Husbandry Helps Harvests of Healthy Shrimp[1]

GEORGE E. KRANTZ and E. S. IVERSEN
Division of Biology and Living Resources
Rosenstiel School of Marine and Atmospheric Science
University of Miami
Miami, Florida 33149

The purpose of this paper is to compare the relative role of husbandry, or control of environmental conditions, and disease in the fluctuations of abundance in populations of marine animals. Since we have included husbandry in this comparison emphasis is placed on cultured animals in the newly evolving industry of mariculture. Also we would like to introduce a recently developed program at the University of Miami which was established to explain and alleviate some of the disease and mortality problems in marine animals.

In recent years there has been a dramatic increase in the public awareness concerning disasters in natural populations of marine animals. Some of these phenomena, known as fish kills, involve many animals with the obvious appearance of a disease condition. Moribund fish frequently have bloody lesions, a spinning-swimming behavior, white patches of skin, or abnormal fin coloration. The news media and environmental groups, especially in the Gulf coastal regions, frequently dramatize these losses of fishes and shellfishes, especially when the scientists and state management agencies fail to provide a rational, scientifically accurate answer for the cause of the mortality.

In the field of mariculture, the Mardela Corporation has recently analyzed the current status of research and commercial ventures in this new field. Their predominate finding was that disease has evolved as a single major deterrent to the mariculture industry. They also noted a significant lack of expertise in scientists competent to study the diseases of marine animals and an absence of any centers to provide disease diagnostic services to private industry. We are not sure how much of the information collected by the Mardela Corporation was a result of real disease problems or how much of the concept was generated as a result of the subjective reasoning by commercial mariculturists who had failed to reach projected production capacities in a given time. For the entrepreneur, disease and mortality is a convenient excuse for production failure. Several mariculture firms have employed management personnel as well as biologists who have had a very poor perspective of the relationship between disease, the health of the animals and the environment in which they are trying to raise the animals. The failure of these commercial ventures to provide minimal biological requirements for the animals produced abnormal stresses which disposed their

[1] Contribution from the Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida 33149.

captive animals to disease. Maintenance of (1) a proper environment and (2) health of the animal is what we have called husbandry. Husbandry, or manipulation of the environment and populations of animals in it, must be considered when one is evaluating reasons for mortality in a mariculture facility, a bay or a river of our coastal waters; and even in large numbers of animals confined in holding pens prior to marketing as in the blue crab industry, the live lobster industry and in live fish markets. Many of our comments also apply broadly to natural populations which support our commercial fisheries.

The relationship between an "aquatic animal", (this can either be a fish, lobster, or crab) its environment, and a parasite and disease component can be illustrated by a simple diagram (Fig. 1). There is a continuous interaction between the animal, and its environment, and populations of disease entities. At any time either the environment, or a specific disease entity could invade the animal and kill it. Usually both the environment and disease work synergistically. The environment can favor the proliferation of a disease or parasite entity, increasing this component to a density that will overwhelm the host's defense mechanism. The host's defense mechanism continually works to repel invasion by parasites and diseases. These defenses consist of the mucous membranes, intact skin or exoskeleton, white blood cells and immune responses in the body. Often a marginal environment in which the animal lives reduces the capacity of the body to produce these defense structures and substances. A lowered defense can result from low oxygen, inadequate diet or incorrect diet, high carbon dioxide levels, changes in pH, pesticides and the presence of heavy metals. These problems are encountered in natural populations especially when they are confined to a coastal estuary, bay or river. Fish, or other marine animal populations, can also modify their own environment and create an unfavorable situation which allows the parasite population to thrive. This is frequently evident when we contain wild animals or crowd captive populations in mariculture facilities. In confinement these animals are exposed to their own excrement and decaying uneaten food. Often densities of these artificially crowded animals exceed the biological capacity of the aquatic environment to provide the oxygen and destroy waste products.

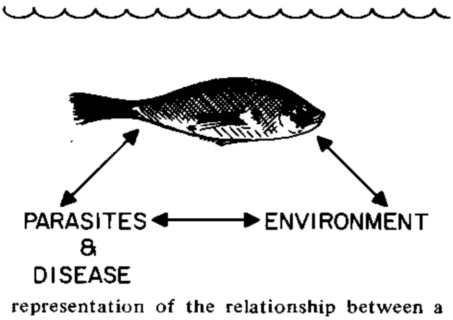

Fig. 1. Diagrammatic representation of the relationship between a host, its parasites and diseases, and their collective environment.

