost, and how New Jersey could avoid such difficulties in development of an aquaculture industry.

I know the Federal Government has a bad reputation in some areas. However, there are certain organizations within the Federal Government that can be of assistance. It may surprise some of you to know that there is a positive policy for aquaculture development on the part of the Federal Government. It was set by the Congress in the 1980 Aquaculture Development Act.

"CONGRESS DECLARES THAT AQUACULTURE HAS THE POTENTIAL FOR AUGMENTING EXISTING COMMERCIAL AND RECREATIONAL FISHERIES AND FOR PRODUCING OTHER RENEWABLE RESOURCES, THEREBY ASSISTING THE UNITED STATES IN MEETING ITS FUTURE FOOD NEEDS AND CONTRIBUTING TO THE SOLUTION OF WORLD RESOURCE PROBLEMS. IT IS, THEREFORE, IN THE NATIONAL INTEREST, AND IT IS THE NATIONAL POLICY, TO ENCOURAGE THE DEVELOPMENT OF AQUACULTURE IN THE UNITED STATES."

The Aquaculture Development Act

This policy declaration says simply that aquaculture is good and the Federal Government is going to support its development. There is a big difference between the stated policy from the Congress and implementation of that policy in the executive agencies. Some of the agencies are not being very aggressive in pushing this policy. Unfortunately, my agency is one of them. The Department of Agriculture, operating primarily on the basis of authorizations contained in the Food and Agriculture bills of the past 10 years, is moving very positively in the development of aquaculture.

They have several agencies conducting activities that will have beneficial results. The Department of the Interior had a very positive policy stated by the Secretary some 4 years ago, which upon subsequent review was changed slightly. Interior's Fish and Wildlife Service now will support aquaculture so long as the activity is consistent with their primary missions; such as their stocking and restocking programs. In the Department of Commerce, NOAA's National Marine Fisheries Service, likewise, is supporting aquaculture in an indirect fashion. They hope that the information developed through research programs aimed at enhancing natural populations will be of assistance to the commercial aquaculture sector. The Sea Grant College Program, which I represent, continues to operate with the policy and mission that we have had since the beginning of the program in 1966. We have a broad research program and extension effort that is directly supportive of commercial aquaculture.

Figure 1 illustrates what the current Federal picture is for aquaculture. There is considerable information available on federal programs, but I've tried to make it fairly simple by putting it into tabular form. This table does not indicate the level of activity and there is a big difference between just doing something and doing it at an effective level.

Figure 1

FEDERAL ASSISTANCE FOR AQUACULTURISTS

	Technical Production Problems	Legal-Regulatory Problems	Business Develop.	R & D Contracts & Grants
Dept. of Agriculture				
Agricltr. Research Serv.	•			•
Agricltr. Marktg. Serv.			•	
Animal & Plant Health Inspection Service	•			
Coop. State Research Serv.	•			•
Economic Research Serv.	•			
Extension Service.	•	•		
Foreign Agricltr. Serv.				
Federal Crop Insr. Corp.				
Farmers Home Administr.			•	
Food & Nutrition Serv.			•	
Nat'l. Agricltr. Library				
Soil Conservation Serv.	•			
Statistical Reporting Serv.			•	
Dept. of Commerce				
Nat'l. Marine Fisher. Serv.	•			
Nat'l. Sea Grant College Program	•	•		•
Dept. of Interior				
U.S. Fish & Wildlife Serv.	•			
Dept. of Defense				
Corps of Engineers		•		?
Dept. of Energy				
Dept. of Health & Human Serv.				
Food & Drug Admin.		•		
Dept. of State				
Agency for Internat'l. Develop.				•
Environmental Protection Agency		•		?
Farm Credit Administration			?	
National Science Foundation				•
Small Business Administration				
Tenessee Valley Authority	•			

The first column entitled "Technical Production Problems" indicates which agencies have or support research scientists or extension programs that can assist in the solution of these problems. You may wonder about the second column titles "Legal-Regulatory Problems" being listed under the heading of assistance because some people feel the Corps of Engineers, EPA, and the Food and Drug Administration inhibit rather than support development of aquaculture. But if one is having a problem with one of these federal agencies, there are individuals who will at least help lead you through the many regulations and components of the organization, and help you determine if there is a workable solution to that problem. The activities under the "Business Development" heading can be in the form of loans, loan guarantees, marketing assistance, etc. In the last column under "R & D Contracts and Grants," one of the largest Federal supporters of aquaculture research is the Agency for International Development (AID). At the present time, AID has a annual funding level of about $15 million a year for aquaculture. Admittedly, that is aimed at developing aquaculture in other countries, but a lot of that same technology is of use to our U.S. aquaculturists.

The question marks on the table mean that the Corps of Engineers, the EPA and the Farm Credit Administration have had some support in those areas in the past, but are now restricted because of budget limitations. They are not necessarily out of the picture. For example, the Corps of Engineers has been looking at the possiblity of doing some experimenting on aquaculture in dredge spoil deposit areas. This proposed program was cancelled by the Department of Defense about two years ago when it was very close to being initiated. It is being proposed again and may still be approved.

On this table there are no check marks for the Department of Energy and the Small Business Administration. This indicates that these agencies had some activities in the past, but no longer are involved in aquaculture. The Small Business Administration had a discrete program for fisheries and aquaculture a few years ago but that has been eliminated. Likewise, the Department of Energy supported R & D on the culture of seaweeds as a biomass energy source, but that too has been terminated.

Now let me just touch on coordination and promotional activities at the Federal level. I am now the Chairman of the Joint Subcommittee on Aquaculture (JSA). This is an effort to coordinate all of the Federal activities in aquaculture. Some of these activities are done for very different purposes and are not necessarily a plus for aquaculturists. The JSA has periodic meetings for the purpose of planning and coordinating activities. We attempt to identify who an individual or organization might go to for assistance on a particular problem.

The Federal government has a sizeable program of international cooperation in aquaculture. This is conducted through a series of bilateral agreements with countries such as Japan, China, and France. In these exchanges of both people and information, we are trying to take advantage of what they know, to bring their technology to the U.S. and make it available to aquaculturists. We have a meeting scheduled with the Japanese next month in Woods Hole. The purpose of the meeting is to exchange information on new developments that are occurring in aquaculture. We will have discussions with them on several topics including genetic engineering. We are trying to make sure our researchers and commercial operators have access to the information that we obtain and will take advantage of it in our U.S. operations.

