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EFFECT OF FISH SIZE ON PREY SIZE SELECTION IN *GAMBUSIA AFFINIS*

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ABSTRACT

Food size selection of the mosquitofish, *Gambusia affinis affinis*, was measured in aquaria using juvenile stages of the mosquito, *Culex tarsalis*, as prey. Fish size varied from recently born fry to large adult females.

Food size selection was positively correlated with fish size. Mosquitofish fry (6-8 mm standard length) attacked and ate primarily first and second instar larvae. Fry attacked larger instars, but attack success on these was low (0 - 50%). Fish larger than 20 mm attached primarily pupae and third and fourth instar larva. No first instar mosquitoes were eaten. Attack success for these fish was above 65% for all instars.

INTRODUCTION.–*Gambusia affinis* is widely used to control mosquito populations, but the efficacy of these fish often varies widely between habitats. Although some information is available on the diets of *Gambusia* (Barney and Anson 1920; Hess and Tarzwell 1942; Harrington and Harrington 1961; Washino and Hokama 1967; Maglio and Rosen 1969; Walters and Legner - in press) relatively little is known about factors influencing predation rates or prey choice, and consequently, little is known about factors affecting the efficacy of the control process. It is extremely difficult to study the predation process in the field since so many factors affecting predation are uncontrolled (i.e., fish size, hunger state, and experience; prey availability, distribution and escape mechanisms; environmental temperature and light levels). By studying predation in the laboratory, we can isolate specific factors and determine their importance to the feeding process. This approach has been used profitably by others studying fish predation (O'Brien 1979, Werner 1977). When enough factors have been investigated we may begin to understand *Gambusia* predation in a complicated natural environment.

An important factor affecting fish feeding is size-selective predation (Brooks and Dodson 1965). There has been a considerable amount of work in aquatic ecology which demonstrates that most fish feed on specific sizes of organisms and that this size selectivity is so important that it can modify community structure (for review, see O'Brien 1979). Most work in this area has emphasized the feeding behavior of large fish, and the conclusion often reached is that "planktivorous fish consume many more large-sized prey than would be the case if the feeding were random" (O'Brien 1979). Unfortunately, the diets of fish larvae and fry are often ignored, so that little is known about their size selectivity. *A priori*, we would not expect a larval fish to consume the largest prey in the environment when that prey might be the same size or larger than the predator. Werner (1974) has shown that fish size is important in determining handling time in sunfishes, and Elston (1975) has shown how fish size influences prey size selection in *Menidia audens*.

This study reports preliminary results on the selective feeding behavior of *Gambusia affinis* ranging in size from recently born fry to large adult females. The prey organisms tested were the five instars of the mosquito, *Culex tarsalis*.

METHODS.–The prey selection experiments were conducted in glass aquaria (5 gallon) filled with 17 liters of water. Surface areas of the rectangular aquaria were 820 cm^2. Temperatures were maintained at 25° ± 2°C during acclimation and during the feeding trials. Flourescent room lights illuminated the aquaria from above.

The experimental fish were from a wild stock obtained at the Wheatland, California, Sewage Treatment Plant. The fish were maintained in the laboratory on prepared flake diets. Fry (6-8 mm) used in the experiments were born in the lab and were between 6 and 60 days old. The larger fish, taken from the field, may have had some feeding experience on mosquito larvae, but they had been kept in the laboartory for over 120 days without access to natural prey organisms.

The *Culex tarsalis* (Davis strain) were reared in synchronous cultures. In most trials 20 of each instar (1-4 and pupae-P) were placed in a 25 mm diameter petri dish before an experiment. In the first set of trials only instars 1-4 were used. Ten feeding trials were conducted on three separate dates.