We have encountered all components discussed above while studying mortalities in the coastal regions of south Florida and especially in the University of Miami's experimental shrimp farm at Turkey Point.

The Turkey Point facility (described by Tabb et al. 1969) is located near Homestead, Florida, on the property of a Florida Power and Light nuclear and fossil fuel plant. We utilize the effluent from this plant in our hatchery operation to provide circulation of water in 7 above-ground grow-out ponds, and in 16 outdoor production-sized (20,000 liter capacity) shrimp larval rearing tanks. The concrete larval culture tanks have a production capacity of three million post larvae per month on a sustained basis. The laboratory which is used to grow algae and diatoms to feed the larval shrimp also has indoor controlled-temperature larval tanks which could yield about 500,000 post-larvae shrimp per month. The major effort of this facility has been to evaluate the economic feasibility of the shrimp hatchery operation and to define and correct some of the problems in the pond culture of penaeid shrimp.

The major problem confronting a hypothetical mariculture industry at Turkey Point is the mortality of shrimp in the grow-out ponds. Untrained biologists and over-anxious laboratory scientists would incorrectly refer to this situation as a disease problem. However our research approach has obtained enough data to define the cause of most of the losses. Since 1968 we have conducted 49 pond culture experiments (Table 1). These culture studies ranged from 3 to 9 months in duration. There were obvious situations of "winter-kill" caused by low water temperatures especially when we attempted to raise shrimp during the November through March period. Therefore the survival data are separated into two groups.

Table 1. Survival in Experimental Shrimp Culture Ponds at the Turkey Point Facility. Survival of Ponds in Column Labeled "Winter" Refers to Culture during the November-March Period

% Survival	Number Winter Experiments	Number Summer Experiments
0- 9	8	3
10-19	0	1
20-29	1	2
30-39	2	0
40-49	7	0
50-59	1	6
60-69	0	0
70-79	1	6
80-89	2	5
90-96	1	3
Total Experiments	23	26

The winter data includes any pond situation which extended into or through the November through March period. In South Florida this period is unsuitable for growth of penaeid shrimp and there is a high probability of mortality in a pond situation. Approximately 40% (9 out of 23 ponds) of the winter pond culture attempts would have been economic disasters. Median survival for ponds through the winter months was about 45%. During summer months ponds that have no catastrophic loss usually have an acceptable survival in the 70% to 90% range; the median survival was about 58%. There was very low survival in 6 of 26 ponds or roughly 23% of our experimental runs. All of these losses were associated with low oxygen conditions in the ponds.

The oxygen regime in a typical pond at Turkey Point is shown in Figure 2. The oxygen concentration in the pond illustrated by dotted lines is compared to an unusual variable – the cumulative amount of food fed to the shrimp in the pond shown as a solid line. The shrimp in this pond were fed a given per cent body weight of food per day. An oxygen deficiency at 6 weeks occurred during a period of cloudy, humid weather. We stopped feeding so as not to aggravate the oxygen depletion problem. Once the pond oxygen level and hopefully the animals recovered, we began feeding again. Typical of many of our pond experiments, the total amount of food (and consequently total BOD) placed into a given pond caused an irreversible oxygen crisis. This was caused by a combination of an ever-increasing amount of fecal material, uneaten food, and the growing shrimp that require more oxygen due to their increased weight. The natural supply of oxygen in these static ponds is limited by the density of photosynthetic algae and the efficiency of their oxygen-producing processes. In every pond calculated to yield an economically feasible biomass of shrimp, we

