INFLUENCE OF *TILAPIA MOSSAMBICA* (PETERS), *T. ZILLII* (GERVAIS) (CICHLIDAE) AND *MOLLIENESIA LATIPINNA* LE SUEUR (POECILIIDAE) ON POND POPULATIONS OF *CULEX* MOSQUITOES AND CHIRONOMID MIDGES[1]

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ABSTRACT. Studies of mosquito and chironomid midge predation by three species of tropical fish, *Tilapia mossambica* (Peters), *T. zillii* (Gervais) and *Mollienesia latipinna* LeSueur in two types of shallow ponds revealed significant and sustained predation of high magnitudes. Both *Tilapia* species continually reduced mosquito larval densities by almost 100 percent during the warmest summer months. Chironomid predation also reached a sustained high level during the warmest months, with *T. zillii* and *T. mossambica* causing more than 80 percent and 65 percent reduction of larvae, respectively. However, the reliability of mosquito and chironomid larval counts to access predation may be questionable as shown by comparisons with adult emergence data. Fish population growth during a 170-day period from Mar. 9 to Aug. 25, 1972 showed that *T. zillii* biomass increased 1,060-fold (to 534 fish) while *T. mossambica* increased 519-fold (to 418 fish) from an initial stocking of 2 ♂ and 3 ♀ each. Fecundity appeared to increase with higher water temperatures. Fish behavior, competition and desirable attributes of these species for biological control are discussed.

INTRODUCTION

The use of fish in mosquito abatement and chironomid midge control is well documented and highly regarded as an adjunct to chemical pesticides. Species employed successfully for chironomid control in California are the common carp, *Cyprinus carpio* L. and goldfish, *Carassius auratus* (L.) (Anderson and Ingram 1960; Bay and Anderson 1965), while *Gambusia affinis-affinis* (Baird and Girard) (Hoy *et al.*, 1971), the guppy, *Poecilia reticulata* Peters, and the Argentine pearl fish, *Cynolebias bellottii* Steindachner, are useful for mosquito control under certain breeding conditions (Bay 1966, 1967, 1968). The potential employment of additional fish species is great, especially in subtropical portions of the American Southwest (Bay 1967; Hallock and Ziebell 1970; Legner and Medved 1972, 1973), with some species acting indirectly through the disruption of insect breeding habitats (Legner *et al.*, 1973). The performance of three tropical fish species in typical southwestern pond habitats was studied. *Tilapia mossambica* and *T. zillii* were chosen because of widespread interest and dissemination of these species as biological weed reducers (Legner *et al.*, 1973) and *Mollienesia latipinna* because of its prominence in irrigated valleys of the lower Colorado River basin.

METHODS AND MATERIALS

Experimental Area. Research to investigate fish predation and behavior was conducted in experimental ponds at the Experiment Station of the University of California, Riverside (Legner and Medved 1972). Two types of earthen ponds were employed that were optimum for chironomid and mosquito production. One was a large type, 5.5 m wide by 7.6 m long and 0.41 m deep that was subdivided into 3 equal portions with barriers constructed

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of 11 mesh/cm plastic screening (Fig. 1). A smaller type pond, 1 m^2 and 0.2 m deep, was framed with redwood and covered with 11 mesh/cm, partially darkened, plastic screen (Fig. 2). Water from the University Experiment Station irrigation system originating in 50 m deep wells was passed through a dragon and gravel filters, and added continuously to the ponds to replace that lost by percolation and evaporation. Water quality varied with agricultural practices as it was recirculated through the Experiment Station area, but was greatly purified by the filtration system before entering experimental ponds.

Predation Studies. Fish cultures were maintained in outdoor heated ponds. Groups of 2 ♂♂ and 3 ♀♀, 6 weeks-old *T. zillii* and *T. mossambica* were introduced separately into each of four random subdivisions of three large ponds on Mar. 9, 1972, and allowed to reproduce until Aug. 25 when progeny were counted and parents weighed. A second group of 6 weeks-old fish was stocked following drying and refilling of the replicates on Aug. 29 and allowed to reproduce until Oct. 31, or just as cold-induced mortality began. In the 2nd stocking on Aug. 29, previous treatments were switched with controls to reduce experimental bias.