Figure 2 is based on data that Ben Drucker of the National Marine Fisheries has collected. The footnotes refer to all of the disclaimers on the data. Much of this information is based on rough estimates that Ben has obtained from the best sources available. The point is, that in spite of problems such as regulatory constraints, there has been fairly steady growth of aquaculture in the United States. It has not been as spectacular as some people projected in the past that it would be, and not really as fast as those who are interested in the growth of this field would like. But as a matter of fact, it is making very positive progress.

Figure 2

U.S. Private Aquaculture Production[2] for 1980, 1982, 1983 and Preliminary Data for 1984

	PRODUCTION [THOUSANDS OF POUNDS][2]				VALUE [THOUSANDS OF DOLLARS]				PERCENT OF TOTAL PRODUCTION			
Species Group	**1980**	**1982**	**1983**	**1984**	**1980**	**1982**	**1983**	**1984**	**1980**	**1982**	**1983**	**1984**
Baitfish[3]	22.046 (10,000)[4]	33.069 (15.000)	33.000 (15.000)	46.398 (21.090)	44,000	100,000	100.000	149.866	10.9	8.5	7.9	9.9
Catfish	76.842 (34.855)	200.419 (90.909)	220,000 (100.000)	239.800 (109.000)	53.572	120,000	132.000	191.840	37.8	51.3	53.0	51.0
Clams	561[5] (255)	645[5] (293)	1,689[6] (768)	1698[6,7] (772)	2.295[5]	2,637[5]	9,500	4.178	0.3	0.2	0.4	0.4
Crawfish	23,917 (10,849)	55.115 (25.000)	60,000 (27,300)	59,400 (27,000)	12.951	27,000	30,000	29,700	11.8	14.1	14.5	12.6
Freshwater Prawns	300 (136)	400 (182)	275 (125)	317 (144)	1.200	1,800	1.500	1.698	0.1	0.1	0.1	0.1
Mussels	NA —	364[5] (165)	775 (352)	917 (417)	NA	1,600	1.500	1.584	—	0.1	0.1	0.2
Oysters	23.755 (10.775)	21.777 (9.878)	23,300 (10.590)	24.549[8] (11.158)	37.085	34,000	31.5000	38.970	11.7	5.6	5.6	5.2
Pacific Salmon[9]	7.616[12] (3.455)	25,544[12] (11.587)	20.600[12] (9.400)	36.617[11,12] (16.644)	3.400[10]	4.000[10]	6.800[12]	19.293[11,12]	3.7	6.5	5.0	7.8
Shrimp[13]	—	—	255 (116)	528 (240)	—	—	874	1,566	—	—	0.1	0.1
Trout	48.141 (21.836)	48,100 (21.818)	48.400 (22.000)	49.940 (22.700)	37.474	48,000	50.000	54.435	23.7	12.3	11.7	10.6
Other Species[14]	NA —	5.000 (2.273)	7,000 (3.200)	9.900 (4,500)	NA	5,000	7,000	9,900	—	1.3	1.7	2.1
TOTALS	203,178 (92.354)	390,433 (177.470)	415.294 (188.770)	470,064 (213,665)	191.977	344.037	370.674	503.030	100.0	100.0	100.0	100.0

FOOTNOTES

1. Some data was not used so that the confidentiality of the person or business submitting the statistics was not disclosed. This is the case where data cannot be aggregated.
2. Data shown are live weight for consumption, except for oysters, clams, and mussels which are meat weight. Excluded are eggs, fingerlings, etc., which are an intermediate product level.
3. Not used for food consumption.
4. Metric tons.
5. Revised figures.
6. Includes east coast clams (primarily *Mercenaria mercenaria*, but some *M. campechiensis* and *Mya arenaria*,) and west coast clams (*Panope generosa*, *Saxidomus giganteus*, *Tresus* (sp.), *Prototheca staminea* and *Venerupis japonica*).
7. East coast figures are for 1983; west coast figures are for 1984.
8. Included some 1983 data.
9. Includes returns from State, Federal, private, non-profit, and private profit hatcheries as well as production from pen-rearing (ocean ranched and pen reared salmon).
10. Value from pen-reared salmon only - ocean ranching returns used for brood stock.
11. 1984 data with the exception of the State of Washington.
12. Production and value is on the low side since some of the returns (productions) were used for broodstock or permitted to escape for natural spawning.
13. Includes *Penaeus vannamei*, *P. setiferus* and *P. axtecus*.
14. Includes species such as sturgeon, carp, buffalo, tilapia, mullet, abalone, etc.

In conclusion, it appears to me that New Jersey is taking a wise approach to developing aquaculture and should take advantage of the experiences in other states and of assistance available from the Federal government.

Questions and comments following Dr. Wildman's presentation

On the question of the major funding sources, Mr. Wildman said,"with respect to the Department of Agriculture, the big research support in U.S.D.A. is through the land-grant university system. The present situation is that Sea Grant and Land Grant are the biggest supporters for extramural research in the Federal government. That excluded AID, which is the largest. With respect to intramural research, the largest one is the Fish and Wildlife Service."

An attendee noted rumors that "something is going to happen to stop the Sea Grant Program."

"There is that possibility," Mr. Wildman agreed. "The Sea Grant program has been essentially level funded over the past five or six years. Each year for the past five we have been proposed for termination and each year the Congress has restored it. I think that that situation may well continue for next few years."

CHAPTER VI

RISKS TO THE AQUACULTURE ENTERPRISE

Harold H. Webber
President, Groton Associates, Inc.
Consultant to Aquaculture Industries

For the past 34 years Harold Webber has been part of the business world, with emphasis for the past two decades on the field of aquaculture. He has been consultant and advisor to a number of enterprises in various parts of the world from Eire and West Germany to Isreal, Egypt, and Latin America. He was Executive Vice President of Maricultura SA, in Costa Rica, one of the first world attempts at mass mariculture of marine shrimp. Dr. Webber has been at various times, Director of Research for the Lowell Technical Research Foundation; a member of the senior staff and resident manager for Arthur D. Little, Inc., and senior corporation scientist for the Brunswick Corporation. He has been president of Groton Associates, a firm specializing in mariculture and aquaculture planning and business management since 1966. He has served as editor-in-chief and associate editor of the world journal, *Aquaculture*. One of his several hobbies, at which he works while traveling the world, is orchid collecting and raising, and he is a licensed importer. The name of his firm derives from its location, in Groton, Massachusetts. Dr. Webber was educated at the University of Texas, where he earned his doctorate in genetics and biochemistry.

As I have been at the aquaculture business for some time, I have gained some experience, and I am reminded that good judgment comes from experience--and experience comes from bad judgment. I have made enough mistakes to earn the title of a super-annuated man, perhaps enough to share with you some of the understanding gained from those mistakes regarding problems of risk confrontation.

