Massive Fish Deaths Explained Using a System Analysis Computer Model

SUSANN O. SMITH, D.V.M.
International Center for Tropical Animal Health (ICTAH)
School of Veterinary Medicine
Tuskegee University, Tuskegee, Alabama 36088

ABSTRACT

Massive fish deaths have occurred sporadically in Bermuda as well as in other areas of warm water habitats. Such occurrences can have a devastating effect on the environment and economy, especially on the fish food chain and the fishing industry. One such epizootic occurred during 1982 and 1983 in Bermuda. This research will provide an epidemiologic analysis using conceptual and systems analysis diagrams describing the cause of fish deaths.

Systems analysis methodology is a technique used to simulate a real life situation in order to gain an understanding of the mechanism of the disease process by analyzing the factors or variables contributing to thedisease. It aids decision makers in making logical assumptions pertinent to problem solving.

A simulation of this model can be used to predict the pattern of occurrence, verify a cause of action, and help to prevent future epizootics of this nature.

Hence, this model will aid fisheries veterinarian officers to manage and control disease problems arising within the fishing industry.

KEY WORDS: Epizootic, massive fish deaths, epidemiologic analysis, systems analysis, computer model, Bermuda.

INTRODUCTION

Disease in fish is quite often missed, as fish rarely show signs of disease or ill health. When signs are seen, those fish will die within 12 hr, or less, and perhaps be consumed by predators or cannibals. Signs of disease are rarely shown as a deliberate protective mechanism for fish to escape predators. Feeding frenzies may result from massive deaths. Therefore, when moribund fish appear on shore in large numbers, who can say how many more fish have died and gone unrecorded? Can we assume that for every one dead fish seen, 20 or 50 more go unseen?

In recent years, massive mortalities of aquatic vertebrates and invertebrates have occurred. Some scientists speculate that it is nature's way of indicating that there are major marine economic disturbances (MMEDs) in our environment (Williams and Bunkley-Williams, 1990b), changes which will have a long term permanent effect on the food web. The full impact of MMEDs cannot be identified using simple epizootic approaches due to limitations in experimental work and the unavailability of reference specimens (Williams and Bunkley-Williams, 1990a). The phenomena may be linked to several factors which when represented in a simulation model may provide us with answers to the causes. The computer is a medium which can help us conceptually grasp the enormity of this situation.

Ozone depletion, increase the ultraviolet rays, global warming, intensified meteorological disturbances (hurricanes), pollution, overfishing and an increase in the competition for food resulting from the massive diadema and herring die-offs are a series of events that have contributed to increased stress on aquatic animals causing a decrease in their resistance to opportunistic organisms that cause disease (Williams, 1990a). These events may have subsequently caused the ultimate demise of aquatic organisms.

Over the past ten years, while there has been a drastic decrease of the catch of traditional Bermuda fish such as grouper, snapper and other pelagics, there has been an increase in the miscellaneous species such as parrot fish (Edness, 1984). The fishery authorities speculate that this is primarily due to overfishing. However, a massive death of brood fish, which normally replenish young fish stock, may also have contributed to the unavailability of quota-sized adult fish.

Since the gulf stream connects Bermuda and the Caribbean, and since there are many similarities among the marine life and the climatic conditions, could the Bermuda mass deaths be related to the Caribbean mass mortalities occurring during the early 1980's (Atwood, 1982)? During the winter and spring months of 1982-1983, fish mortalities occurred concurrently among two populations of fish (Rand, 1983a). One population involved mortalities of families of fish from inshore Bermuda waters whilst the other consisted of aquarium fish. On histologic investigation, one wild fish was infected with *Amyloodinium ocellatum* (a dinoflagellate) and *Icthyophorus* (a fungi), while the aquarium fish were heavily infected with *A. ocellatum* amd *Cryptocaryon irritans* (Rand, 1983a).

There was a high incidence of deaths among Carangidae, *Caranx crysos*, while low incidence occurred in the following four families: Blennidae, Priacanthidae, Serranidae, and Sparidae (Rand, 1983b). Fish from the above families share a commonality since they are all warm-water, shallow-reef marine fish. However, the question arises, why these fish were affected and not other shallow reef fish? Several risk factors were identified: water temperature; salinity (or water quality); season of the year; the prescence of *A. ocellatum, C. irritans* and *Icthyophorous*.

This research will provide an epidemiologic analysis of fish deaths using conceptual and systems analysis diagrams describing the various contributing causes of the fish deaths. Furthermore, a simulation of this model can be used to help predict the pattern of occurrence and initialize effective management by verifying a course of action and prevent future epizootics of this nature.

MATERIALS AND METHODS

Knowledge Base Development

Extensive research of the host, parasite, environment interaction is needed to develop a knowledge base for the computer model. Where data is not available, inferences as close to real life as possible will be made to help complete the epidemiological problem-oriented approach (EPOA) simulation model.

