NAVY MOSQUITO FISH PROGRAM[1, 2]

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ABSTRACT. The use of the mosquito fish, *Gambusia affinis*, for mosquito control was evaluated at 16 Naval shore activities. The effectiveness of the fish, requirements and procedures for establishing mosquito fish programs, and techniques for collecting, transporting and stocking fish are discussed.

INTRODUCTION. The biological control of mosquitoes using larvivorous fish has received increased attention in the past 5 years. One reason for this is greater public concern over the possible side effects of pesticides on the environment, and the subsequent interest in biological control agents. In conjunction with the U. S. Navy's continuing effort to improve environmental quality, an investigation was conducted to evaluate the use of the mosquito fish, *Gambusia affinis*, for mosquito control at Naval shore activities. To accomplish this, it was necessary to study *Gambusia* husbandry and determine which methods of mosquito fish culture and management were most suitable for each activity. The purpose of this paper is to review the results obtained in anticipation that they will be of interest to other military installations and civil agencies.

PROCEDURE. Sixteen Naval shore activities were selected for the investigation: 3 in northeastern North Carolina and 13 in southeastern Virginia. During the summer of 1971, surveys were made at these activities and all active and potential mosquito breeding sites were identified to determine those suitable for stocking *Gambusia*. In cases where suitable sites were found, the activities were assisted in the application of mosquito fish husbandry techniques which included methods for collecting, transporting and stocking the fish.

For capturing large numbers of fish, two basic collecting methods were utilized: active and passive. In active collecting, the fish were chased or physically surrounded using either an aquatic dip net consisting of a mesh bag on the end of a long wooden handle, or a minnow seine which may vary in size from a small scoop to a large drag net of 6 x 50 feet. In passive collecting, two types of traps were used in which the fish captured themselves: the wire minnow trap and the box-style trap. The minnow trap (Figure 1) is a popular bait fish trap constructed of small mesh hardware cloth in the shape of a barrel or cylinder with funnels at both ends. It is baited inside with dry bread or dog food and positioned in shallow water with both funnel ends submerged. An attached cord anchors the trap to the bank. The box-style traps described by Caton and Sjogren (1969) and Stains (1970) are basically oversized minnow traps and while effective for collecting large numbers of fish, they are too cumbersome for easy transportation and use in different areas or locations. A modified and portable box trap designed by Ehrhardt and Sholdt (1972) was, therefore, evaluated.

Gambusia were transported in either open or closed containers, such as garbage cans and plastic bags. Aeration was necessary and in open containers diffusers or porous air stones were used. Compressed air cylinders were utilized as air sources, however, an air compressor would be adequate. A metering valve on the cylinders controlled the air flow through a length of tygon tubing to the diffuser. One type of cylinder used could be recharged with a service station tire pump and when filled

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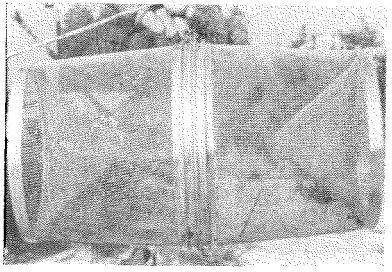

FIG. 1.—Wire minnow trap. (Official photograph "U.S. Navy".)

to capacity could deliver air for 5–7 hours (Figure 2).

The use of plastic bags as sealed containers for fish transportation has been known to tropical fish importers for several years (Miller, 1956). For *Gambusia* transportation, 5- to 20-gallon, heavy duty plastic bags were filled about ¼ to ⅓ full of water and a maximum of 200 fish per gallon were added. After deflating the bag, oxygen was added from a compressed air cylinder and then the top of the bag was twisted, folded over and fastened with a rubber band. The bags were contained in styrofoam boxes (Figure 3), which when covered provided good insulation against temperature fluctuations. In studies with two different species of fish, Nemoto (1957) found that survival time was increased 20 to 70 hours when air in sealed containers was replaced with pure oxygen. Therefore, pure oxygen was used at all times instead of atmospheric air.

