LABORATORY STUDIES ON THE POTENTIAL OF *DUGESIA TIGRINA* FOR MOSQUITO PREDATION

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ABSTRACT. The planarian *Dugesia tigrina* (Girard) was studied in the laboratory to assess its ability to prey on mosquito larvae. Different size ranges of planaria tested showed no significant differences in ability to consume larvae of mosquitoes. *Dugesia tigrina* more effectively reduced numbers of 2nd and 3rd instar mosquito larvae than 1st or 4th instar larvae or pupae. No significant mortality could be attributed solely to mucous secretions produced by the planaria; however, when planaria were present the secretions served as a mechanical aid to temporarily entrap larvae which were subsequently fed upon. Chironomid larvae were more easily fed upon than mosquito larvae and *Gammerus* sp. were captured less frequently than mosquitoes.

INTRODUCTION

Planarian flatworms have long been known as predators of mosquitoes. Lischetti (1919) reported that 6 triclads in the genus *Planaria* consumed 106 3–4mm long mosquito larvae in 3–4 hrs. *Planaria maculata* Leidy (= *Dugesia tigrina* (Girard)) were reported by Stage and Yates (1939) to consume 1–2 mosquito larvae per day. Medved and Legner (1974) found that populations of mosquitoes in rearing pools were decimated by the flatworm *Dugesia dorotocephala* (Woodworth). Yu and Legner (1976) found that *D. dorotocephala* significantly reduced populations of mosquitoes and chironomids both in laboratory and field studies. In addition, mucous secreted by this planarian physically immobilized and was somewhat toxic to mosquito larvae (Legner and Yu 1975). George (1978) found that *D. tigrina* consumed an average of 1.2 mosquito larvae per day in the laboratory and significantly reduced *Culex restuans* Theobald and *Cx. pipiens* Linnaeus in catch basins in Ontario.

Studies reported here were designed to determine (1) the effect of planarian size on predation, (2) the effect of prey density on predation, (3) prey acceptability and (4) the effect of the mucous secretions of *D. tigrina* on mosquito larvae.

MATERIALS AND METHODS

Experiments were conducted in 150 mm diam. petri dishes containing ca. 175 mm of water (depth ca. 1 cm). Dishes were stocked with *D. tigrina* 48 hr before any prey were added to assure that planarians would be ready to feed at the start of each experiment. Mosquito larvae were provided with food (ground Tetra-Min®) when initially stocked in treatment and control dishes and additional food was added and surface scum was removed as necessary during the course of experiments. The number of replicates was limited by availability of subject organisms. Planaria for use in the studies were collected from the Red River at Fargo and were maintained in aerated aquaria. Mosquitoes used were either laboratory reared *Cx. pipiens* or larvae reared from field-collected egg rafts of *Cx. restuans*.

EFFECT OF PLANARIAN SIZE ON PREDATION. *Dugesia tigrina* were separated into groups based on the planarian's length; those longer than 8 mm, those between 5 and 8 mm and those less than 5 mm. Control dishes received no planaria. Twenty-five *D. tigrina* of a particular size were put in treatment dishes along with 50 1st instar *Culex restuans* larvae. Each replication was maintained for 7 days.

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The number of larvae consumed in 7 days per planarian for each size group was determined. Significance of differences in the larvae eaten per planarian in each size group was tested by analysis of variance.

EFFECT OF PREY DENSITY ON PREDATION BY PLANARIA. Prey densities of 50, 100 and 200 were tested for each of the 1st through 3rd instars of *Cx. pipiens* larvae; of 50 and 100 4th instar larvae and 50 pupae with the predator population at 25 *D. tigrina* per dish. Larvae at the same instar and a given density were put into 3 treatment and 3 control dishes.

After each 24-hr period, surviving larvae were counted and removed, and new water and new groups of larvae were added at the original instar and density. Each replication was continued in this manner for 7 days.

The mass of each instar and pupae consumed per *D. tigrina* was calculated by multiplying the number of each instar and pupae by the weight of a single individual. Individual weights were determined as the mean weight based on 5 group weighings for each of the mosquito stages.

PREY PREFERENCE. Prey preference for 3 types of natural prey of *Dugesia tigrina* was tested in the petri dish bioassay. Groups of 15 *Chironomus* sp. ca. 10 mm long, 15 *Gammerus* sp. ca. 5 mm long and 15 2nd instar *Cx. restuans* were each put into 4 petri dishes. Twenty-five *D. tigrina* were stocked in 3 dishes and 1 dish remained as a control. Surviving prey organisms were counted after 3 days.

To determine which immature stage of mosquito is most susceptible to *D. tigrina* predation, 25 *Cx. pipiens* larvae of each instar and 25 pupae were placed in each of 3 treatment and control dishes. Each replication lasted 7 days. The immature mosquitoes surviving in each dish were counted and discarded daily, water in the dishes was changed and new groups of mosquitoes of the original composition were added to treatments and controls. *D. tigrina* in treatment dishes were counted on the 7th day. The numbers of each instar and pupae eaten per planarian in 7 days were compared by analysis of variance and then the mean number of each instar eaten per planarian was compared using Duncan's New Multiple Range Test.