In the m^2 ponds a single 6 weeks-old *T. mossambica* and *Mollienesia latipinna* female was introduced separately on June 5 into each of six ponds selected at random, where they were allowed to remain until Oct. 16 without reproduction. A *T. zillii* female was introduced into each of six random ponds on Aug. 3 and left there until Sept. 2.

In order to stimulate continuous chironomid midge production in the m^2 ponds, 12 g of chick-start feeding mash were applied weekly to each replicate. No supplementary food was applied to

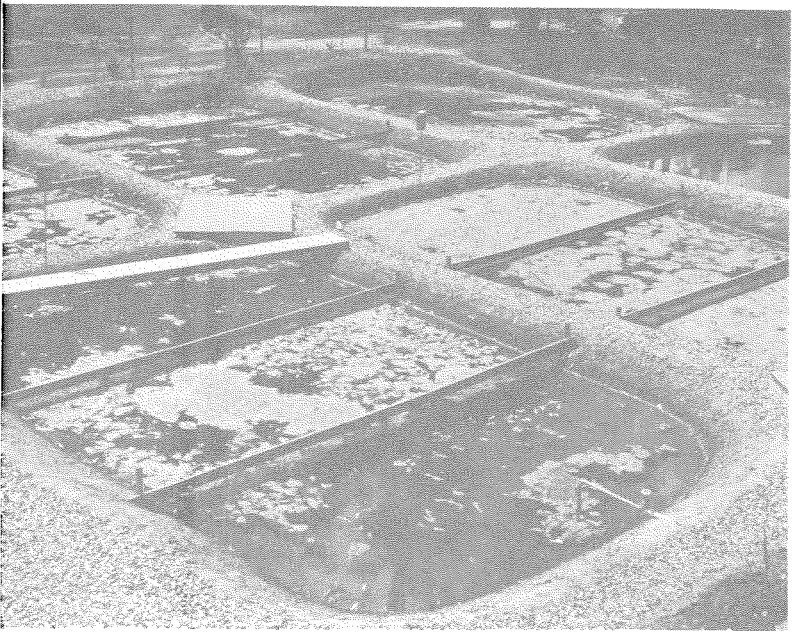

Fig. 1.—Large earthen ponds, 5.5 m wide by 7.6 m long and 0.41 m deep showing subdivisions of each into 3 sections for predation studies with *Tilapia* spp.

the large ponds where mosquito and chironomid breeding was continuous. Mosquito breeding gradually ceased in the screened m^2 ponds as blood meals were precluded.

All experimental replicates were sampled on a regular schedule with dip and dredge samples to estimate densities of mosquito and chironomid larvae. A standard 500 ml dipper was used for mosquitoes in the large ponds with four dips being taken at random per each replicate every 7 days. Only 4th instars were counted and all stages were replaced in each replicate. Small ponds were similarly sampled with a 40 ml dipper, four random dips per replicate every 7 days.

A 250 ml benthos scoop dredge was designed and used for chironomids in the large ponds. The semicircular dredge measured 8.9 cm long by 8.9 cm wide and 4.5 cm deep, and was plunged into the benthic ooze at a 45° angle to a depth of 5 cm and then pushed forward at that depth to fill the 250 ml. Three scoops were taken at random per each section every 14 days. The m^2 ponds were sampled with a 120 ml dredge, similarly manipulated, one scoop at random every 7 days.

Emerged adult mosquitoes and chironomids were collected daily from the m^2 ponds in screened receptacles placed above each replicate (Fig. 2). Water temperature was measured continuously with a thermistor located at a depth of 0.21 m, the middle depth of one large control pond.

Statistical Analyses. Treatments were assigned randomly to experimental units of both pond types. Significance tests were made between one treatment (fish present) and a control by employing

