USE OF AN INDIGENOUS FISH SPECIES, *FUNDULUS ZEBRINUS*, IN A MOSQUITO ABATEMENT PROGRAM: A FIELD COMPARISON WITH THE MOSQUITOFISH, *GAMBUSIA AFFINIS*

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ABSTRACT. Studies were conducted relating mosquito production in small ponds to presence or absence of larvivorous fishes. Data collected showed that native killifish and introduced mosquitofish controlled mosquito larvae at the same level and support the use of indigenous fish species in mosquito abatement programs.

INTRODUCTION

Various health agencies have recognized that larvivorous fishes are among the most important agents used for mosquito control. As a result, the mosquitofish (*Gambusia affinis*), a warm-water fish, native to eastern and central United States (Eddy and Underhill 1978), has been widely introduced for mosquito control throughout North America and the subtropics (Haas and Pal 1984).

While it is believed that mosquitofish can be successful in suppressing mosquito populations (Sholdt et al. 1972), the World Health Organization (WHO) expert committee recommends their cautious application to areas outside their original distribution because of negative effects on indigenous fish species (WHO 1982). In addition, there can be high economic costs related to mosquitofish use. This is particularly true in temperate regions where an inability to overwinter in some habitats causes production and distribution costs on an annual basis. For these reasons, Haas and Pal (1984) suggest "the need for more careful evaluation" of larvivorous fish species besides *G. affinis*, "especially those which already occur in the geographical area where their systematic use has promise."

In Colorado and other parts of the United States, *G. affinis* is used for mosquito control purposes by local health organizations in spite of the presence of indigenous fish species of the genus *Fundulus* (Family Cyprinodontidae) that morphologically (upward pointing mouth, dorsoventrally flattened head with large eyes, and small size) appear to be suited for mosquito control. This study was undertaken to determine the usefulness of the Plains killifish (*F. zebrinus*) as a larvivore in mosquito control and to compare it to *G. affinis* in this respect in the field. The Plains killifish (adult size 38–100 mm total length) is common in parts of eastern Colorado and occurs from southeastern Montana east to Missouri and south to Texas (Lee et al. 1980).

MATERIALS AND METHODS

The original study plan called for comparison of mosquito production between replicate ponds (i.e., 3 containing only *G. affinis*, 3 containing only *F. zebrinus*, and 3 nonfish sites). As the season progressed, however, sites were rapidly lost because of drought conditions and urban development. For purposes of replication, two fish sites (one with *G. affinis* and one with *F. zebrinus*) were compared to two nonfish sites up until July 14, 1987. At this point, one of the nonfish sites (Wexford Pond) had to be treated with *Bacillus thuringiensis* var. *israelensis* because of the presence of numerous mosquito larvae and the pond's close proximity to human habitation. These data were collected over a period of 6 weeks.

The study then was modified to compare mosquito production in the 3 remaining small ponds. The pond designated as Oscars' Pond had been stocked with approximately 1,000 adult *G. affinis* on April 9, 1987. Horse Pond contained a naturally occurring and self perpetuating population of *F. zebrinus*, while Nor-Flo Flow was a fishless body of water left untreated during this part of the study. The ponds, located in Westminster, CO, were all less than 1 m deep and ranged from 36 to 142 m^2 in surface area. These 3 ponds were sampled weekly from May 21 to August 25, 1987.

Sampling of mosquito larvae took place with a standard white dipper (450 ml). Presence of larva in a dip was the index of larval abundance that was utilized during this study. This index was used rather than total number of larvae because mosquito larvae are typically contagiously distributed and numbers of larvae in clumps vary with larval age. Since different ponds could theoretically have different aged larvae, it seemed best to use the index.

There were differences between ponds in size and amount of potential larval habitat (i.e., emergent vegetation, floating wood and tumbleweeds). In order to standardize the data ob-

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Table 1. Areas and number of dips taken weekly at each pond.