I am not sure that I know how to manage risks, but perhaps I can identify a few of them, and I think I have learned how to avoid some of them. The obvious problems and risks that confront any bioindustry, as we may term aquaculture, derive from natural forces and resources, or the lack of them.

To elaborate a bit, it is for meteorological and geographic reasons that aquaculture in the bays, estuaries, and near-shore waters of New Jersey carry inherent risks. Storms and other similar phenomena are not very manageable except as one chooses not to contend with them by selecting sites not often susceptible to the costs of wave action damage, destruction by hurricane winds or other high energy risks. Avoidance is not always feasible; oysters, after all, cannot be grown economically away from salty waters. So risk management in such cases comes down to proper economic planning, based on the probability that one will be wiped out for a year or season at random intervals.

I have a long list of risks and a relatively short list of ways to avoid them. At the top of my list is the risk that comes from lack of a sound management plan. I class the management plan as maybe the only really big problem in aquaculture. The design of a plan must be based on far more than an understanding of the technology; more important is the understanding of the problems of integrating complex systems into productive enterprises. We have difficulty in truly understanding how miniscule is our comprehension of this complex world, how little we know about all the interacting variables which constitute a system such as a sound business aquaculture enterprise.

I have broken some of the variables down into two or three categories which may aid understanding. The larger clusters of variables are in biological/chemical interactions within the environment and within the living organisms. These variables are so obvious, at least in our awareness of their existence, that perhaps they deserve mention only to be complete.

The risk of disease is an obvious one in this category. There are parasites that plague a high-density confined population of animals, and there are bacteria and viruses, too. Our next speaker, Carl Sindermann, has made substantial contributions in this field of aquaculture and fishery diseases and has helped us all to avoid some of the risks. Yet, I dare say, he will join me in saying that the larger part of the problem remains to be solved. In other words, our ability to manage disease is growing, but it is by no means sufficient unto the need.

Problems relating to the physiology of the organism we are attempting to grow constitute another group of risks in the bio-chemical category. Some risks derive from the nature of their reproductive mechanisms and from our ignorance of the subtleties even in the animals we grow with a good degree of success. This has special importance because of the need for seed production. Unless we can stock our environment, we clearly will not be able to achieve the kind of productivity that is required to warrant the magnitude of our investment. Again, we are making progress, as Mike Castagna reported, but in comparison to seed production for agriculture business, most of the high hills of knowledge are still to be climbed, and more difficult to climb because they are underwater.

Because our aquafarms are under water--and furthermore presumably under productive water with good populations of food organisms for our animals--visibility leaves much to be desired. There are impositions on production and productivity especially in natural water areas where we have relatively little knowledge of the total number of all kinds of beasts in the system. We are unclear about problems related to predation and competition, and the effects of other organisms which share the environment in which our crop of animals is placed. One can help a little to minimize risks by taking advantage of all available knowledge of the environment, and adding to that knowledge as feasible, but reducing the risk from underwater predation and competition may sometimes be like reducing the risk from storms--picking a better location.

Predation is something very difficult to manage unless we are in complete control in a closed system, and such systems are not always practicable, either because of economics or the nature of the animal. Very often, in open pond systems, the management plan fails to take into account predation by land and air creatures which have a taste for our organisms. Such avian gourmets as cranes and herons discover shallow pond cultures very quickly, and comorants are very efficient fisherman. Raccoons can cause difficulties. I don't mean to exaggerate these problems, but they can be devastating, and I have returned to a pond to find nothing because of the predators that were there before me. Often the risk can be reduced if not eliminated, if the enterprise can bear the cost.

The competition for the environment itself--the bottom or the water column--is a significant problem area for which risk must be anticipated. It is difficult to keep competitors out. We have tried, but have had only limited success because we just do not know how to deal with screening a natural environment, or sometimes we cannot afford to do what we think we know how to do. For instance, it is costly to screen incoming waters for the larval forms of predators or competitors. Costs of labor are high if screens are to be kept open by removing the captured mass.

The matter of inventory control in the system is a risk problem that I have not resolved. As you gaze at the placid surface of your system, how can you know how many beasts are involved? As productiviey is increased, as animal density is increased, the matter of inventory control becomes increasingly out of hand. Yet, your inventory is your stock in trade.

By and large, in open systems, we do not know how much we have got. Therefore, we do not know how much to feed it, or how frequently to change the water. Setting up a monitoring system may be beyond our abilities, or beyond our pocketbooks if we do know how. How does one stimulate natural productivity without impairing the health of the whole system? Most of this problem area remains yet to be quantified, if not better understood. When we add together the very substantial influences on water quality which are a consequence of poor feeding practices, poor inventory control, poor water quality control, poor predator control, the system is beyond our abiity to manage. In many cases, I hasten to add, we know how to manage the system and all these factors better than we can afford to.

The larger risk area, and the one I think is limiting, relates to social and economic risks. Social risks come first because that are perhaps a bit easier to deal with. The selection of an environment in which you are encouraged to establish an aquaculture business is primary. It is especially critical for an animal farm, even an aquatic one. There are many parts of the world one might choose for an aquatic farm because of good water quality, water and air temperatures, water exchange, and similar environmental factors, yet rule out the choice for social reasons.

As we move to lower latitudes where political systems are not like ours, we frequently have to face political instability. Even when the social climate seems quite salubrious, protection against human predators, outlaws or dissidents armed with high technology claws or fangs may be an occasional hazard--especially to Americans.

Even when there is peace and relative safety, success of an aquaculture venture in the lower latitudes depends on the strength and state of technological development of the society in which one attempts to work. You cannot go off into the boondocks without realizing that you cannot go around the corner to the hardware store to buy the widget you need. Such factors may be of a small order of importance, but they sometimes become the back breakers. Other kinds of limitations include an infrastructure which includes roads, dependable power, schools, and other amenities of living. These in turn, help to determine the kinds of people you can attract in order to manage the farm. The whole world in which an aquaculture farming venture is undertaken becomes an influence on decisions to make the investment.

The availablilty of land, land costs, constraints on land use, costs of labor, cost of security, and the costs of doing business offer risks to any venture, particularly so when one goes off into distant areas to find appropriate environments for aquatic farms.

There is one concept which may be determining in many cases. This is the concept of the so-called Maritime Mile in the Western hemisphere. Under this concept, any beast in the water is available to anyone who chooses to catch it. The government owns all the edges of the sea and excludes certain kinds of activities, or taxes certain kinds of activities, or rigidly controls certain kinds of activities. It is within this concept that we in this country must live, and it is not an easy or simple thing because the constraints are different from those imposed on land farmers, often unfairly so.