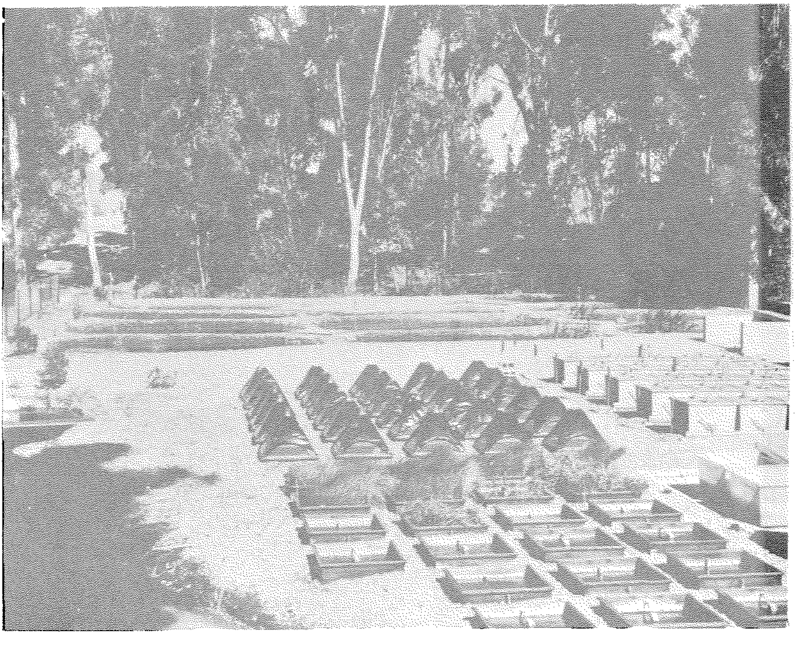

Fig. 2—Small m^2 and 0.2 m-deep ponds enclosed with redwood frames (foreground). The same type of ponds covered with 11 mesh/cm partially darkened plastic screen in the background, with screened emergence traps located at each apex. For studies involving single females of *Tilapia* spp. and *Mollienesia latipinna*.

the simple Student "t" test (Snedecor 1946). Differences in the performance of two or three fish species were not tested due to limitations in the experimental design.

RESULTS AND DISCUSSION

Mosquito and Chironomid Species Present. The relative abundance of four principal mosquito species reared from larvae collected in the large control ponds is shown in Fig. 3. *Culex peus* Speiser and *C. tarsalis* Coquillett predominated and were largely coincident during the experimental period; while *Culex pipiens quinquefasciatus* Say and *C. incidens* (Thomson) were relatively scarce (Fig. 3).

Chironomid midge species were not easily distinguished and consisted of several generic complexes. Present taxonomic knowledge of this group allowed the identification of a large, apparent mutant *Chironomus* sp. (named C–51); at least two other *Chironomus* spp.; one species each of *Dicrotendipes* and *Procladius; Tanytarsus* spp. and *Micropsectra nigripila* (Johannsen). *Chironomus* spp., *Dicrotendipes* sp. and *Procladius* sp. as an unseparable group accounted for 74.2 percent of the total chironomid larvae sampled in control ponds from April through August, while *Tanytarsus* spp. and *M. nigripila* accounted for 19.3 percent and 6.5 percent, respectively.

Mosquito Reduction. Mosquito larval density (Fig. 4 and Table 1) and adult emergence (Table 1) were significantly reduced by all three fish species tested, with the *Tilapia* appearing to excel in predation. The effect of 6-weeks-old *Tilapia* on reducing mosquito larval populations was immediate as evidenced by the great difference in larval density between the control and treatment curves for both *Tilapia* species after restocking in Aug. (Fig. 4). Analyses of variance of the pooled weekly data for each month shown in Fig. 4 indicated that differences between treatments and controls were significant at t_{05} in April and t_{01} for all subsequent months and both *Tilapia* species. The percent mosquito larval re-

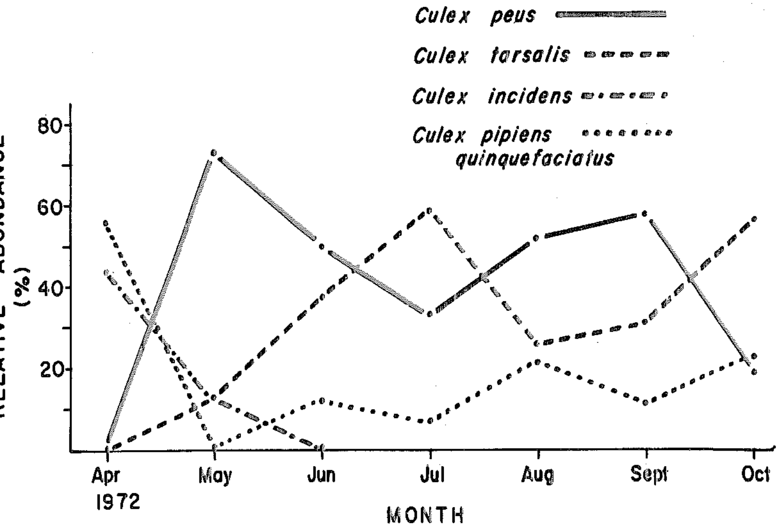

Fig. 3.—The relative abundance of mosquito species breeding in large control ponds as judged by adult emergence from randomly collected larvae.