Before a trial, the fish were allowed to feed for one hour on a flake diet. Five similarly sized fish were then placed in a test aquarium and kept for three hours without food to provide a moderate, standardized, hunger level. The prey organisms were introduced by sinking the petri dish in the center of the aquaria. Behavioral observations were made throughout the feeding bout. The number of attacks and attack success on particular insects were recorded during the trial. A larvae was considered "attacked" if the fish contacted it. A successful attack resulted in an ingestion. Unsuccessful attacks occurred if the instar evaded the predator or if the predator discharged the prey from its mouth. The accuracy of this behavioral observation is limited due to the difficulty in correctly differentiating the five instars during an attack. The fish usually began feeding within thirty sec. after the prey were introduced, and feeding activity often decreased considerably after the first 3 to 5 min. This was probably due to the fish becoming satiated and to the fact that after several minutes, many of the mosquitoes had moved to the periphery of the tank and were relatively inconspicuous there in the meniscus. After the fish had fed for ten minutes, they were netted from the tank and preserved.

The actual ingestion of the various instars was determined by dissecting the fish and measuring the head capsule widths of the prey at 30X magnification. The standard length of each fish was also recorded. Many of the larvae in the guts were partially digested. However, head capsules of the larvae were usually intact and were used to identify and count instars. The head capsule widths of the different instars were determined on freshly preserved larvae (Figure 1B), which allowed us to assign a prey item to an instar category. The relationship between head capsule width and total body length (tip of head of the end of the abdomen with siphon excluded) was also determined (Figure 1A). This regression was used to assign lengths to the prey eaten.

RESULTS.–The feeding trials demonstrated that *Gambusia* size effects prey-size selection. Fish less than 8 mm ate primarily first and second instar larvae (Figure 2). The few third instar larvae eaten had an estimated size of 3 mm. No fourth instar or pupae were eaten by fry. *Gambusia* between 12 and 18 mm ate approximately equal proportions of all instars. The body lengths of first instars through fourth instars ranged from 1 to 5 mm. Fish larger than 20 mm ate primarily late instars with very few second and no first instars being chosen. The corresponding size range of prey eaten was 2 to 5 mm. Fish larger than 30 mm chose primarily fourth instar larvae. However, we have only experimented with five fish of this size, so our results are only tentative.

The behavioral observations indicated that *Gambusia* will attack a wider range of prey sizes than they are capable of eating. *Gambusia* fry attacked second instar larvae more than any other prey (Figure 3) and attack success was maximal for this instar (Figure 4). Fry also attacked fourth instars and pupae, but all of these prey escaped and consequently did not appear in the diet. Fry also attacked a high proportion of third instar larvae, but attack success was only 50% (Figure 4) and consequently relatively few third instars appeared in the diet.

In contrast to fry, intermediate sized *Gambusia* (18-26 mm) attacked primarily the third, fourth, and pupal instars (Figure 3). Only 7% of the attacks were on second instar larvae. We also recorded several successful attacks on first instar larvae. However, since no first instars appeared in the guts of these fish (Figure 2), this may have been due to incorrect instar identification during the observations. Attack success varied from 100% on second instar larvae to 68% on fourth instars (Figure 4). Many of the unsuccessful attacks we observed were