Conceptual Model Development

Conceptual diagrams aid in simplifying the problem by first identifying the subsystems involved. By identifying etiological agents, their life cycles, the hosts (fish species) involved and the environment, states of health or ill health can be applied.

The fish subsystem depicts fish as being susceptible, stressed, chronically sick, recovered, immune, or having lost immunity states. After conceptualizing the system one can go further and identify rates of transition between states in each subsystem, and parameters and constraints that the rates depend on. At this point, the way in which the environment affects the systems is also examined (Oryang *et al.*, 1991).

Systems Analysis Development

A simulation model systems analysis can be developed using an object oriented programming (OOP) tool which allows for modifications and user-friendly applications. Effective epidemiological dynamics can be displayed simply or as detailed and complex interrelationships using the Systems Thinking, Experimental Learning Laboratory with Animation software package (STELLA). As newfound knowledge and data become available, they can be easily inserted into the structural diagrams. The dynamics of the system can show established states with the dependent rate variables whilst allowing for diversified parameters and constraints.

Mathmatical Model Development

Using mathematical equations, a population of fish in any state is defined to be dependent on the initial population in that state and the rates of the population as it moves in and out of a state over time. The quantitative analysis of epidemiologic parameters such as infection rates is challenging (Oryang *et al.*, 1991).

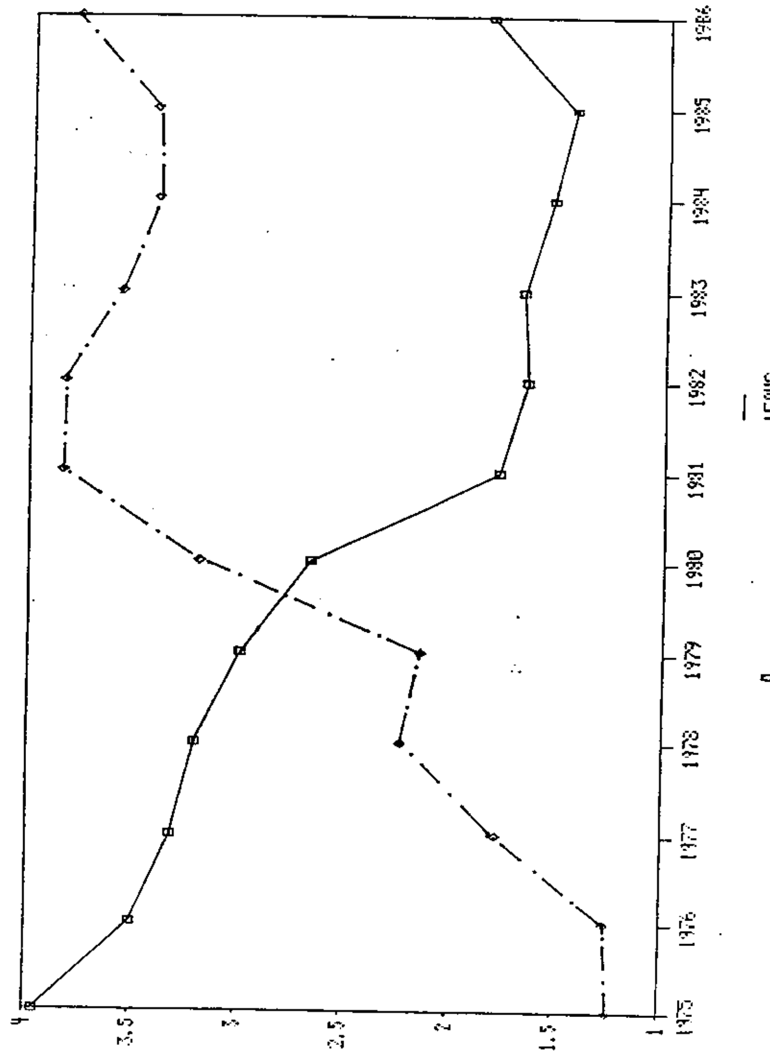

Figure 1. Catch per pot haul for groupers and miscellaneous species, 1975 to 1986.