Stocking was the final phase of mosquito fish husbandry studied. As a guideline, a minimum stocking rate of 300 mature females per surface acre was used, based on the findings of Hoy *et al.* (1971). In most cases, however, overstocking was not considered to be critical and the fish were often added in sufficient numbers to provide immediate control. In North Carolina, ponds were observed to support populations of both game fish and *Gambusia* with no apparent adverse effects. However, there have been reports of mosquito fish competing with game fish and reducing their populations (Myers, 1965), so areas designed for sport fishing were not stocked.

RESULTS AND DISCUSSION. According to Hildebrand (1921), mosquito fish in the southern U. S. are commonly found in most sluggish and standing waters that are accessible through natural channels. Naturally occurring populations of *Gambusia* were, in fact, found at all but two of the activities surveyed. However, personnel at these activities were usually unaware of the presence of the fish and their potential usefulness for mosquito control.

In some cases it was evident that the fish were preventing potential breeding sites from becoming active. In others, emergent vegetation was reducing the effectiveness of the fish by protecting the larvae. In these instances, vegetation control using herbicides or mechanical methods was needed. Populations were so extensive that sites which required stocking with *Gambusia* were found at only six of the activities (two in North Carolina and four in Virginia). Of the aquatic areas observed at all activities, it was estimated that 75–90 percent were: (1) Already inhabited with mosquito fish or were (2) suitable for stocking. These sites were generally artificial or man-made situations such as drainage ditches, ponds, seepage areas, borrow pits, waste stabilization ponds, sewage Imhoff tanks, water hazards on golf courses and other areas of standing water.

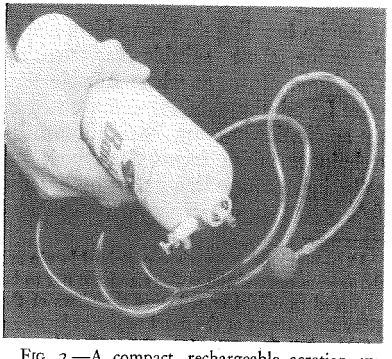

FIG. 2.—A compact, rechargeable aeration system useful for transporting *Gambusia* in open containers. (Official photograph "U.S. Navy".)

FIG. 3.—Closed container equipment for transporting mosquito fish. (Official photograph "U.S. Navy".)

Concerning the mosquito fish husbandry techniques used to stock the above sites, collecting with the aquatic dip net was found to be time-consuming, ineffective and, usually a stress to the fish. A small minnow seine (4′ x 6′) or the wire minnow trap was found adequate for collecting relatively small numbers of fish. Of the two, the minnow trap was favored since it could be set by just one person and caused less stress to the fish. The minnow trap is also more discriminate and is less likely to capture a variety of fish species requiring sorting prior to stocking. The portable box trap was suitable for collecting large numbers of fish on a frequent basis. The ideal mesh size of the hardware cloth on the minnow and box traps was found to be either eight mesh (⅛″) for collecting large numbers of males and females or four mesh (¼″) when only the larger mature females were desired.

For transporting small numbers (200–300 fish), a commercial minnow bucket or 2–3 gallon pail was adequate, but when larger numbers were involved, 15-gallon garbage cans were utilized. Using the latter, 3,000 *Gambusia* were transported 150 miles during a 3-hour period with negligible mortality. Russell (1970) states, however, that for short periods, as many as 10,000 to 15,000 fish have been transported in such containers. The plastic bag technique was preferred when transportation involved extended holding periods or required ground or air transportation over long distances. As discussed by Miller (1956), plastic bags have additional advantages over metal containers in that they: (1) prevent injuries to fish bumping into the container walls; (2) protect against temperature changes more effectively; (3) are light but durable; (4) are portable; (5) require little storage room and (6) do not rust. The bags also readily facilitate water temperature equalization when floated at the stocking site before releasing the fish. *Gambusia* could be held as long as 2–3 days if the bags remained fully inflated. The technique is also inexpensive as the bags and styrofoam

boxes can often be obtained from tropical fish dealers at minimum or no cost.