Certainly there is competition from other users of the environment, and from some people who do not want it used. There are cases where an aquaculturist met all requirements, abided by all laws, only to find that his rafts were objectionable to those who owned houses overlooking the water--those with more political muscle than he could bring to bear. While this may be unfair, it is not necessarily illegal, because most laws are so written that creative interpretation is possible when the heat level becomes high enough.

How much of this applies to New Jersey and similar United States coastal regions I am not at all sure, but perhaps the troubled history of some aquaculture ventures and the experiences of aquafarmers in far lands may offer bits of illumination for planning in fairer social climates.

In the end, the overwhelming problems which account for so many of the failures in aquaculture are purely economic with the other risks I've mentioned acting more as irritation than serious trouble. Economics is where we ought to focus in any potential aquaculture venture. If we are to manage intensive populations of organisms at high productivity, clearly we cannot depend on natural processes to supply nutrients for our growing crops. So the cost of feed becomes, in some cases, dominant. Somewhere on the order of 60 percent to 80 percent of the total cost of producing the crop is in the feed bill. There is reliance on formulated rations for some kinds of animals, particularly for some of the finfish and crustaceans we are trying to raise. This reliance on formulated rations, which frequently use high cost components, becomes the limiting factor in the economic success of the venture.

So feed costs dominate, and one should not approach the design of a business without carefully evaluating this factor. Too often it is done haphazardly.

The hopeful entrepreneur says, "Of course we're going to feed them. We will feed them bananas." I have seen this happen in the presence of mountains of banana skins with no understanding of the composition of this waste material. The whole plan was predicated on the use of United Fruit's pureed plant wastes, which produced tons of banana skins which were going to be the reason for building an aquaculture farm.

I do not think many of you would do such a thing, but it has been done and probably it will be done again. There are many folks who approach the problems with great lack of thought or study. But feed costs remain critical and probably are the most important production problem aside from disease, seed, and the management of the environment.

Ultimately, the other important factor influencing the overall economics of the venture is "can you sell it?" Several of my coleagues have told you there is no object in producing the product unless you can sell it. This is perhaps obvious, yet what is saleable is sometimes difficult to quantify. Consumer preferences and organic, historical, and cultural choices of foods all influence buying decisions. All of these factors and more play a part in planning a venture and deciding whether and where to make the investment.

There are various approaches to problems of this sort. Market research is, of course, a well-developed technology and it can be applied. If you are attempting to produce something that is not common in the marketplace, trial feedings and taste tests are useful.

I feel that I have moved past an essential problem area solution, and that is to do the development in a pilot or demonstration stage before making the major commitment. During the period when you are producing relatively small quantities, market trials obviously are appropriate. One must determine not only whether people like shrimp--you know they do--but the product form, the presentation of the package. One must decide whether to go into the consumer market at all or instead go into the wholesale market.

Unless such factors play a role in designing a venture, the risk is increased. Frankly, the factors often are neglected because the aquaculture firm is the product of the technologist and not of the market. That is, the wishful aquatic farmer knows and has demonstrated that we can get this creature to reproduce, and we can get them to grow and survive in the environment we provide. Therefore, let us go into business and grow this creature for sale to the waiting world. Before the problems really have been studied and met head on, we are in business without knowing the answer to the basic question--can we sell it? Or how can we sell it best, and, can we sell it for more than it costs to produce it?

This is the kind of subject, the confrontation of risks, about which we could talk for hours, spinning endless tales of the world of aquaculture as it has been. But let the tale end here, and open the conference to questions and comments.

Questions and comments following Dr. Webber's presentation

It was noted that consultants in aquaculture deal primarily in risk assessment and Dr. Webber was asked about the rough percentage of successes in assessments that such consultants have made. He replied that consultants like himself have designed relatively few successful aquaculture ventures, with less than 10 percent success, perhaps closer to four or five percent. The successful farms, he said, "have grown kind of willy-nilly out of the experience of less sophisticated people. We have tried to bring technologies and concepts which are both too much and not enough in some ways for the complexity of the problem."

Projecting ahead, "I think that as we build a stronger, broader, more secure base in fundamental knowledge regarding the animals that we are attempting to grow, we are going to gain a marginal success...as we build a better understanding of natural resource management, which is lacking in most parts of the world, we will gain...but I am not enthusiastic about the next decade or two for aquaculture to become significant contributor of food production for humans. I think we will make small gains; and in some parts of the world the gains are significant to small populations, as in Taiwan, but not in many places and not in large numbers."

"On the other hand, if you look down the road, as we exploit our natural resources, the oceans themselves, damaging or altering them. We will be driven to more intensive management of these resources."

A conferee pointed out that there are two basic kinds of products which can be produced by aquaculture. One is the self-contained product, like clams and oysters, which needs only minimal handling. The other is the product which needs a great deal of processing, as in the case of finfish. The degree of handling is important to the economics of the venture, bacause filleting, packaging, freezing, and so on is very costly. The next problem is volume; most marketers, supermarket chains or fast food restaurant chains, cannot be bothered with small quantities. But, despite the problems of aquaculture, it has a distinct advantage from the marketing point of view--when production is successful and assured, it provides continuity of supply, unlike the seasonal supplies of seafoods from the natural harvest.

In discussing successful aquaculture ventures, the case of shrimp in Equador was raised. The success, it was noted, is due to Equador's recruitment of juvenile shrimp from the estuaries and ocean, thus avoiding the need for and cost of hatchery operations. But the risk remains, because there is no guarantee that the supply of seed shrimp will be there for the taking every year; there are great fluctuations in some shrimp populations. So, in the end, hatchery operations may be necessary.

A final discussion centered on the desirability of the aquaculturists joining forces with those in related and necessary businesses, including food processing, food transportation, and food marketing, instead of thinking that "we could stand on our own little place and produce these animals and somehow somebody was going to buy them in the marketplace." Joining with other businesses would involve sharing in risk capital, and in joint planning.

Dr. Webber: "Frequently the person who is developing the aquaculture technology really does not care about the other end of the spectrum He gets his kicks out of raising fish, or whatever. And, too often, he will not cooperate with the other end by modifying product development. Aquaculture farming is a biologist's business; it isn't a businessman's business, unfortunately. I hope it will become so, and not too long from now.

