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TWO EMERGING PROBLEMS IN MARINE AQUACULTURE COASTAL POLLUTION AND DISEASE

by

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Aquaculture research and development activity by government agencies, universities, and industry is ongoing in the United States, as it is in a number of other nations around the world. Notable commercial success has been achieved with a few fresh-water or anadromous fish species (salmon, trout, catfish, carp). Less commercial success has been achieved with marine and estuarine species, with the exception of oysters and clams. Technology for marine aquaculture of species such as shrimps, lobsters, flatfish, and pompano, is still incomplete, even though it is being developed in a number of places. Major deterrents to successful commercial culture of marine species at present seem to be

1. inability to control the complete life cycle of certain species;

2. inadequate precise knowledge of the nutritional requirements of the species;

3. inability to control mortalities due to diseases, especially in closed systems;

4. inability of products derived from marine aquaculture to compete economically with similar products from the natural environment; and

5. a progressive deterioration of estuarine and coastal aquaculture areas due to human activities.

Other problems, such as absence of genetically modified stocks, could also be identified.

This paper will be concerned with only two of these problems: coastal pollution and disease. Both have been of continuing concern to research groups of the Middle Atlantic Coastal Fisheries Center, National Marine Fisheries Service, at its research laboratories in Oxford, Maryland; Sandy Hook, New Jersey; and Milford, Connecticut.

COASTAL POLLUTION

The principal pollution-related problems in open-system marine aquaculture seem to be those produced by industrial sources rather than domestic ones. In fact, except for microbial contaminants, domestic wastes, if properly handled and dispersed, can be positive factors available for nutrient enrichment of culture areas. Nevertheless, pollutants can exert an impact on aquaculture by effects on reproduction, survival, and growth of cultivated animals, and by creation of public health problems.

Effects on Reproduction, Survival and Growth

Most estuarine and coastal species, including those important to marine aquaculture, survive in a variable chemical, thermal, and biological environment. Even so, human modification of that environment can cause changes that are intolerable to certain species, or can cause changes in certain environmental factors great enough to place continuing stress on the species, or can introduce new chemical factors with which the species has had no previous evolutionary experience. Such human modifications can cause mortality, interfere with reproduction, reduce survival and growth.

Organic loading of coastal waters can lead to higher population levels of bacteria (vibrios, pseudomonads, aeromonads) which act as facultative pathogens of marine animals. Concentrations of such bacteria may provide sufficient infection pressure on fish and shellfish so that disease and mortalities result. This is especially feasible if the resource populations are under other types of environmental stress simultaneously. Some evidence for this sequence of events has been presented recently (Mahoney et al., 1973; Snieszko, 1973) in studies of "fin rot" in heavily polluted waters.

Use of heated effluents from electric generating stations has been widely publicized for a positive role in permitting year-round growth in temperate zone waters. Some evidence is accumulating, however, to indicate that the positive effects of thermal additions on growth may be offset by increased mortality due to disease. Viral and bacterial disease prevalence has been found to be increased in certain fish and shellfish populations existing in heated effluents (Farley et al., 1972; Sindermann, in press). Evidence is still minimal, but the potential problem deserves further attention. It is interesting, and perhaps relevant, that a recent authoritative news article (Anonymous, 1973) reports that the Japanese are holding in abeyance their yellowtail fish culture attempts in heated effluents because of continuing high levels of mortalities.

Man-induced chemical changes in estuarine and coastal waters used for aquaculture can exert profound effects on survival, growth and reproduction of marine species. Larval and early juvenile stages of a number of marine fish and shellfish have been shown to be particularly sensitive to chemical modifications of their environment (Woelke, 1967, 1968; Wiseley and Blick, 1967; Kuhnhold, 1971; Okubo and Okubo, 1972). Petroleum fractions, heavy metals, and chlorinated hydrocarbons have been demonstrated experimentally to have growth retardant or lethal effects on early life history stages.

Public Health Problems

Potential or actual pollution of growing areas for marine aquaculture must be of serious concern, because of microbial or chemical hazards.

Viruses affecting humans (hepatitis is the best example) have been shown to be transmitted by ingestion of raw shellfish from polluted waters (Mason and McLean, 1962); and have been found to have a surprisingly long survival time in sea water and shellfish (Metcalf and Stiles, 1966). Such viruses thus constitute a critical problem for aquaculture operations in coastal and estuarine areas where even limited domestic pollution exists -- and this would include much of the area now used or planned for use in food production.

While viruses constitute what is probably the most vexing microbial problem to marine aquaculture, pathogenic enteric bacteria form a continuing threat. At present much attention is being paid to the role of a marine vibrio, V. parahemolyticus, in outbreaks of food poisoning in Asia (and recently in the United States) related to seafood consumption. Other pollution-associated bacteria, such as Clostridium, Shigella, and Salmonella, should not be ignored, since even a single outbreak of disease related to any marine species can have drastic impact on markets for all seafoods.

Chemical contaminants of marine products, at levels toxic to humans, must also be of concern to marine aquaculture. The spectrum of such contaminants is broad. Heavy metals (mercury in particular) have received a great amount of research attention, and the horrors of Minamata Disease in Japan have been fully described to the world in news stories. Increased and continuous surveillance of all production areas would lessen the likelihood of another such incident, but would be costly.