Pond name/treatment	Surface area (m^2)	Potential larval habitat area (m^2)	No. of dips
Horse Pond/Killifish	36	19	10
Oscars' Pond/Mosquitofish	142	25	13
Nor-Flo Flow/Untreated	52	33	17
Wexford Pond/Untreated	134	33	17

Table 2. Percentage of positive[a] dips obtained for control and fish treated ponds. The percentage of dips containing mosquito larvae was decreased in ponds containing fish.

	Control ponds		Ponds treated with fish	
Date (1987)	Wexford	Nor-Flo	Horse	Oscars'
June 11	0	5.9	0	15.4
June 18	0	5.9	20	7.7
June 25	0	5.9	0	15.4
July 2	17.6	0	10	0
July 9	47.0	52.9	10	15.4
July 14	57.5	52.9	10	23.1
Average %	20.4	20.6	8.3	12.8

[a] Positive dips contained one or more mosquito larvae.

tained and to equalize the probability of obtaining a positive (larva present) dip between ponds, the potential mosquito larval habitat was measured, and a proportionate number of dips were then taken. The intent was to expend equal effort for capture of larvae that was dependent on area of larval habitat. Table 1 presents surface area of pond sites, larval habitat area and number of dips taken each week.

Data collected from replicate sites were statistically compared utilizing a Fisher exact test for proportions (Zar 1984) where percentages of positive dips during the season were compared. Level of significance was defined to be $P \leq 0.05$. Other data were compared graphically.

At the end of the mosquito season, in August 1987, 100 each of *G. affinis* and *F. zebrinus* were transferred to Nor-Flo Flow to determine the overwintering success of the respective species in this shallow pond. After the successful introduction of fish into this pond, mosquito production was monitored and compared to prefish introduction levels.

RESULTS AND DISCUSSION

Mosquito larval abatement: Native killifish and mosquitofish resulted in about the same level of control, with both fishes reducing the larval abundance compared to the untreated ponds. Statistically, there was no difference ($0.20 < P < 0.50$) in number of positive dips between Horse Pond (contained *F. zebrinus*) and Oscars' Pond (contained *G. affinis*). Control pond replicates also showed no significant differences ($0.20 < P < 0.50$). There was, however, a significant difference ($P < 0.001$) between pooled treated data (fish present) vs. pooled controls. Data from these ponds are presented in Table 2.

Data from the entire season are shown graphically in Fig. 1. It appears that killifish and mosquitofish reduced mosquito larvae throughout the season. Data from July 30 show the effects of a localized heavy thunderstorm on the evening prior to sampling. Apparently the larvae were washed out of Nor-Flo Flow.

Overwintering and drought survival: Nor-Flo Flow was visually examined in the spring of 1988 to determine whether fish stocked at the end of the previous mosquito season had survived the winter. The only species observed and captured through dip netting was *F. zebrinus*, indicating that *G. affinis* was unable to survive through the winter. This supports the observation of Woodling (1985) that most *G. affinis* populations are unable to survive the cold temperatures of Colorado winters. This pond was seined in the spring of 1989 as an additional check and only *F. zebrinus* was recovered.

Mosquito production was monitored in this pond during 1989 and is compared to 1987 levels in Fig. 2. It appeared that killifish were successful in abatement of mosquito larvae up until the end of July. At this point, the pond almost dried up (approximately 0.5 m^2 of water surface area remained) resulting in substantial fish mortality. The pond dried rapidly so that habitat was available for mosquito larvae for most of July. The pond then filled from rains at the beginning