CHAPTER VII

OUTLOOK FOR THE FUTURE

Carl Sindermann
Visiting Professor, University of Miami

Although Carl Sindermann's distinguished career has been as a fisheries scientist, he has been a strong supporter of aquaculture research and development and has made extremely important contributions to the state of the art with three books on the role of diseases in marine populations, which are the most comprehensive references available to the aquaculturist. But Dr. Sindermann's writing has not been limited to scientific and technical matters: his books include two contributions to the sociology of science, *"Winning the Games Scientists Play,"* a wry and informative look at the inner workings of scientific politics, and *"The Joy of Science,"* published in 1985. He is at work on a third.

Dr. Sindermann's visiting professorship at the Division of Biology and Living Resources of the University of Miami's Rosnesteil School of Marine and Atmospheric Science is for two years under the Intergovernmental Personnel Act which allows exchange of Federal personnel with Academic and business specialists. Until he accepted the appointment, he was Director of the Sandy Hook Laboratory in New Jersey and Assistant Center Director for Environmental Management of the Northeast Fisheries Center of the National Marine Fisheries Service. He has traveled widely as scientific advisor to several international fisheries commissions and has been active in a number of professional societies. He is an adjunct professor at several universities including Rhode Island, Lehigh, Cornell, and Guelph (Ontario). He received his advanced degrees from Harvard.

In preparation for this conference, I went to my files for a document that I prepared just six years ago for a Congressional round table discussion, in which I tried to project the future of aquaculture in the United States. Reviewing the projections, I found that not much had changed in that time. My view then was one of cautious optimism, and that is my view today.

I'm perhaps somewhat more optimistic about aquaculture on a worldwide basis than I am a national basis. If we take an overall world view, there are high spots as well as a lot of low spots, some failures and some marginal successes.

To cite one example in the culture of a high-value fish, at a conference a short time ago, a person from Scotland announced that, as of this year, there are 153 sites for the pen-rearing of Atlantic salmon in Scotland alone, whereas in 1970 there was only one such site.

When I heard this I wondered if perhaps we hear and talk too much about the down side and not enough about positive results. I'm sure most of you know about the successes in Norway with Atlantic salmon. One of my colleagues at the University of Miami just got back from a two-week tour of Norway and he feels that many of the Norwegian coastal areas now resemble parts of Japan where major coastal areas have been given over to the pen-rearing of fish.

Clearly, the overriding influences on aquaculture development are economic and nutritional. If national nutrition requirements create a demand for aquatic foods, then aquaculture is going to succeed eventually. This is the case in both Norway and Japan. If it is not the case, as it doesn't seem to be in the United States, there is less likely to be any great forward movement.

In looking at the United States, we find a couple of interesting developments. It's not my assignment to review the whole spectrum of development, but to predict the future, so let me take off from one kind of activity which has impressed me over the past several years and that is ocean ranching, about which you have all heard a great deal.

The Japanese have started to accumulate data which show that impacts on productivity can result from ocean ranching, and I see this as a definite prospect for the future in this country. Of course we have had a number of projects of various scales in salmon ranching, mostly on the West Coast, but also to some extent on the Atlantic Coast. Across the street from my office at the university is a hatchery devoted to the rearing and release of snook, and there is also a much larger operation for the release of red drum.

These activities are signs for the future if they are not used for special interest purposes, and if we make it clear that they are experimental--for research--and not yet the start of major, large-scale production. I think there is room for further work on ocean ranching, not only with Pacific salmon, but with other species as well. Aquaculture really includes the controllable, ensured culture of marine animals under all suitable conditions, and this can include sending some of these animals to sea.

The total picture, it seems to me, is in three parts. First, to manage portions of the natural populations for maximum return. Second, to deal intensively with aquaculture systems close to shore. Third, to send some animals to sea to fatten and mature and expect to get an economically sensible portion of them back.

Looking more specifically at New Jersey, I think it is well to contrast the recent interest here with the history of aquaculture in other Northeastern states. As a generalization, I think it is safe to say that every state in the Northeast has flirted in some way with aquaculture development, and a few have developed meaningful relationships.

As another generalization, the hopes and prospects and public pronouncements rarely have been satisfied. Even so, there always is some positive residue from these attempts, even if what remains is only an increase in the available technology, or in knowing what won't work.

As a third point, for almost two decades Sea Grant has been a major supporting force in every one of those states in which significant aquaculture development progress has been made. Moving down the coast from North to South there are examples which seem to have great promise. Some prospered for a while then declined, others continued to be viable. Go to Maine and you see the culture of the European flat oyster and the blue mussel, many small but enthusiastic enterprises stimulated by initial Sea Grant support. In Rhode Island, Representative Claudine Schnieder has been a focus for increased interest in aquaculture in Narragansett Bay. In Delaware there has been for a number of years a large-scale study of controlled-system shellfish culture, which seems to have peaked and now waned. Maryland and Virginia have extensive hatchery operations, and Mike Castagna, from whom you have heard a really excellent discussion of shellfish potential, has demonstrated potential himself in his own projects and programs.

The reality, though, is that most seafood production continues to be from natural populations, and activities that have been very successful at laboratory or even pilot scale have not resulted in any major industrial development. South Carolina, for instance, has large, new aquaculture facilities, and also has a history of extensive research on fresh water *Macrobrachium* prawn culture which has not been translated into commercial production on any significant scale.

In most cases we have seen intitial enthusiasm followed by some successes, but with later decline of both interest and enthusiasm--sometimes as the realities of economics overtake the experimental successes.

New Jersey has not been apart from the history of aquaculture. With us in this conference is Dr. Al Eble who carried on for a number of years aquaculture development in the heated waste water from the Mercer generating plant. Also here is Dr. Hal Haskin, who is internationally recognized for his work with oyster culture, and especially his programs in Delaware Bay. New Jersey has limiting factors, of course, which must be addressed in any aquaculture development plans; but I don't want to dwell on them because I have a couple of suggestions to make.

To prepare for this conference, we had a meeting of the organizing committee, and a concept emerged that we discussed briefly. I don't recall who proposed it initially, but I did some homework on it later and I think it is entirely feasible.

The proposal is that we continue to do whatever may be possible in New Jersey to reduce the amount of environmental degradation that we hear or read about every day, but that we not be defeatist about the possible results. Instead, we should push hard for the development of marginal water aquaculture. For example, there is

Raritan Bay. In terms of primary productivity, it is one of the most productive bodies of water in the world But the quality of its water is marginal, in terms of degradation. There should be a way or several ways to take advantage of the fact of Raritan Bay's great primary productivitry for aquaculture in spite of its marginal quality I see this as a reasonable concept which New Jersey could explore, and so make a contribution not only to the state, but to the nation and to other nations faced with similar problems.