Possible toxic effects of pesticides in foods have been discussed on many occasions. Butler (1969a) stated that "Despite the wide occurrence of persistent pesticide residues in the world fauna, their magnitude is for the most part too small to have any known significant effects on human health." A monitoring program was instituted in the United States in 1965 to scrutinize pesticide levels in estuarine fish and shellfish (Butler, 1969b). Thus far pesticide residues in all samples from 15 states involved in the program have been below levels considered hazardous to humans. Even though indiscriminate use of pesticides is coming under some measure of control in a few countries, their use in other parts of the world is expanding, and, because of their persistence in the environment, and their accumulation by successive levels of food chains, the pesticides continue to be threats in nearshore ocean areas, including those devoted to marine aquaculture.

Some petroleum derivatives, in addition to effects on growth and survival of marine plants and animals, have been demonstrated to be carcinogenic to humans. While no direct association has yet been made of occurrence and persistence of petroleum components in the marine environment, uptake of oil hydrocarbons by food chain organisms, transfer to humans through fish and shellfish, and carcinogenesis -- the potential problem must be further explored. Probably of more direct concern would be the tainting and rejection of aquaculture products as a result of oil spills or other types of deliberate petroleum discharge in coastal waters.

DISEASE

Apart from those aspects of disease which may be influenced by coastal pollution, there are other important negative contributions of aquatic animal diseases to successful marine aquaculture operations. Diseases may exert effects on cultivated populations either by causing sudden catastrophic mortalities, or by producing continued erosion of population numbers over longer periods. Mass mortalities, often of microbial origin, are of particular importance in larval and early juvenile populations. Dollar values for losses sustained because of disease and the necessity for disease control have been estimated for trout and shrimp production at from 20 to 30% of total costs. There is little residual doubt about their importance, even though such estimates may be inflated by inclusion of unexplained mortalities arbitrarily attributed to disease, but really caused by lethal levels of other environmental factors.

At present there are three particularly significant disease problems in marine aquaculture (among the many continuing problems which exist). These are larval diseases, the special case of virus diseases, and the role of environmental stress in diseases of cultivated species.

Larval diseases in aquaculture operations are extremely difficult to cope with -- beyond the ultimate and often unpalatable solution of discarding the entire batch. Larvae are very small and their numbers are large, so the individual organism does not receive proper scrutiny. Only when mortalities reach unusual levels is any attention paid to the possible role of disease in larvae. Reasonable levels of mortality are tolerated, and even ignored, as long as larval populations do not dwindle too much or too rapidly. Several recent reports describe diseases of larvae: the fungus Lagenidium in shrimp larvae; the bacterium Leucothrix in lobsters; and an unidentified fungus disease of Macrobrachium larvae. Again though, at least some of these larval diseases are undoubtedly indications of other environmental problems -- especially nutrition and water quality -- and are produced by secondary pathogens.

Viruses of aquatic vertebrates and invertebrates have received much recent attention. Three years ago, only one virus disease of marine invertebrates (a crab) was known. Since then, two quite distinct virus diseases have been reported from oysters, two more from crabs, two from cephalopods, and one from shrimps. One of the oyster viruses (Farley et al., 1972) was implicated in higher mortality rates in a very limited study -- while the shrimp virus was observed in shrimps being used experimentally in studies of effects of chlorinated hydrocarbons (Couch, 1974). Unfortunately, no established cell lines from marine invertebrates are presently available to carry on adequate studies of the organisms already recognized.

Much current research emphasis is also focused on virus diseases of fresh-water fishes. At a 1972 FAO-sponsored symposium on communicable diseases of fish, about 80% of the time and discussion was occupied with viruses -- producing an impressive array of present-day problems. Other microbial diseases such as furunculosis, lymphocystis and whirling disease of salmonids were also considered during the symposium, but the relatively recently recognized viral infections clearly occupied center stage.

Another extremely complex and often very frustrating aspect of present-day aquatic animal disease research is that concerned with environmental influence -- the examination and definition of environmental stress as a major determinant of disease. It has been long recognized that non-optimum conditions in culture operations -- high temperatures, low oxygen, inadequate diets, presence of metabolites in closed systems -- could enhance effects of known pathogens and encourage activities of facultative pathogens.

In considering such problems in marine aquaculture, it is important to distinguish between what we can label primary pathogens, such as Gaffkya (Pediococcus) in lobsters, which can kill even when other environmental factors are reasonably adequate, and facultative or opportunistic pathogens such as vibrios, pseudomonads, and aeromonads which kill when other physiological or environmental factors are poor or marginal. What is referred to as disease in culture operations is often a consequence of one or more of such marginal environmental factors: nutrition, water quality, oxygen, temperature, salinity, and high bacterial populations.

SUMMARY

Among the numerous problems associated with and in some instances impeding economically successful marine aquaculture, coastal pollution and disease must rank as among the very significant. Industrial, and to a lesser extent domestic, pollutants can exert effects on cultivated marine and estuarine animals by causing mass mortalities, reducing survival and growth, inhibiting reproduction, or by introducing public health hazards -- real or potential. Problems can be categorized as principally chemical or microbiological nature.

Disease has been identified as a major deterrent to successful aquaculture, and significant investment must be made in understanding and controlling disease outbreaks. Larval diseases and associated mass mortalities constitute an important present-day problem, and the role of viruses in marine aquaculture is just beginning to be explored. Stresses associated with artificial culture conditions, particularly poor water quality, can enhance disease effects on cultivated populations.

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