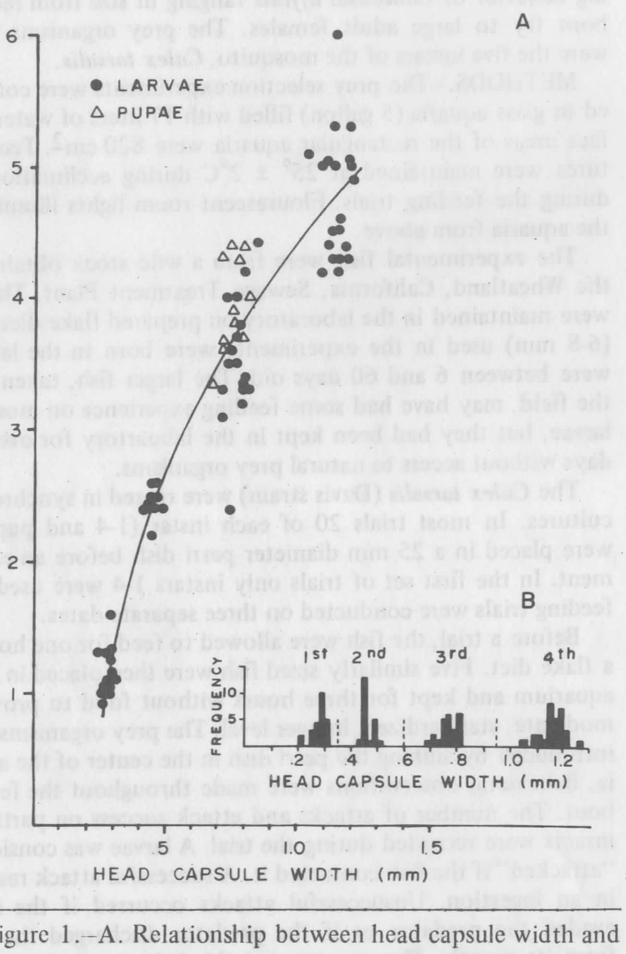

Figure 1.–A. Relationship between head capsule width and total length (less siphon) in *Cx. tarsalis* (curve fitted by eye). B. Frequency distribution of head capsule widths of larval *Cx. tarsalis*.

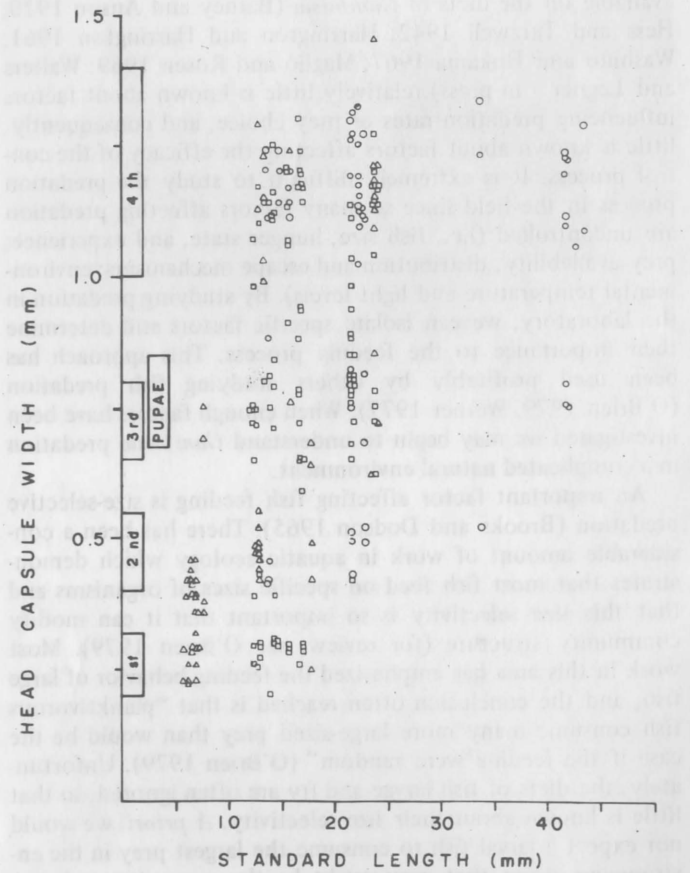

Figure 2.–Relationship between *Gambusia* length and head capsule widths of ingested *Culex tarsalis*. The bars near the ordinate indicate the approximate size range of each instar.

due to fish discharging the prey from their mouths. This was particularly evident for attacks on pupae in late stages of development.