Based on data available from mosquito light trap indices and larval surveys, *Culex pipiens,* breeding primarily on-base, was the major mosquito species affecting the shore activities in Virginia. It might be expected, therefore, that mosquito fish could significantly suppress the mosquito populations. While the activities in North Carolina had considerable on-base breeding by a number of different species, including *C. pipiens,* they were primarily affected by the salt-marsh mosquitoes, *Aedes taeniorhynchus* and *A. sollicitans,* originating off-base. The effects of mosquito fish at these activities would, therefore, be much less pronounced. However, larviciding operations might be significantly reduced at all the activities.

Such observations were, in fact, reported by activity personnel. For instance, at one Virginia activity (Zapienzo, 1971, personal communication) a serious *Culex pipiens* problem was originating from four abandoned sewage Imhoff tanks. Prior to stocking in July, larval dips at each tank yielded an estimated 500 to 1,000 larvae per dip with all stages present. Each tank was stocked with 200 male and female fish and within 10 days complete control was achieved. The fish survived, reproduced and no further mosquito breeding occurred. The well-known and phenomenal fecundity of the fish was also demonstrated at this activity. A waste stabilization pond, one acre in size, was stocked with 600 male and female fish. Three months later, the resultant population was estimated at between 75,000 to 100,000. Using this pond for a source of fish, all suitable areas of standing water on the activity were planted with fish and the need for larviciding was virtually eliminated during the mosquito season. Satisfactory data on the effectiveness of the fish at the other activities were not available, since follow-up surveys could not be made regularly.

All activity personnel associated with the program were attuned to the problems of environmental pollution and were exceptionally receptive and interested in the use of fish for mosquito control. Often their initial reaction was that mosquito fish would completely supplant the use of insecticides. However, as these individuals became involved in the program, they developed a better understanding of the limitations of a biological control agent and an appreciation of the fact that mosquito fish were useful only as a supplementary measure to pesticides. This opportunity to educate Naval activity personnel in a proper understanding of pesticides and environmental pollution seemed, in itself, to justify the program.

Successful use of fish at any activity was found to be dependent upon the close cooperation of three departments: (1) *Medical,* which is technically responsible for identifying mosquito breeding areas and can, therefore, recommend sites suitable for stocking fish; (2) *Public Works* (Pest Control), which is responsible for all control operations and, therefore, can assist in stocking as well as instituting integrated control efforts such as vegetation control; and (3) *Fish and Wildlife,* which is concerned with the management of on-base natural resources and can often best advise which areas to stock without causing adverse effects to the aquatic environment. In the Tidewater, Virginia area, the program became established as a coordinated effort of the Navy, the state health department and local mosquito control commissions. Such coordinated efforts provide for a greater impact on mosquitoes affecting the activities and adjacent communities.

It was apparent during the investigation that mosquito fish would fail in areas where their biology and their ecological requirements were not thoroughly understood. While extensive literature has been published on the subject (see Gerberich and Laird, 1968), it is not readily available to those in the field. In addition, detailed data on the husbandry of mosquito fish are generally not available in any one source. Finally, the effect of the fish on the environment cannot be underestimated as recent studies have shown that under

certain circumstances mosquito fish can be detrimental to an aquatic ecosystem (Hurlbert, 1972; Fanara, Ph.D. Thesis, 1972; Stephanides, 1964; Deacon *et al.*, 1964). These problems prompted the preparation of a mosquito fish *Guide* by Sholdt *et al.*, (1972) which provides a compact reference on the bionomics and husbandry of mosquito fish and gives guidelines for using the fish in an effective but conscientious manner based on sound ecological considerations. Copies of the *Guide* were distributed to Naval activities interested in initiating a mosquito fish program. Along with the *Guide,* mounts of male and female *Gambusia* embedded in plastic were also made available (Figure 4). Such mounts were found invaluable in assisting personnel in making positive identification of the species and for use as displays when presenting the program to command personnel, visitors and others. As a practical supplement to the *Guide,* a 2-day training course on mosquito fish was developed and offered to interested military and civilian personnel.