Human inputs would be required at both ends of the development chain. Some animals might not be able to reproduce in the degraded water and controlled conditions could be developed by the state to breed and raise animals to a stage where they could be planted in Raritan waters and grow well in its natural productivity At the other end of the cycle, time could be spent on methods of chemical and/or physical depuration to remove any toxic or deleterious matter from the animal crop.

The defeatist attitued which says, "we can't do it here" must be avoided; instead, take advantage of what is available. If input is supplied at both ends of the chain, I think aquaculture in the state's marginal waters is feasible.

My second suggestion is to make far better utilization of the high scientific and technical skills available here in New Jersey. We heard about genetic engineering from Dr. Singleton, and I think there are several species, both vertebrate and invertebrate, which are good prospects here in New Jersey. I think the genetic engineering initially could be oriented toward pharmaceuticals, and not necessarily toward production of human food. Of course New Jersey is known for its major pharmaceutical industry, and the genetic manipulations I have read about imply that many pharmaceutically important ingredients might be derived from the engineering of marine animals and plants as well as those of the land.

I think the future could be very exciting if New Jersey were to take the lead in combining aquaculture and genetic development, perhaps in a major experimental facility where selective breeding of a few animals could take place.

It would also be well to follow up on Mike Castagna's suggestion that the hard clam farming industry in protected bays in some parts of the state could be increased enormously, particularly with hatchery production of seed.

Another future possibility could be the application of the closed system aquaculture methods developed by the University of Delaware to the American lobster here in New Jersey. There is a substantial body of experience in lobster aquaculture and this may be the time to apply it and seek innovative technologies

I'm sure the ideas presented by my colleagues on the program will stimulate exploration of other ideas, but the two I'd like to emphasize are these:

- The concept of marginal water aquaculture.
- The utilization of the tremendous skills available in New Jersey for exploration of genetic engineering for aquaculture.

I know of no other major efforts in either direction, so the opportunity clearly exists for New Jersey to take the lead to an exciting future.

CHAPTER VIII

THE ESSENCE OF AQUACULTURE: A SUMMATION

Harold L. Goodwin & Robert B. Abel

Robert Abel and Harold Goodwin worked together at the birth of the Sea Grant Program in the National Science Foundation in 1966. They were joined by Robert D. Wildman and Arthur Alexiou and operated the program as a quartet for its formative years. Sea Grant became the principal government supporter for aquaculture research, with Goodwin and Wildman as aquaculture program managers.

Dr. Robert B. Abel brought to the program, a wide background in oceanic affairs, starting as a chemical oceanographer for Woods Hole Oceanographic Institution after his graduation from Brown University. For several years he was Executive Secretary of the Federal Interagency Committee on Oceanography, the Federal government's prime planning and development organization for marine affairs. After serving as Director of the National Sea Grant Program for 10 years, he retired from Federal Service in 1977 and joined Texas A & M University as Assistant Vice President for Marine Affairs, leaving to join the NJMSC in 1978.

Harold Goodwin left the Sea Grant Program in 1974 and formed his own firm, specializing in aquaculture planning and marine education. He became a consultant to NJMSC in 1976. Before joining the new Sea Grant Program he had widely varied experience as a scientific and technical program manager, including six years with NASA, three years as Science Advisor to the U.S. Information Agency, and eight years as a Director of Atomic Test Operations for the Federal Civil Defense Administration. Among his many honors is honorary life membership in the World Mariculture Society.

The inflated aquaculture hopes of a decade ago have given way to a reality which is that, no matter how great its contribution, aquaculture will not feed the world. And while American science and technology have made, and will continue to make, important and perhaps vital contributions to world aquaculture, actual production of aquatic organisms in the United States cannot be expected to make so much as a ripple in world consumption statistics.

On the other hand, aquaculture still offers potential for the United States, not for essential protein, because we are not a protein-short nation, but for a dependable, consistent, high-quality supply of certain valued seafoods which can be raised and sold at a profit.

There is also potential, which may or may not be realized because of economic uncertainty, for some non-food used of aquaculture including the use of modern genetic engineering to so alter some marine organisms that they become valuable sources of such non-food products as stabilizers, texture agents, and pharmaceuticals.

A certain potential exists for social uses of aquaculture in addition to economic values, though these have not been widely discussed. In fact, the most successful and longest-running aquaculture activities in the United States have been without profit motivation, though they have had significant economic as well as social impact We take them for granted; they are the breeding and raising of trout to stock streams for recreational fishing.

The Status of Aquaculture

The simplest definition of aquaculture is that given by Idyll: "Aquaculture is the controlled production and harvest of aquatic animals and plants." But, as Idyll and others have noted, with only a few exceptions the aquaculturist has far less control over his animals than does the farmer. Most aquaculture productivity world-wide is based on collection of seed--spawn or juveniles--in the wild, and uncertain dependence because of natural variations and sometimes a danger because excessive collection of wild seed causes a decline in the natural fishery.

The highest productivity in world aquaculture is in such species as milkfish, carp, and tilapia, of low market value in the United States. The exceptions are shrimp in Equador, salmon in Norway and Scotland, and fresh water prawns in Hawaii and other places. These are in addition to the near-universal culture of oysters, and the more geographically restricted culture of mussels.

It is also generally true that aquaculture is relatively expensive, producing products of moderate-to-expensive value; it is not a source of cheap food.

Where aquaculture has succeeded, it is because nutritional and economic needs or opportunities have made it important, and where either government support or, at least, laissez-faire have created an encouraging climate.

In contrast, the United States has no vital nutritional need for aquacultured products. Though Americans enjoy certain seafoods, enjoyment which can be translated into economic advantage, a favorable social and political climate has been lacking and the government, in most cases, has shown little interest or encouragement. This situation is changing, though not as rapidly as the culturist would like. Passage of the Aquaculture Act of 1980 put the Federal government on record but did not result in greatly heightened Federal activity.

Increasingly, it is clear that creation of an encouraging climate and infrastructure for aquaculture is the role of the individual states. Needed is legislation, perhaps a model Act, which clarifies the legal structure set up for other purposes and now inhibiting aquaculture; an act which encourages aquaculture, and defines the role of state agencies. Such legislation should be derived in the first place from a clear exposition of state goals and objectives.

Factors In Aquaculture Planning

There is consensus: the first requirement for choice of a species to be cultured is "Can you sell it?" Inherent in this deceptively simple question are such elements as market demand, market structure--jobbers, wholesalers, food chains--competition with natural fishery products, degree of government or other control, the form the product is to take, whether as-harvested or with some degree of handling and processing.

Further, market demand and saleability determine price, and Castagna has summed it up best: "If it costs a dime to grow a thing you can only sell for a nickel, don't grow it."