DISCUSSION. Our data and observations indicate that several factors influence prey choice in *Gambusia*, even in the simple experimental systems we used. The data demonstrate that both fish size and prey size interact to determine prey choice. While small fry attacked some large prey, they were unsuccessful in capturing them and the diet consisted primarily of early instars. Larger fish had little difficulty eating either early or late instar larvae. However, most of their attacks were directed at the largest prey available. Consequently, it appears that *Gambusia* will choose the largest prey they can successfully capture. O'Brien et al. (1976) have developed a model for prey choice in planktivorous fish which predicts that because large prey are more visible than small prey, they will be attacked proportionately more often than the smaller organisms. Our results indicate that this model must be modified for fish larvae and fry, which reduce attacks on large prey which they could not consume.

Our behavioral observations indicate that relative size alone does not determine prey choice. As suggested by Zaret and Kerfoot (1975), factors affecting visibility will influence predator choice. One factor which may have influenced prey visibility in our tests was prey movement. Larvae or pupae were attacked more often if they moved in the visual field of a fish. O'Brien et al. (1976) report similar findings for bluegill sunfish. In some trials, pupae were quickly discharged by the fish after they were captured. Pupae may become physically or chemically unpalatable during the period when they are immobile and easily captured. Kerfoot (1979) has recently identified cases of unpalatability and aposematism in some aquatic invertebrates.

Since different sized fish show differences in the size of mosquito larvae they consume (Harrington and Harrington 1961; and our data), all size classes of fish must be considered to determine the dynamics of this predator-prey interaction. The importance of juvenile fish in mosquito control should not be underestimated since both juvenile fish and early instar larvae will be more numerous in most habitats than the larger fish and late instar mosquitoes. Additionally, since fry can consume nearly 100% of their body weight per day (W. Wurtsbaugh; unpublished data), they may have a high impact on prey populations despite their small size.

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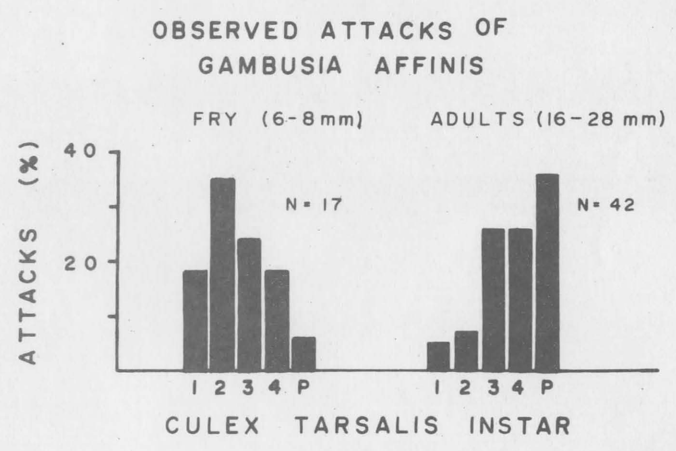

Figure 3.–Frequency distribution of attacks on different instars of *Culex tarsalis* by fry and intermediate sized *Gambusia*.

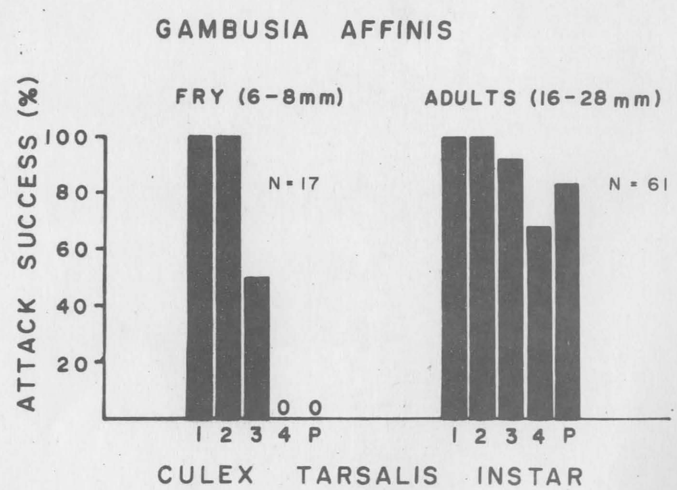

Figure 4.–Attack success of *Gambusia* on the instars of *Culex tarsalis.*

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