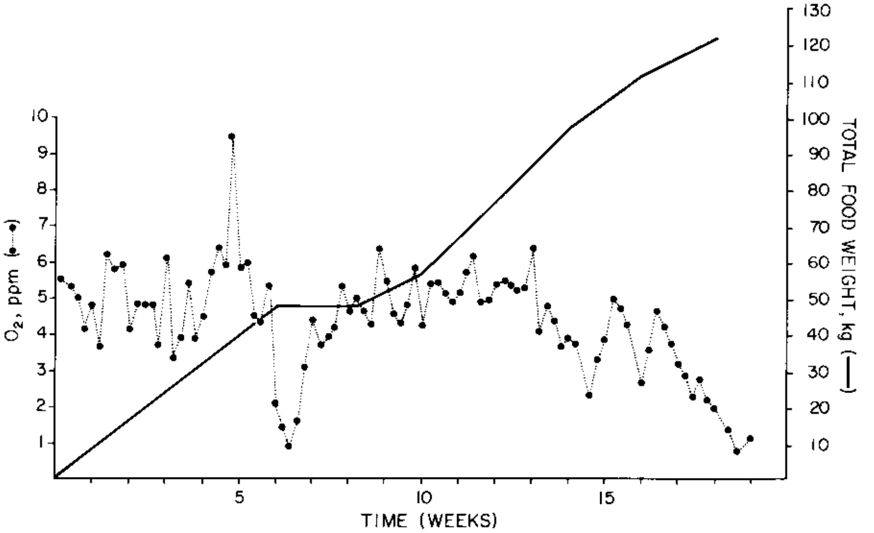

Fig. 2. Typical shrimp pond oxygen concentration in ppm (dotted line) compared to cumulative weight (in kilograms) of food placed in the 0.08 hectare pond during a growth period. (Time in weeks.)

have had to adjust our feeding rate to maintain the oxygen level. Therefore we have not provided optimum levels of food for the growing shrimp. This situation can be remedied by using optimal stocking densities based on the oxygen carrying capacity of the individual pond and not the concept of maximum production. However, most research biologists and commercial firms in mariculture are striving for maximum production so as to be able to justify the economic investment in land, equipment and manpower.

Figure 2 illustrates the need for new water management innovations if we are to successfully farm shrimp in ponds. These ponds will need aeration devices to maintain oxygen levels. Research is needed to optimize stocking densities and diets should be developed that produce little waste. Methods of rapidly assessing the physical condition of the shrimp and the pond water are also badly needed. Sea Grant supported mariculture programs at the University of Miami are attacking each of these problems.

One question frequently posed by scientists, businessmen, Sea Grant funding agencies and recently the general public who are concerned about food shortages, is how much useable food can we expect an acre of water to produce using various mariculture techniques? A review of the existing literature and recent Sea Grant supported mariculture research reveals some levels of production that we can expect (Table 2). We find that the natural productivity in salt water is very low. This is most easily explained as a lack of nutrients (phosphates and nitrates) which are precipitated in sea water. Estuaries and fresh water ponds have a higher productivity because of the continual water runoff from land which maintains the concentration of nutrients to be used in the food chain which ultimately feeds the fishery product used by man. The concept of nutrient enrichment was used by Dr. Swingle and his colleagues at Auburn University to produce more biomass from a given body of fresh water through the addition of fertilizer. This technique doubled the maximum productivity of water. Sewage ponds in Europe, Asia, and more recently, Australia, are super-

Table 2. Expected Annual Range of Fish Production from Various Aquatic Environments (Pounds per Acre per Year)

			Pounds per Acre per Year
Natural water, salt	0.5	–	18
estuarine	10	–	575
fresh	40	–	300
Fertilized pond	200	–	500
Sewage pond (carp)	800	–	1,400
Catfish culture	1,000	–	2,400
Carp culture	1,000	–	13,500
Trout culture	40,000	–	100,000

enriched, flowing environments which produce even more fish, or about a three-fold increase over the fertilized ponds. The addition of landgrown food, such as in carp and catfish culture, further increases production, but this aquaculture system requires more labor for feeding and more land to grow the food. Carp being more tolerant of low oxygen and their own waste materials can reach higher biomass in the same body of water than can catfish. Trout culture systems, which utilize flowing water to wash away fecal material and provide oxygen, yield high densities of animals per acre but utilize high feeding rates and a well researched culture system. It has taken roughly a hundred years to reach these levels of productivity and it is naive to expect the same technology to be developed for shrimp, clams, oysters, pompano, or lobsters in the few years since mariculture has become a popular "idea" in the United States.

