the legal framework now exists, as it never did before in Brazil, to enable the government to put into action a rational and technically sound program of fishery development.

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Shellfish Mariculture[1]

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Abstract

The increasing need for food, the development of techniques for rearing of several of the commercial mollusks including oysters and the quahaug clam,

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the possibilities of pond culture and other techniques of controlled sea farming, the serious inroads in shellfish production caused by diseases, predators and other factors have caused an increasing interest in scientific mariculture. Laboratory rearing of the mollusks will result in a constant supply of seed. Techniques have been developed for the chemical control of predators and only await adequate application. Chemical and genetical control of diseases and the production of faster growing strains of mollusks are now being explored. Technology has advanced so that the sea foods can be harvested and processed more efficiently. Additional research in many problems is needed. Needed are pilot operations to determine if the laboratory developed techniques are applicable to mariculture. Needed are the development and testing of disease and predator control, production of more vigorous and faster growing "crops," and crops that will reach market size uniformly to allow machine harvesting. There are many other facets that need to be explored and perfected in order that mariculture can compete with agriculture in the mass production of food.

INTRODUCTION

AT PRESENT, the United States has a surplus of food, principally because of advanced agricultural techniques based on mechanization, extensive use of fertilizers, and research concerning what to grow when, chemical control of insects and parasites, and development of higher-yielding and more disease-resistant strains. But our arable land is being diminished by housing developments, super-highways, and the like, as our population steadily increases. The extrapolation of these two processes leads to prediction of food shortages in the future.

Recognizing one means of meeting these shortages, President Kennedy, in a letter of March 29, 1961, wrote to Vice President Johnson, President of the Senate:

> "The seas offer a wealth of nutritional resources. They are a principal source of protein. They can provide many times the current supply if we but learn how to garner and husband this self-renewing larder. To meet the vast needs of our expanding population the bounty of the sea must be made more available. Within two decades, our nation will require over a million more tons of seafood than we now harvest."

There remain millions of acres of undeveloped or unexploited land available to the United States—the shallow-water areas along our coasts, the bays, inlets, and mouths of estuaries suited to production of shellfish. Production of oysters on "farms" has shown that husbandry of marine forms, or *mariculture,* is feasible, but the potential is still far from being realized. Many of the factors that must be brought under control through further research are already apparent, e.g. disease (Mackin, 1960) and predators (Loosanoff, 1960). Fertilizers, so effective in aquiculture of fresh-water fish (Swingle and Smith, 1950) have not yet been used in mariculture.

Two aspects of shellfish mariculture are being investigated in our laboratory. An attempt is being made to find a chemical or biological control for the disease of oysters caused by the fungus, *Dermocystidium marinum,* and pilot operations are being conducted to determine whether the quahaug clam, *Mercenaria mercenaria,* can be raised profitably on a commercial scale in Florida waters.

METHODS

Attempts at chemical control of the fungus disease in oysters were concerned, at first, with introducing antifungal chemicals into closed containers with infected oysters. This method proved unwieldy since it involved determining infection on a statistical basis and screening large numbers of chemicals at various concentrations. At present, we are attempting to culture the tissues of oysters. When we are successful, we can then infect the tissues and study the effect of the chemical directly.

The biological control requires selection of a strain of oysters resistant to the disease, which has been attempted in pond culture. Brood oysters have been secured from several areas where the disease is endemic; and from other areas, encompassed by the range of occurrance, where it is seemingly absent. Progeny from these brood stocks have been planted in areas where the disease occurs and periodic examinations have been made of growth and mortality. The results have not been conclusive but are not very encouraging.

Preliminary studies of clams showed that unless the clams were protected from predators, mortality was very high (Menzel, 1960). Fenced areas were constructed and approximately 100,000 clams have been planted in concentrations ranging from ten to seventy five per square foot. Clams have been planted with no protection to serve as controls. These experiments have been in progress only six months, but so far survival and growth are encouraging.

DISCUSSION

Chemical control of pests and disease, though effective in agriculture, is still far from ideal. The habitats involved in mariculture are very much more complex. Great care must be taken to avoid damage to other organisms in the community which are important in stabilizing the habitat. Before widespread use of chemicals is advocated, careful experiments must be conducted to determine effects on all aspects of the environment. If a chemical safe for all organisms except the fungus is found, an effective and economical method of application must be devised. The problem of application has been discussed with chemists and engineers of the Dow Chemical Company, and they seem certain that chemicals could be incorporated in pellets which could be sown over the oyster beds, where they would sink among the shells, and release the chemicals slowly.