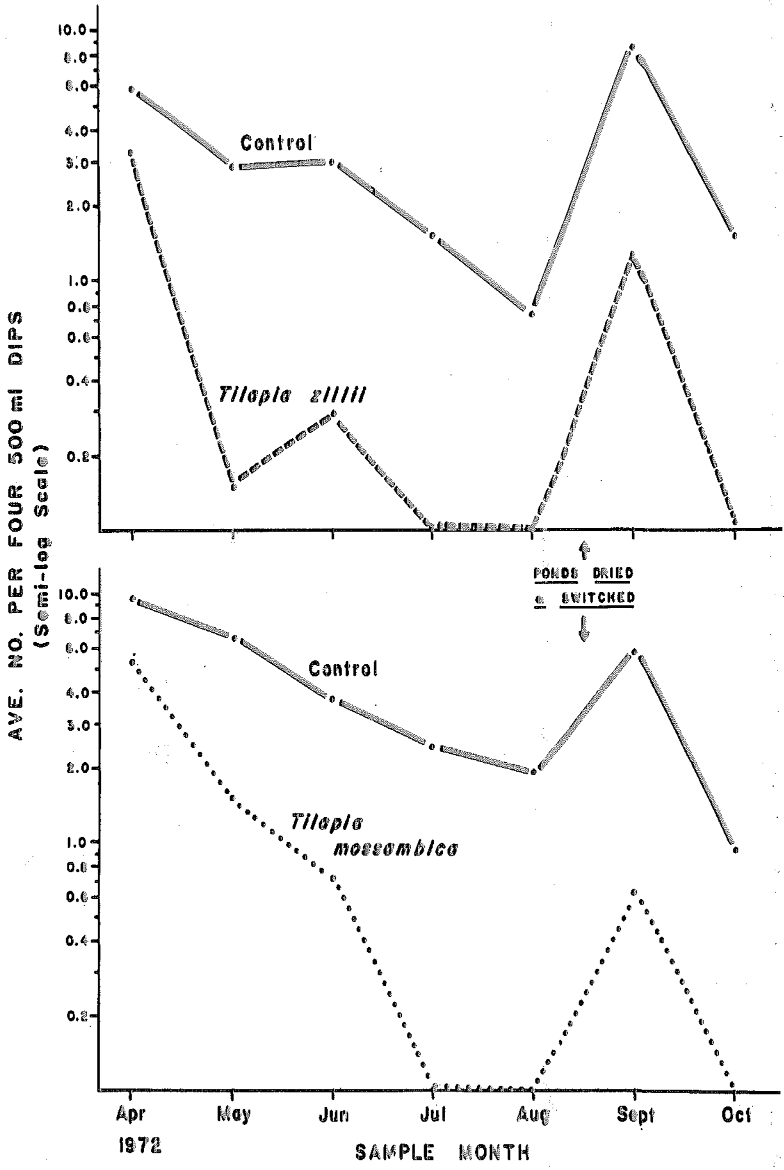

FIG. 4.—The average number of 4th instar mosquito larvae sampled from large ponds that contained an initial 2 ♂ and 3 ♀ *Tilapia zillii* or *T. mossambica* (6 weeks old) compared to their respective controls. Ponds were drained and dried, switched and restocked with fish on Aug. 29th.

ABLE 1.—*Culex peus* 4th instar larval density and adult emergence from meter-square ponds containing single females of *Tilapia mossambica* and *Mollienesia latipinna* at Riverside, California, June through July 1972.

	Larval evaluation				Adult evaluation			
	T. mossambica		*M. latipinna*		*T. mossambica*		*M. latipinna*	
Sample interval	Avg. no. larvae/dip	% reduction	Avg. no. larvae/dip	% reduction	Avg. no. adults emerged	% reduction	Avg. no. adults emerged	% reduction
/5–6/11	8.83*[b]	5.36	9.83	—5.36	27.40*	28.27	38.83	—1.65
/12–6/18	0.67**	74.91	1.33*	50.19	2.75	—5.36	2.92	—11.88
/19–6/25	0	100.00	0.17**	87.22	0	.....	0	.....
/26–7/2	0.17*	48.48	0	100.00	0	.....	0	.....
/3–7/9	0.17	......	0.33	......	0	.....	0	.....
/10–7/17	0	......	0	......	0	.....	0	.....
vg. all dates	1.64	28.07	1.94	14.91	5.03	26.03	6.96	—2.35

[a] % reduction = 100 — (treatment/control) x 100.
[b] Significantly lower than control: * at $t_{.05}$; ** at $t_{.01}$.

duction by both species gradually increased and generally exceeded 80 percent after Apr. (Fig. 4), with *T. zillii* being apparently superior.