How much it costs to grow the organism depends on many factors, some of which are not peculiar to aquaculture, but in the past have been overlooked or not sufficiently studied. These include the cost of land, cost of energy, cost of conforming to local zoning or other regulations, and in some cases the attitude of the neighbors.

Assuming that the general location and similar geographic factors pose no problems, the cost of feed becomes paramount. For many high value species which are not sufficiently fed by the natural waters,feed becomes the most critical element and planning must include assurance of its availability, or of the components from which it is made.

In some locations, and for culture of some species, there may be surprisingly high costs involved in the disposal of effluent or wastes; there may also be stringent regulations to be met which pose design problems affecting the entire operation.

All such considerations are, of course, elements of a management plan. When the key factor responsible for the failure of many aquaculture enterprises is isolated, that factor turns out to be bad management, usually because of lack of good management plans.

Selection of Species

For the business of aquaculture, Castagna has given us an entirely pragmatic checklist, and has stressed--as have others--that if profit is not the motive, it isn't aquaculture business, it's a hobby or something else.

With profit in mind, and with saleability and market demand known factors, elements which play a part in selection are:

- The right climate for the species. It has been noted that one can grow anything anywhere if willing to pay the cost, but in aquaculture it makes no economic sense to choose an animal for culture in the temperate regions when the hot tropics are its abode.

• A species which is environmentally compatible, not a potential hazard or competitor to native species or to the environment itself.

• If for business and profit, a species for which the technology of culture exists. A profit-making operation should not have to develop the technology, even though research conducted during presumable profitable operations can improve the technology and increase the profit.

• A species which, in accordance with the complete and well-developed management plan will not suddenly pose problems of meeting health or other standards.

• A species which can be grown in an acceptable length of time. Time not only increases cost but increases hazard. The longer it takes to bring a species to market size, the greater the chance of mishap, perhaps from an unprecedented storm which wipes out the facility or cuts off power for extended periods, or perhaps from something like an equally unprecedented disease.

Risks to the Aquaculture Enterprise

Any enterprise involved with living organisms, whether animal or plant, is risky, the risks ranging from the ever-present possibility of freak weather to equally freakish economic disasters caused by changes in government policy. Farmers know this very well.

Risks to aquatic farming are those of the land farmer to a considerable extent, with some added possibilities inherent in the water environment. The possibilities of disease are there, but may exist in greater variety which are deadly to marine organisms, especially if environmental plaques are included. In addition to bacteria and parasites, organisms cultured in the natural environment are subject to blooms of toxic organisms, and while most of these may have the effect of making the aquaculture crop temporarily unsaleable, there are others--as has happened off New Jersey--which deprive molluscs of oxygen under some conditions and cause their deaths.

Most cultured aquatic organisms are not only smaller than those grown on land but are much more fragile, especially in their early development or growth stages. Further, aquaculture must produce in any one animal crop a far greater number of organisms than does the farmer per unit of space and time; disease or similar events can be relatively more devastating to the crop, and hence to the economic stability of the enterprise.

As in land farming, there is always the risk of predation, but aquatic farming faces a greater variety of risks because of predators in the very environment in which the crop must be grown. Mulluscs, for example, can be eaten by marine snails, crabs, and other local inhabitants. Crustacean species and small finfish are prized by birds and by land animals not commonly a significant hazard to farm animals and poultry, including possums, raccoons, and snakes. In extensive culture--open water areas--the predation can be great enough to constitute economic disaster. Perhaps to a greater extent than in garden farming, human predation can be a problem: a net full of succulent shrimp can be taken rather quickly in an undefended area.

The natural harvest of certain aquatic species poses a degree of risk to the aquaculturist. First, there is competition which may be resented by fishermen; second, price depends on supply, and natural fisheries have occasional bumper crops, too, in which the culturist's product simply cannot compete in cost with a large supply from the fishery.

An inherent risk, whether from weather, disease or accident, is that the entire aquaculture crop may be wiped out, a risk not too different from that which the farmer takes every year.

The management plan may take disaster into account by ensuring adequate capitalization of the enterprise. It was noted earlier that most aquaculture failures were the result of a bad management plan, and inadequate capitalization ranks high among the management failures.

Goals and Objectives

For the most part, the terms aquaculture and mariculture have been interpreted as meaning aquatic businesses, designed to bring a profit. Aquaculture is now taken to mean the culture of any aquatic organism whether in fresh or salt water. The chief advocate of the term mariculture, the World Mariculture Society, has just changed its name to the World Aquaculture Society.

In introducing this chapter, we pointed out that the longest running success in American aquaculture has probably been the trout hatcheries which stock our trout streams. Certainly this has had economic impact to no small extent, as any manufacturer of fly fishing gear, or operators of a number of fishing resorts, can testify. Yet, the basic goal is a social one, and it has the advantage of establishing a useful precedent.

A cautionary note is that the social objective can, in some cases, become a politicized one. There are states in which the responsible state agency deliberately kills by chemical means all the perch, blue gills, crappies, bass, and other species in a pond or lake to restock entirely with trout, thus depriving the family pan-fishermen while pleasing the fewer trout fishermen who are backed by an organization with political clout.

Because recreational fishing is very important, both economically and socially, the possible uses of aquaculture in innovative approaches to sport fishing need some serious thought. While sport fishing may create an image of expensive tackle, boats, and game fish, it covers everything from crabbing with net and chicken necks on a string, worm fishing for anything that will bite, hooking one of the multitudes of shad or alewives enroute upstream to spawn, or just pushing bare feet through muck to bring up a hard clam. It is well to keep in mind, too, that for more than a few of our less affluent citizens, especially in metropolitan areas, "sport" fishing is truly subsistence fishing.

The decline of rockfish--striped bass--has resulted in a surge of concern, and the application of a known technology for spawning and raising these important fish to help restore the natural populations. Again, while there are strong economic values, rockfish are a prized sport fish, and the social values may be even higher; there are more sport rockfish fishermen than commercial rockfish fishermen. This is an other precedent worthy of further consideration.

While businesses and the state may conduct research and contribute to development of aquaculture science and technology, research is primarily the role of the universities. Funding from any appropriate source include the state, foundations, businesses and business associations, and the Federal government. The objective of the university is not alone the development of a technology, but the education of competent scientists and engineers, and social scientists of several different specialities. While Sea Grant often is credited with being the principal supporter of aquaculture, it is important to remember that Sea Grant is a matching program in which at least one third of the grant must be from non-Federal funds. It is not a coincidence that the states in which the Universities have made the greatest contributions to aquaculture are those states in which the legislature has made sure that adequate matching funds for Sea Grant are a regular appropriations item.