In future investigations, attempts will be made to evaluate the use of fish at activities in other geographic areas and to study their effectiveness in different ecological situations in more detail. In addition, the integrated use of herbicides and

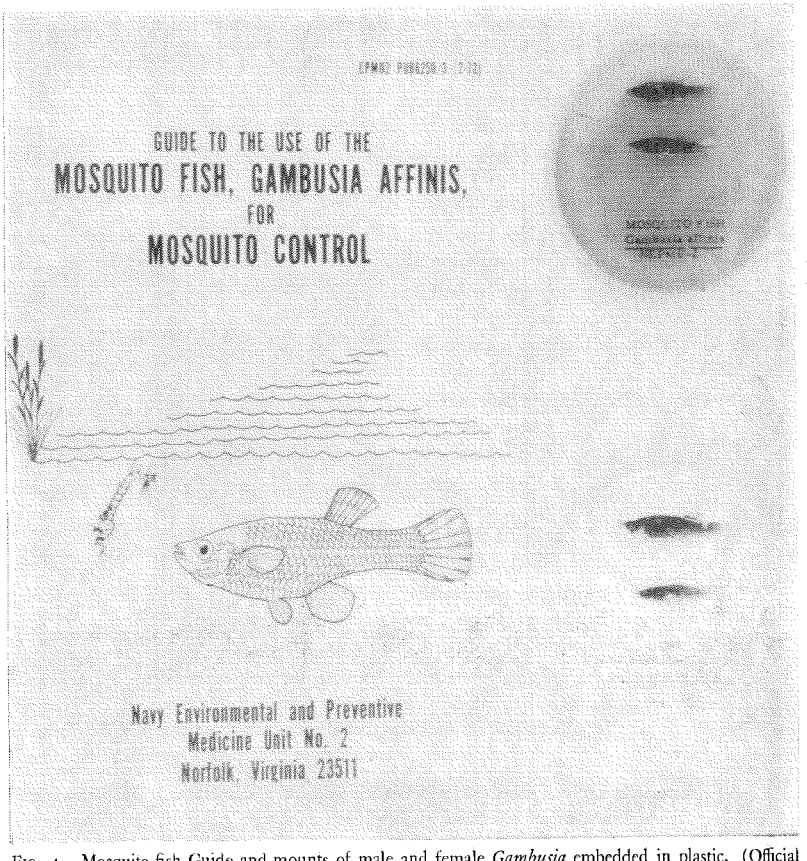

FIG. 4.—Mosquito fish Guide and mounts of male and female *Gambusia* embedded in plastic. (Official photograph "U.S. Navy.")

larvicides will be studied to augment the biological control efforts of the fish.

SUMMARY AND CONCLUSIONS. Based on investigations at 16 Naval shore activities, it is concluded that mosquito fish can play a definite role in Navy mosquito control operations. The effectiveness of a mosquito fish program will depend upon: (1) proper coordination between medical, public works and fish and wildlife management personnel; (2) thorough knowledge of the biology and ecological requirements of mosquito fish and (3) utilization of efficient and effective husbandry techniques. While a majority of the mosquito breeding sources at an activity will probably be suitable for stocking with *Gambusia,* their effectiveness will probably depend on the amount of mosquito breeding occurring on-base as compared to that originating off-base. In areas where mosquito fish are native or have become well established, their natural presence in many sites may be anticipated. However, vegetation control may be required to assist the fish in effectively reaching mosquito control densities. An added benefit of a mosquito fish program may be a better understanding of the necessary role of pesticides in mosquito control in those situations where fish cannot be utilized.

ACKNOWLEDGMENTS. In the preparation of this manuscript, the authors are particularly indebted to Dr. E. C. Bay and G. L. Sims for their invaluable suggestions and constructive criticisms. We also extend our gratitude to A. W. Sapienzo, HMC G. A. Kueczynski and HMl W. Elizondo for their technical assistance. Finally, we gratefully acknowledge the support and encouragement of Capt. E. J. Clarke, Jr., MC, USN who made this investigation possible.

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