A strain of oysters resistant to the fungus disease may be the best solution. Oysters lend themselves so well to mariculture that planting of seed oysters is already a widespread operation, so that a resistant strain could rapidly supplant the unresistant stock. The finding of such a strain would also give impetus to the search for a strain of oysters resistant to other diseases, such as that which is presently causing severe mortalities in the Delaware Bay and the lower Chesapeake Bay. The re-establishment of the East Canadian oyster industry after the catastrophic mortality during 1915-20 gives an indication that a naturally resistant strain of oysters was present (Logie, et al., 1960). Even if completely resistant strains are not found to exist, it may be possible to breed a resistant strain, as has often been done in agricultural plants.

The mariculture of clams is much further from the speculative stage than is the controlling of the fungus in oysters. But there remain many problems before clams can be raised profitably in Florida. Belding (1931) proposed the farming of clams and stated how profitable it could be. In our southern waters the growth is much more rapid than in northern waters and hence clam mariculture should be even more profitable.

One of the bottlenecks in clam mariculture is a lack of constant supply of seed clams. The techniques for rearing clams in the laboratory have been perfected by Loosanoff (1954). Commercial clam hatcheries have been established but I do not know just how successful these ventures have been. Among the special facilities needed is sea water at controlled temperatures to induce spawning of brood clams (Loosanoff and Davis, 1950). Constant temperature cabinets or apparatus for growing algae used in feeding larvae and newly metamorphosed clams are also needed (Davis and Ukeles, 1961). Techniques must be devised or existing techniques modified to rear clams on a large scale, from metamorphosis to planting size. More effective controls of predators must be devised.

Harvesting of clams is economical with machines already in use. However, economy of machine harvesting would be improved if clams of uniform size could be obtained, hence eliminating the labor involved in culling and grading. Our growth experiments show that the rate of growth varies several hundred per cent among individual clams in a year's time. There should be developed in the laboratory, through selection, clams which will all reach harvesting size at approximately the same time. This has been accomplished in machine harvested agricultural plant crops.

Observations to date have shown that clams grow about equally well at all concentrations up to 50 per square foot. These, however, were small plantings and it is not known how large plants would affect the food supply and hence the growth. Fences are one of the more expensive items in clam mariculture and the denser it is possible to plant clams and still have satisfactory growth the more economical it will be. It might be more economical to plant clams at denser concentrations, even though the growth rate would be reduced.

There are many other problems, many of basic scientific interest as well as practical importance. The clam mariculturist wants the fastest growing clam possible. Experiments at the U.S. Fish and Wildlife Service Laboratory at Milford, Connecticut, have shown it is possible, by selection to produce strains that are superior in growth rate to the heterogenous populations (Chanley, 1959). It may be possible to produce clams that will reach market size in half the time it now takes. This might be accomplished not only by selection but also by crossing the quahaug from separated geographical areas to obtain so-called hybrid vigor. Hybrids of the northern quahaug, *Mercenaria mercenaria,* have been made with a closely related species, the southern quahaug, *M. campechiensis,* and the crosses have shown good growth, better than the northern parent. (Chestnut, Fahy and Porter, 1956; Haven and Andrews, 1956; Loosanoff, 1954).

CONCLUSION

We have been mainly garners and hunters of the sea and not farmers. We are still in an uncivilized state when it comes to fishing. It is true that our methods of capture of the various seafoods as well as the processing have advanced, in some instances, as fast as the technology of agriculture. In other instances we are still using the primitive hand tongs to harvest oysters. The need for more food may be upon us within a few decades. Initially the expense of producing oysters and clams by scientific mariculture would be high but the expense should be offset by the high return from these high value seafoods. It is believed that with more refined techniques and large operations, the per unit costs of production will be so decreased that mariculture will become a very profitable venture.

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Preliminary Experiments on the Rearing of the Fresh Water Shrimp, Macrobrachium carcinus (L)

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Abstract

M. carcinus is a freshwater shrimp which has been reported from fresh and brackish water in Eastern America from Florida to Southern Brazil. It reaches a large size at maturity, specimens of 200 mm being not unusual.