In the screened m² ponds, mosquitoes were not produced after July when *T. zillii* was introduced. Therefore, only an evaluation of *T. mossambica* and *M. latipinna* was possible. Table 1 shows the average larval densities and adult emergence densities obtained. Single mature female fish of both species significantly destroyed mosquito larvae in these tests, although the reductions were not as pronounced as in the large open ponds (Fig. 4). However, the larval reduction was not correlated with a similar reduction in mosquito adult emergence, especially during the beginning weeks of the experiment in June (Table 1). Therefore, the reliability of using larval mosquito counts to assess predation magnitude was questionable.

Fish reduced mosquito densities directly by predation, there being no evidence of habitat disruption that would create unsuitable conditions for mosquito development. Both mature fish and young fry were effective, the large numbers of the latter accelerating the rate of predation generally about 2 weeks after their initial appearance. The fish also adversely affected the mosquito population by destroying floating mats of filamentous algae which provided protective niches for mosquito larvae and pupae.

CHIRONOMID REDUCTION. The effects of *T. zillii* and *T. mossambica* populations on the density of chironomid species in large ponds are shown in Table 2. Percent reduction attributable to the presence of fish generally increased progressively after initial stocking through Aug., with one exception noted on June 22. This was probably due to the diversion of parents from normal foraging activity by newly hatched fry which were guarded for a period of about 2 weeks by both species. Parental foraging activity in the benthos was, consequently, reduced. The same phenomenon was observed after restocking in the Sept. 7 data for *T. zillii* and the Sept. 21–Oct. 5 data for *T. mossambica* (Table 2). The 6 weeks-old parental fish spent a major portion of their time tending fry after reproduction. Distractions by fry apparently had no noticeable effect on reducing mosquito predation, however (Fig. 4). Percent chironomid reduction by *T. zillii* was apparently superior (about 80 percent vs. 65 percent by *T. mossambica*); however, the experimental design used would not accurately measure this difference.

Tilapia were very prolific in the large ponds during the initial 170 days of experi-

TABLE 2.—Effect of *Tilapia* on density of benthos chironomid larvae in large ponds during the period May 25–October 20, 1972. Riverside, California.

Sample date	Avg. no. larvae per 250-ml scoop[a, b] *T. zillii*	% reduction[c]	Avg. no. larvae per 250-ml scoop *T. mossambica*	% reduction
Experiment 1 (Initial flooding of ponds)				
May 25	6.92*[d]	30.83	5.92*	35.22
Jun 8	5.08*	36.46	3.17*	31.16
Jun 22	3.67*	26.67	3.33*	26.47
Jul 6	1.50*	65.38	2.92*	38.38
Jul 20	1.00*	80.52	1.50*	59.09
Aug 3	0.58*	83.80	1.00*	55.88
Aug 17	0.58*	79.65	1.00*	65.91
Avg.	2.76	50.36	2.69	40.88
Experiment 2 (Ponds drained and treatments switched with controls)				
Sept 7	3.20	−13.07	2.67*	34.69
Sept 21	3.27	21.60	2.87	14.00
Oct 5	1.93*	22.67	2.00	14.28
Oct. 20	0.87*	19.99	0.93*	30.00
Avg.	2.32	12.45	2.12	23.47

[a] Average of 3 subreplicates per each of 4 ponds.
[b] Chironomid species were *Chironomus* sp. C-51; *Chironomus* spp; *Procladius* spp; *Dicrotendipes* spp; *Micropsectra nigripila* and *Tanytarsus* spp.
[c] 100 — (treatment/conrol) x 100.
[d] Significantly lower than control at t_{05}.

ments while water temperature was increasing (Fig. 5), with *T. zillii* exceeding in fecundity (Table 3). Reproductive rates of both species markedly decreased in the final 64 days after Aug. 29, which may have been due to a cooling of the average water temperature (Fig. 5).