The most important concept depicted by Table 2 is that in all culture systems and for each species of animal, there is an upper limit to the biological carrying capacity of the system. Husbandry, which is the manipulation of the feeding rate, the animals, and the water quality, permits the fish culturist to reach these levels. Attempts to reach or exceed the upper levels usually result in high mortality. Often this mortality is accompanied by the presence of high levels of disease organisms and parasites on the cultured animals. For a mariculturist to determine whether disease or husbandry was the primary cause of the problem requires careful analysis of the culture system, the environment, the captive animals and the specific disease problem.

The University of Miami has recently established a multi-discipline program designed to solve this type of production management problem for mariculturists and to provide disease diagnostic service to the tropical fish industry, to the commercial fishing industry, to state, federal and local agencies responsible for the protection of our natural marine resources. The University of Miami has requested Sea Grant support for this project. A former U.S. Customs Quarantine Station is being used for our admissions office and field studies. At this well equipped facility we conduct initial autopsy, prepare slides for histological and pathological examination, and prepare samples for detailed analysis by other specialists in existing laboratory facilities throughout the University of Miami campus. As indicated in Figure 3, the specialists are provided adequate samples for the detailed determination of bacterial species, viruses, fungi, pesticides, "PCB's", heavy metals and any other toxic materials that we suspect may have been involved in the situation. When applicable we coordinate our studies with the local public health and field pollution control personnel. Our aim is to simultaneously investigate all aspects of probable causes of marine fish mortality. A field crew of scientists and technicians is available to do the on-site analysis whenever a problem arises in natural waters or in mariculture facilities. We hope to serve the public and the mariculture industry by providing answers based on scientific data from several disciplines rather than the subjective opinion from any one investigator. Therefore, we have an executive committee to review our findings before we release them. We invite industry and state and federal agencies to utilize our services and participate in our program.

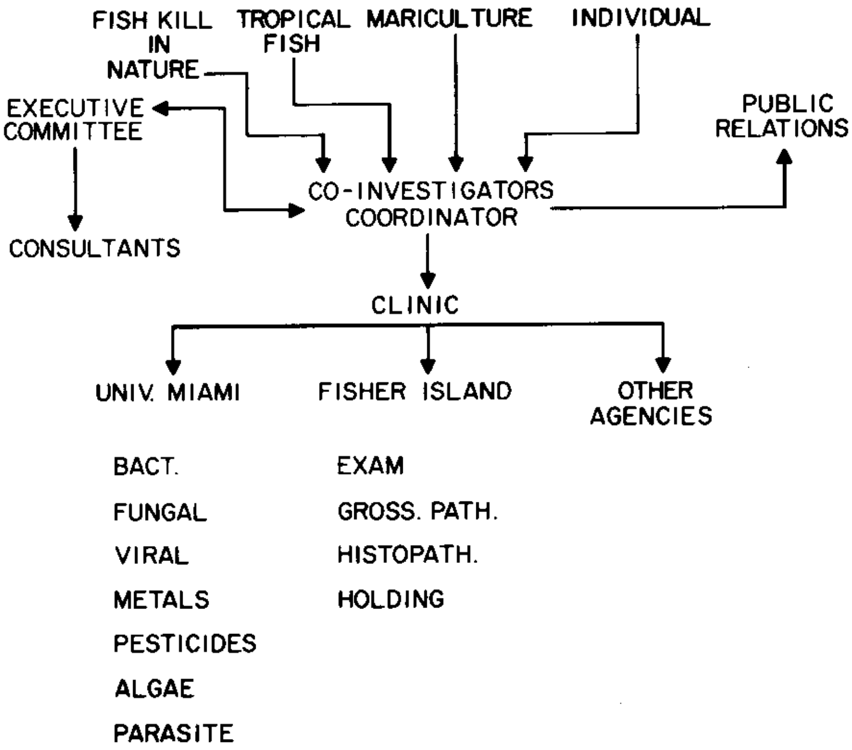

Fig. 3. A proposed program at the University of Miami for investigation of diseases of marine animals.

LITERATURE CITED

Tabb, D. C., W. T. Yang, C. P. Idyll and E. S. Iversen
1969. Research in marine aquaculture at the Institute of Marine Sciences, Univ. of Miami. Trans. Am. Fish. Soc. 98(4): 738-742.