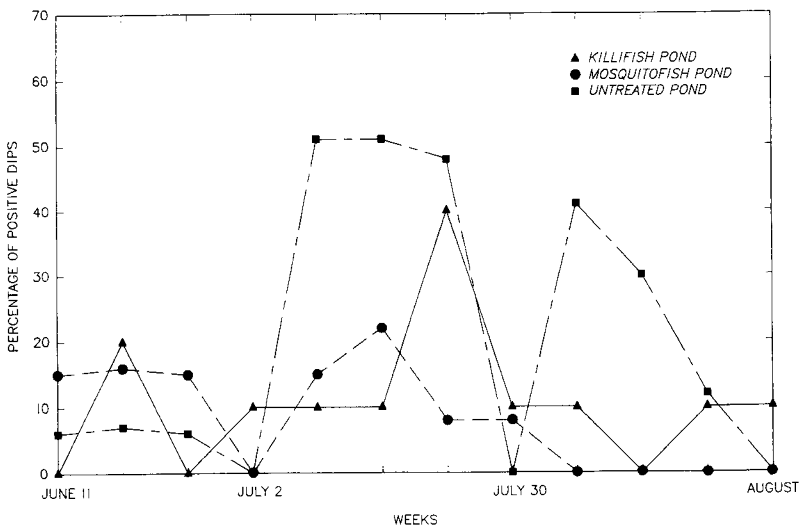

Fig. 1. Larval mosquito production in 3 different ponds. Qualitatively, mosquito production was lower in ponds containing fish.

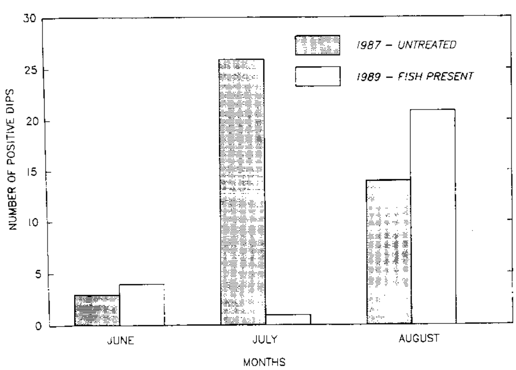

Fig. 2. Comparison of mosquito production in Nor-Flo Flow before and after the introduction of killifish. Mosquito larvae decreased after the introduction of killifish up to the point where drought conditions removed most of the fish.

of August allowing for mosquito production unimpeded by this reduced fish population. On August 9 two fish were observed in the pond. Survival of killifish under drought conditions may be possible because of their ability to bury themselves in the substrate (Minckley and Klaassen 1969).

Comparison of pond and fish characteristics: Ponds used during the study were typical of habitat utilized by *Culex tarsalis* Coq. (vector of Western equine encephalitis) and larvae collected from each of the sites were identified as such. Ponds were grossly similar in size and types of vegetation present and differences in larval index values were probably attributable to presence or absence of fish species. Qualitatively, fish density in ponds appeared to be similar, with populations probably approaching 100 to 200 fish per m^2 by the end of the season. A more accurate estimate of fish densities was not considered necessary in this study. Both of the fish species in this study are highly prolific and can rapidly populate a body of water. In both species, young fish were initially observed at the beginning of June and then throughout the summer. Fernandez-Delgado (1989) described the life-history of *G. affinis* as being characterized by fast growth, early maturity, a high level of reproductive effort, and a short life span; traits that he found to be similar to those of the cyprinodontids, *Aphanius ibereus* and *F. heteroclitus*. It is quite probable that *F. zebrinus* would fall into this same category. Field observations by the authors confirm the ability of *F. zebrinus* to rapidly populate areas.

Value of using indigenous fish species in mosquito abatement: Data obtained during this study support the early belief that various *Fundulus* species are useful as mosquito control agents (USPHS and TVA 1947). It seems unfortunate, in light of articles exposing the dangers of mosquitofish to native fish populations (Minckley and Deacon 1968, WHO 1982, Meffe 1985, Marsh and Minckley 1990) that more literature on larval mosquito control by fishes indigenous to control areas has not been reported. It is possible that in the haste to disseminate mosquitofish for use in mosquito control, that native fish populations that were acting as larvivores, at less environmental and economical cost, have been decimated.

Economically, killifish would appear advantageous over mosquitofish, particularly in climates where, due to harsh winters, mosquitofish would have to be restocked yearly in order to control mosquito larvae. Also it is possible that killifish may have an advantage over mosquitofish in the area of drought resistance. We hope that this article, along with others (Schoenherr 1981, Mian et al. 1986, Cech and Linden 1987), will increase interest in utilizing fishes other than *Gambusia affinis* in mosquito control work.

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