Parental fish more than doubled their size during the first 170 days while their weight increased 7- to 10-fold (Table 3). Size and weight increases of a smaller magnitude were also observed in the second experiment. This growth occurred by feeding on both the aquatic fauna and flora, with filamentous algae (*Chara, Cladophora,* etc.) and Chironomidae (Hallock and Ziebell, 1970) probably providing a substantial portion of their

TABLE 3.—Growth data for *Tilapia* species in large ponds and average number of all age groups collected at the termination of 2 experiments after an initial stocking of 3 females and 2 males per replicate. Riverside, California 1972.

Experiment and fish species	Initial (3/9/72)[a] Length (cm)[1] ♂	♀	Weight (g)[1] ♂	♀	No.	Final (8/25/72)[a] Length (cm) ♂	♀	Weight (g) ♂	♀	Avg. no.	Approx. biomass increase (-fold)
1st Experiment (170 days)											
T. zillii	7.68	7.10	10.90	9.85	5	18.14	15.03	127.44	76.54	533.75	1,060.12
T. mossambica	7.15	6.55	10.15	9.33	5	16.53	13.43	75.16	44.91	417.50	519.04
	Initial (8/29/72)[b]					Final (10/31/72)[b]					
2nd Experiment (64 days)											
T. zillii	6.50	5.80	4.40	3.10	5	9.40	8.30	14.50	11.80	13.00	9.44
T. mossambica	11.20	9.02	20.30	10.50	5	13.70	10.80	56.70	24.50	18.60	10.47

[a] Average of 4 replicates with 3 fish per replicate.
[b] Average of 4 replicates with 1 fish per replicate.

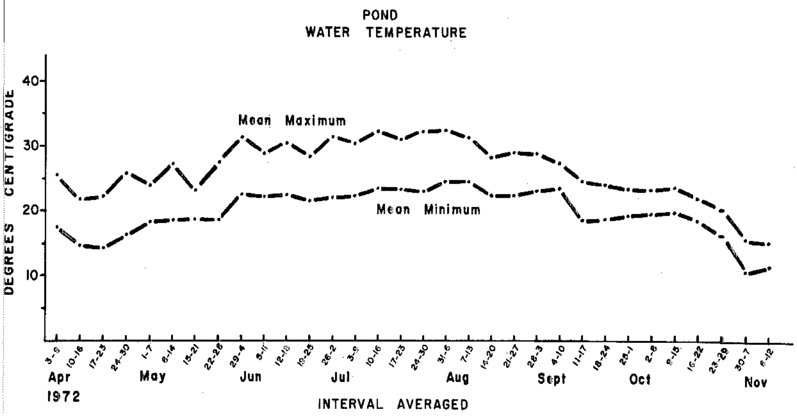

FIG. 5.—Mean maximum and minimum water temperatures from the mid-depth (0.2 m) of large ponds during the experimental interval (temperatures recorded continuously and means derived therefrom).

food. The ability of both *Tilapia* species to eliminate most aquatic vegetation in pond habitats was reported earlier (Legner and Medved, 1972; Legner *et al.*, 1973), with some effects visible in the two end sections of the fore pond as shown in Fig. 1. *Mollienesia* are also effective algae feeders (Legner and Medved, 1972).

Tables 4 and 5 show the effects of single female *T. zillii, T. mossambica* and *M. latipinna* on artificially stimulated populations of chironomid midge larvae and adults, respectively, in screened m^2 ponds. *T. zillii* excelled in the reduction of both benthos larvae and adult midges, while M. *latipinna* was apparently inferior to both species (Tables 4 and 5). However, detailed comparisons of the performance of the three fish species are not apropos, especially when their size is considered, with *M. latipinna* averaging about 1/4 that of the smallest *Tilapia* shown in Table 4.

Fish feeding in the benthic ooze may have disrupted the larval habitats of some chironomid species more than others, thereby favoring the development of certain species. Continuing studies to describe the species and elucidate the behavioral characteristics of emerging species may lead to better assessment of the importance of fish in abating chironomid nuisances. Fish also reduce chironomid larvae through direct predation in the benthos as gut analyses showed (our data; Hallock and Ziebell, 1970).