In planning, it is also well to note that the Federal government is not noted for its staying power. Grant funds do not continue indefinitely for most things, certainly not for individual projects. Even Sea Grant, with better continuity than most, has considered itself a start-up source not created to maintain production after a given point. For the long term in establishing something new in aquaculture, the state is the prime source and should be the prime mover.

Steps to a Coherent Aquaculture Program

1. The program necessarily starts with the State's own goals, if it is to be coherent and of maximum use to the people of the state. Customarily, these goals are stated in an Aquaculture Act which takes into account all related state responsibilities and defines its aquaculture goals in terms of the aquatic environment, the needs and responsibilities of its political subdivision, and the activities which compete for time and space especially along the shore, including fisheries, transportation and boating, recreation, swimming and sunbathing, and economic development...not to mention aesthetics, which too often are considered post-factum. Of course no one has said creating a genuinely good state plan would be easy.

2. It is the responsibility of the state, within the framework of its organic aquaculture act, to define the role of its agencies. Normally, agency missions are clearly enough defined in terms of the agency's traditional functions. But aquaculture needs and the implementation of the state's intent may conflict with traditional regulations. It was said repeatedly during discussions that the bureaucracy gets in the way. It does, but it doesn't mean to, and the reasons are twofold: first, badly written laws and legislative guidance; second, fear on the part of the employee that deviation from established writ, even for the sake of common sense, will bring personal grief.

It is also the responsibility of the aquaculturist to communicate with the agency, and to do so in the spirit of cooperation and not hostility, to assist the agency in formulating or reformulating sensible regulations--with which the aquaculturist may sometimes disagree no matter how sound the agency's position.

3. It is the responsibility of the state to bring order out of organizational chaos should it exist and specify which of the state's entities does what. Specifically, the state should ensure that the competences within the state are fully used, recognizing that competence in aquatic animal physiology is only a small part of the competence necessary in aquaculture. Implementation of a viable, coherent program requires many kinds of scientists, engineers, economists, business administrators, and political scientists, and these talents are found throughout the state and its entities.

4. Recognizing that the various competing entities within the state should not be expected to agree on where the greatest competence and leadership are to be found, provision should be made for outside experts to give strong assistance in identifying strength, noting that choice of persons for a committee, board, or commission should be from qualified and competent scientists, engineers, and businessmen with reputations *among their peers* in the field of aquaculture. The recommendations of such a group should be taken very seriously indeed. It might be pointed out that one report on New Jersey aquaculture, presumable authoritative, demonstrated either lack of knowledge about aquaculture activities and competence in New Jersey or serious distortion.

5. Built into the plan should be provision for independent review of aquaculture proposals, whether received from a business, a state agency, a university, or any other source. There is no expectation anywhere these days that generous supplies of money will be available, and a review procedure that ensures competent objectivity is the best saver of scarce money. Neither states nor the Federal government can claim freedom from aquaculture nonsense. One Federal agency issued a grant for a multi-million dollar aquaculture project which horrified every experienced aquaculturist who heard of it. Intense questioning could not identify a single member of known competence and experience in the aquaculture community who had ever seen the proposal. The millions were wasted on a project which had no remote possibility of success.

6. Another requirement in a sound plan is a place for an ombudsman, a person within the state establishment who represents the state's aquaculture community. The function of such a person is to assist in finding the right person within the right agency, acting as intermediary to be sure there is at least good communication when agency and aquaculturist disagree, and being a voice for the aquaculture community within state councils when needed.

Suggestions for the Aquaculture Future

Implicit in each paper delivered at the New Jersey Aquaculture Conference were suggestions for directions a state program might take. Some of these suggestions are here summarized for serious consideration in development of a state program, once a state plan is reconsidered and developed as necessary.

1. Look backward, Michael Castagna suggested. Examine the history of New Jersey's fisheries and its species to see if well-liked and marketable species once present in significant numbers but now in decline or vanished from the markets might offer possibilities for aquaculture. While still available, oysters and hard clams have declined in numbers and are high value species worth continued and expanded effort. Specifically, he suggested that the state should play a stronger role, perhaps in providing the hatchery for oyster seed, using the latest technology. He also pointed to the once-plentiful sturgeon, a gourmet item whether as caviar or smoked fish, and noted that culture technology has been developed on the West Coast.

2. John Ryther's discussion of non-food uses of aquaculture focused on seaweeds and some higher plants, the latter useful for stripping nutrients from waste water but presenting their own problems of economic disposal. While water hyacinth is not for New Jersey, other higher water plants exist, some of which may have useful characteristics while presenting less of a disposal problem. Ryther's discussion of waste water was also a reminder that some lower marine organisms are known to concentrate specific chamicals, including metals, and may be worth some study for use in helping to clean up polluted waters. Of higher potential was Ryther's report on mutated seaweeds, specifically gracilaria, which contain significant amounts of very high value organic compounds.

When Ryther's report is combined with the discussion by Fred Singleton on the potential of genetic engineering, what comes to mind immediately is the high New Jersey ability and experience in pharmaceuticals and the state's distinguished history in this field. While it is true that many researchers have looked for active biological substances in marine plants and animals, there has been relatively little work in the culture of those which appear most promising, especially when genetic manipulation may bring significant and perhaps dramatic improvement.

3. Castagna suggested and Carl Sindermann expanded the suggestion into a strong recommendation that New Jersey take the lead for its own sake and for the sake of other areas in what is termed marginal water aquaculture. Marginal means somewhat polluted, not ordinarily the quality of water one would choose in which to grow food organisms. But, as Sindermann said, human inputs at both ends of the culture cycle would make the difference: at the breeding end to develop resistant strains, perhaps, but certainly to raise the animals to a stage where they were less fragile than in the larval or early juvenile stages. At the harvest end, effective depuration to remove any toxicants or disease organisms would be used. Research for both ends is needed. If successful, and the probabilities of success seem high, some of the very productive waters now denied to food use could be used.

4. Sindermann, in his look to the future, also urged that New Jersey put its talents and experience to work along the lines Ryther and Singleton discussed, an approach that would require a serious, long-range commitment and innovative methods of cooperation and joint management among universities, pharmaceutical and biological businesses of several kinds, and state agencies. Given developments in recombinant engineering in the past few years, the potential seems to warrant a major program.

5. Several speakers said it, both from the platform and the floor: aquaculture must be carried to pilot scale as part of the research and development process. There have been many cases where laboratory successes simply would not scale up, for reasons that could not have been fully anticipated. Pilot scale may be described as any scale large enough to demonstrate the production success of the culture technology.