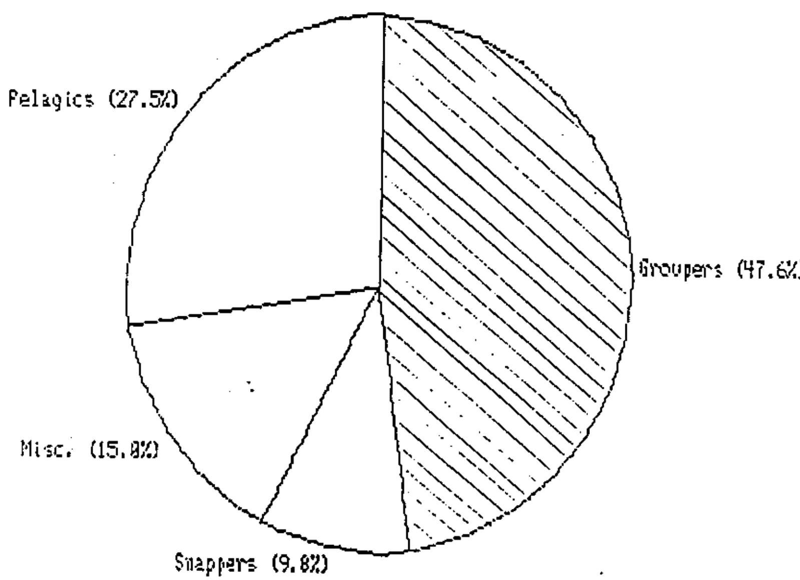

Figure 2. Composition of landings of foodfish in 1975.

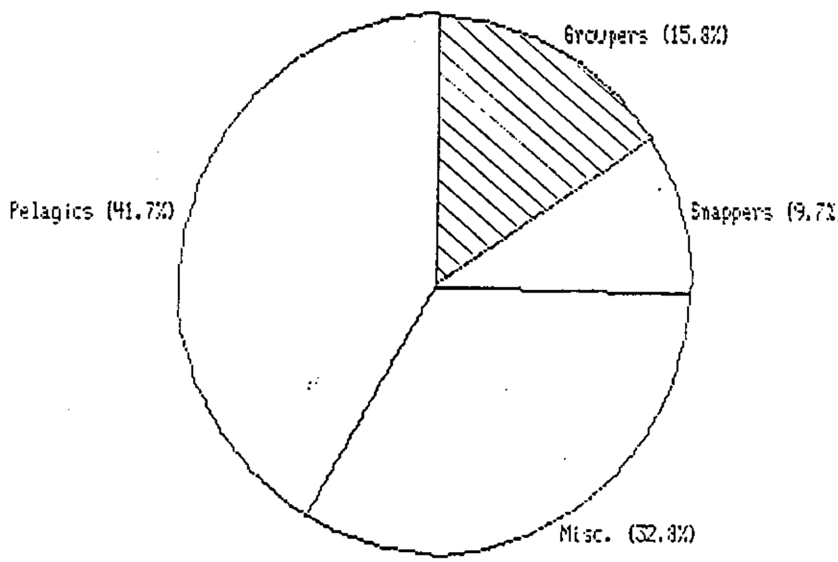

Figure 3. Composition of landings of foodfish in 1986.

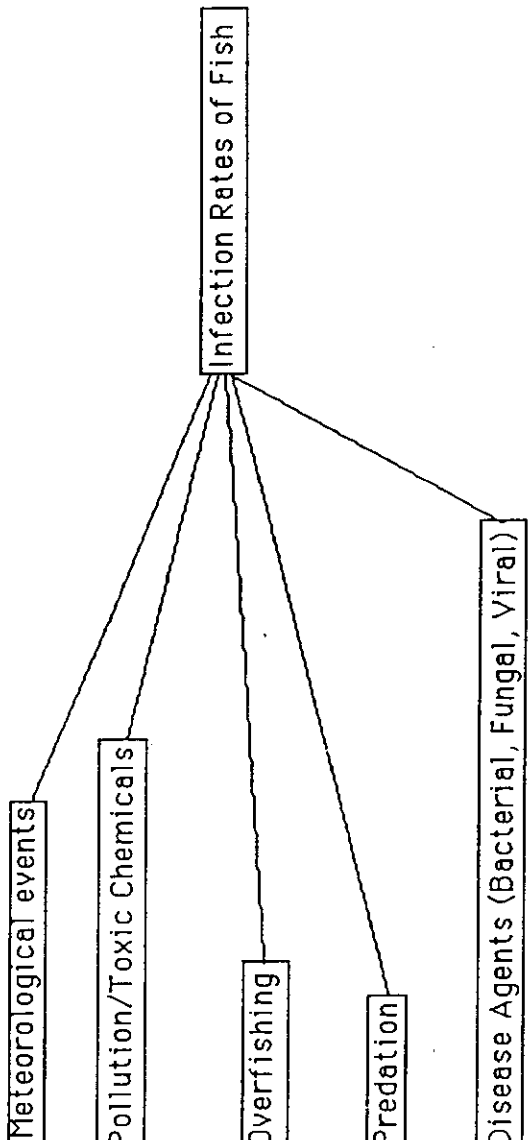

Figure 4. Factors affecting the infection rate of fish.