FISH BEHAVIOR. The males of both *Tilapia* species begin the breeding process by constructing a bowl-shaped nest, 20–31 cm in diameter and 7–10 cm in depth. In addition *T. zillii* constructs one or several tubes, 5–7.6 cm diameter and 15–20 cm deep, in the bottom of each nest. A female is eventually lured into the nest (in 1–4 days) where egg laying occurs. In the case of *T. zillii* the eggs are deposited in the tubes, fertilized and incubated there. The male *T. mossambica* releases sperm in the general area of the nest and the female swims through the area fertilizing the eggs which she retains in her mouth. Eggs are then incubated for 8–10 days in her mouth and the fry are subsequently protected by taking refuge in the mother's mouth until the age of about 3 weeks (about 1 cm long). Both parent *T. zillii* guard their fry, even in the absence of other fish, by herding them in a compact mass near the tube nest or just beneath them. This species is not a mouthbreeder.

Both *Tilapia* species were observed re-

TABLE 4.—Effect of one female *Tilapia* and *Mollienesia* on the density of benthos chironomid larva in meter-square ponds during the period May 25–October 20, 1972. Riverside, California.

Sample month	Avg. no. larvae/[a, b] 40-ml scoop		Avg. no. larvae/ 40-ml scoop		Avg. no. larvae/ 40-ml scoop	
	T. zillii	% reduction[c]	*T. mossambica*	% reduction	*M. latipinna*	% reductior
June	....	.....	12.74*	39.51	16.12*	23.46
July	....	.....	17.99*	52.81	21.54*	43.52
Aug.	7.67**	60.34	17.10**	70.21	35.55*	38.07
Sept.	0.40**	97.14	21.40*	45.74	26.23*	33.49
Oct.	....	.....	13.33*	59.85	21.16*	36.27
Avg. all dates	4.04**	75.79	16.51*	55.38	24.12*	36.27

[a] Average of 6 replicates per each of 4 sample intervals per month.
[b] Chironomid species were *Chironomus* sp. C-51; *Chironomus* spp; *Procladius* spp; *Dicrotendipes* spp; *Micropsectra nigripila* and *Tanytarsus* spp.
[c] 100 — (treatment/control) x 100.
[d] * Significantly lower than control at t_{05}; ** at t_{01}.

peatedly in test ponds in the lower Colorado River basin to protect their young from the ravages of other predatory fish occurring in the area, such as bass, *Micropterus salmoides* (Lacépède), and blue gills, *Lepomis macrochirus* Rafinesque. Protection appeared to be most complete in *T. zillii* where both parents engaged predators, menacing them away. No inhibition of the populations of bass, channel catfish, *Ictalurus punctatus* (Rafinesque), nor *Gambusia* by *Tilapia* was detected amid varying densities of all competitors. Cannibalism was common among fry in the 3–5 week old rang when parental care ceased. Breeding o both species commences at about 6 week of age in 24° C. average water tempera ture. The number of eggs laid in a batcl increases from about 325 initially to ove 1,000 by the 4th batch.

Mollienesia latipinna is a prolific liv bearer, and although parental care wa not observed, this species persists in larg natural populations in the presence o the other fish species cited.

Fish feeding directly on mosquito larva and pupae was clearly discernible in al

TABLE 5.—Effect of one female *Tilapia* and *Mollienesia* on chironomid adult emergence fron meter-square ponds during the period May 25–October 20, 1972. Riverside, California.

Sample month	Avg. no. adults[a, b] emerged/day		Avg. no. adults emerged/day		Avg. no. adults emerged/day	
	T. zillii	% reduction[c]	*T. mossambica*	% reduction	*M. latipinna*	% reduction
June	.....	.....	179.68*	18.98	213.00	3.95
July	83.90	17.71	81.40*	40.31	110.84*	18.72
Aug.	27.28*[d]	42.13	67.18*	38.05	104.95	3.22
Sept.	9.90	87.06	50.97*	31.48	66.46	10.66
Oct.	.....	.....	16.28*	65.30	26.51*	43.50
Avg. all dates	40.36*	46.33	79.11*	32.72	104.36*	11.24

[a] Average of 6 replicates per each of 4 sample intervals per month.
[b] Chironomid species were *Chironomus* sp. C-51; *Chironomus* spp; *Procladius* spp; *Dicrotendipes* spp; *Micropsectra nigripila* and *Tanytarsus* spp.
[c] 100 — (treatment/control) x 100.
[d] * Significantly lower than control at t_{05}.

three species. Feeding in the benthos seemed highly developed in adult *Tilapia* (6 weeks old) which were continuously observed to gather bottom sand and debris, expelling it to expose chironomid larvae which either they or their fry devoured. Such benthic feeding left small 3–6 cm crater-like depressions in the benthos. Aquatic plants were also continually utilized by all three species, the leaves of vascular species being stripped from their thicker stems. *Tilapia zillii* in addition effectively grazed the rhizomes of cattails (*Typha* spp.), curtailing subsequent growth and eventually reducing established stands of these plants.

Schooling was characteristic of both *Tilapia* species and a tendency toward male dominance was observed in about 4-months-old fish. This dominance acted to scatter fish and reduce population densities. Observations of *T. mossambica* populations that were established for 3 years in the lower Colorado River basin revealed an enhancement of the male dominance trait that seemed to reduce the average population density.

CONCLUSIONS

The fish species reported herein may be regarded as useful candidates for integrated mosquito and chironomid midge control, their effectiveness varying with water temperature and other characteristics of the breeding habitat. The sustained ability of these fish to consume immature stages of mosquitoes and chironomids and the elimination by some of protective niches in floating filamentous algae and emergent vegetation, further makes these species potentially good biological control candidates.

Field assessment under varied habitat conditions will be required, however, before wider application can be made of these fish for insect control. One obvious difficulty not detected in small pond culture that apparently greatly influences the degree of control attainable with these species involves fish population age structure. In field establishment trials in irrigation drains located in the lower Colorado River basin, the appearance of dominant male *Tilapia* in one-year-old stock acts to reduce fish density through the mechanism of territorial behavior. Interrupting or precluding the appearance of dominant males seems essential to produce the population densities required for satisfactory insect control.

Another consideration in the practical use of these species is the impact that new species may have on the environment. Studies have shown that populations of *T. mossambica* decline rapidly in water below 12° C. (St. Amant, 1966), and *T. zillii* below 7° C., and *M. latipinna* below 15° C. (our unpublished data), which greatly reduces field populations annually. Though prolific in water above 22° C., they will sustain a significant annual dieback in waters of the southwestern United States where average winter temperatures drop below 7° C. Thus, any tendency toward overpopulation as observed in southeast Asian populations of *T. hornorum* Trewazas (Hickling, 1961) is precluded. We also observed that significant predation by predatory fish such as bass further reduces the number of fry in summer. These mortality factors plus the territorial behavior would act to maintain unmanaged populations of *Tilapia* at a low level that would not pose outbreak threats in aquatic habitats of the American Southwest. Data with *T. mossambica* already established in the Imperial Valley for at least 8 years attest to the reliability of this assumption. Also, *M. latipinna* is already firmly established throughout the warmer areas of the lower Colorado River basin and may be contributing significantly to mosquito reduction. Both *Tilapia* species are good game fish that respond favorably to angling, and young adults in the size range of 16–30 cm have good edible qualities.

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SOME ERRORS INHERENT IN U. L. V. OPERATIONS

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Several errors inherent in spraying operations are magnified as application rates become smaller per unit area. The most common errors result from faulty measurement of the pesticide during application. The apparent lack of appreciation of the problem should be of concern.

As the volume of solution to be applied per unit area decreases, the percentage of the active agent in the spray solution necessarily becomes greater. The lesser the amount being applied per unit area, the greater becomes the probability of an error in measurement (Thompson, 1970a). Errors increase as the emission rate decreases when equipment is used in actual field operations.

The difficulty involved in measuring the flow rate of a viscous liquid, whose temperature is changing, is of considerable magnitude (Tate, 1968). The flow rate does not vary as a smooth curve function. The curve representing the rate of flow against temperature is basically a hyperbola. The hyperbolic curve will be interrupted by a plateau (Ford and Furmidge 1969) caused by the flow-rate remaining constant throughout a range of temperatures. This plateau, if it occurs within operational limits, can be useful as equipment can be designed to operate within a flow-rate plateau. A range of several degrees of temperature within which to operate would allow comparatively crude controls to keep the pesticide solution within that range. Should the plateau extend over only 1 or 2 degrees, or no plateau be available, a small temperature change can, and will, significantly change the emission rate of the pesticide solution

An error will occur, even with a flow meter monitoring the rate of flow, unless the temperature of the solution is maintained at the point at which the calibration was made. We have observed that a change of 12° allowed the flow t