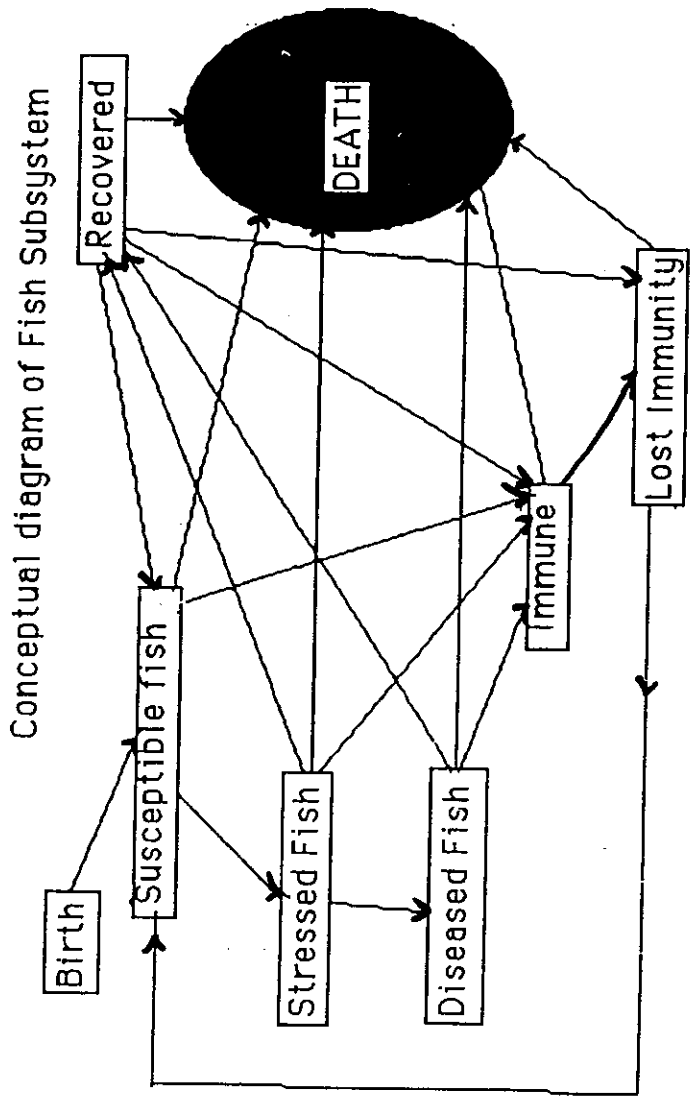

Figure 5. Conceptual diagram of fish subsystem.

RESULTS

Test and Validate the Simulation Model

With given factors, the model can be tested by running it and comparing it with the real life situation. Sensitivity must be acknowledged by adjusting the equation parameters, thereby justifying the realism of the model.

DISCUSSION

Fish mortality data is difficult to collect from natural habitats due to predation. Accurate data can be achieved from aquaria or mariculture operations. Only anectotal accounts are available at present, until proven methods of data collection can be made. Once a test is validated, new information can analyzed and converted into equations that will further verify the course of MMEDs and hence enable fisheries and veterinary authorities to prepare for, manage, and control stress-causing factors in the fishing industry. A simulation model will save time and money, taking the place of expensive equipment and personnel. The model will serve as a training tool for other Caribbean nations and allow for the insertion of pertinent data, including age and sex of the fish, environmental conditions, population characteristics, time of disease onset, disease agent detection, etc.

LITERATURE CITED

Atwood, Donald. 1982. Summary Report of a Symposium on Recent Mass Fish Mortalities in the Caribbean Area. *Caribbean Conservation News.* Volume 3 (2): 12-16.

Edness, Quinton L. 1984. A Comprehensive Fisheries Management and Development Program. Department of Agriculture and Fisheries, Botanical Gardens, Paget, Bermuda.

Oryang, D., T. Habtemarium and V. Robnett. Systems Analysis as a Method to Develop Epidemiologic Models. BIMS Project, School of Veterinary Medicine, Tuskegee University, Tuskegee, Al. 36088.

Rand, Thomas. 1983a. Diseases of Bermuda Fishes. a. Department of Agriculture and Fisheries, Bermuda. Volume 54, no. 6.

Rand, Thomas. 1983b. Bermuda Aquarium and Zoo. Unpublished data.

Williams, Ernest H. and Lucy Bunkley-Williams.1990 a. Caribbean Marine Mass Mortalities; A Problem with a Solution. *Oceanus* **30** **(4)**: 69-75.

Williams, Ernest H. and Lucy Bunkley-Williams.1990 b. Recurring Mass Mortalities of Caribbean Herrings; Implication for the study of Major Marine Ecological Disturbances. *Journal of Aquatic Animal Health* **2** (3): 230-236.