EFFECTS OF SECRETIONS OF *Dugesia tigrina* ON MOSQUITO LARVAE. Petri dishes were treated by maintaining 25 *D. tigrina* in each dish for 9 days after which the planaria were removed and fresh water was added. One hundred 1st instar *Cx. pipiens* larvae were put into each of the 3 treatment and control dishes. Surviving larvae were counted after 24 hours. The same procedure was repeated using 100 2nd instar *Cx. pipiens*.

RESULTS AND DISCUSSION

Dugesia tigrina glided across the substrate of the surface film in search of food. Observations reported by George (1978) that injured larvae elicited a strongly attractive response from planarians were confirmed in our bioassays. Movements of larvae that were uninjured but trapped in planarian secretions attracted planarians. Free, uninjured prey were caught as the result of accidental encounters with planaria. When one planaria began feeding, others, probably responding to disturbances in the water and fluids escaping from the injured prey, began to search for food. Frequently several planaria fed on a single larva. Mosquitoes temporarily held in *D. tigrina* secretions were contacted by the anterior end of planaria. The planaria then wrapped its body around the prey and secured itself to the substrate with the anterior portion of the body while holding the larva with the posterior section. Other planaria oriented toward injured larvae and began to feed. Only the exoskeletons of larvae remained when feeding ceased.

EFFECT OF PLANARIAN'S SIZE ON PREDATION. There was no significant difference between size groups ($p = 0.05$) in the number of larvae destroyed per planarian in 7 days. Small planarians con-

sumed the most larvae during the first 2 days of the experiment but were surpassed by medium and large *D. tigrina* on the third day (Fig. 1).

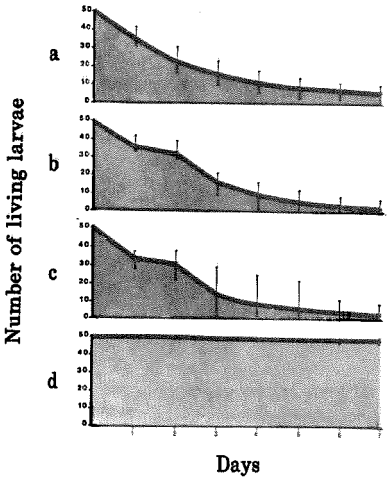

Fig. 1. Number of larvae surviving predation by 3 size ranges of *Dugesia tigrina*. a) Planaria less than 5mm long, b) Planaria 5–8mm long, c) Planaria over 8mm long, d) Control.

Some asexual reproduction occurred in dishes with medium and large planaria; however, individuals resulting from fission were incapable of feeding until their food getting apparatus had been regenerated. Small *D. tigrina* were capable of consuming more food for their mass than larger planaria and were also more active than larger individuals. Size had minimal influence on planarians ability to subdue even substantially larger prey.

EFFECT OF PREY DENSITY ON PREDATION BY PLANARIA. We observed in preliminary work that *D. tigrina* would never consume all the larvae in a container yet would readily feed on a larva offered to them, especially if the larva was injured.Thus, we suspected that the planaria were inefficient in searching for prey. Consumption of 1st and 2nd instar *Cx. pipiens* larvae approximately doubled each time the number of larvae per dish doubled. Consumption of 3rd instar larvae increased when the number of larvae per dish was raised from 50 to 100 but not when it was raised from 100 to 200 larvae, and there was no increase in the number of 4th instar larvae consumed per *D. tigrina* when larvae were increased from 50 to 100 per dish. Pupae were only appreciably preyed upon by starved planaria (Table 1 and Fig. 2).

Table 1. Weight in milligrams of *Culex pipiens* larvae and pupae consumed per *Dugesia tigrina* in 7 days at 3 prey densities.

Cx. pipiens stage	Individual weight (mg)	50/dish	100/dish	200/dish
1st	0.02	0.08	0.17	0.42
2nd	0.12	1.24	2.41	3.98
3rd	0.60	5.18	7.95	7.96
4th	3.00	8.95	8.78	
pupae	2.90	4.71		

An individual *D. tigrina* could consume as much as 8.9 mg of mosquito larvae in 7 days but this potential was only approached in preying on 100 or more 3rd instar, and attained when preying on 50 or more 4th instar larvae per dish. Although there was a surplus of larvae in all replications, the weight of 1st and 2nd instar larvae consumed was far below the satiation point of the planaria. This indicates that predation on these small larvae is limited by the ability of the planaria to successfully search for prey. The ability to consume larvae apparently limited predation of 3rd instar larvae at densities greater than 100 per dish and 4th instar larvae at densities greater than 50 per dish. Pupae were not preyed on as successfully as larvae. This was probably because pupae remained at the surface most of the time rather than on the bottom of the dishes where most of the planaria remained, so contacts between predator and prey were low.

PREY PREFERRED BY PLANARIA. More *Chironomus* sp. larvae were consumed in 3 days than either *Cx. restuans* larvae or *Gammerus* sp. (Fig. 3). *Culex* larvae were

utilized as food more frequently than *Gammerus*. Prey preference related directly to the mobility of the prey and the duration of time the prey species remained on the bottom of the assay chambers. *Chironomus* sp. larvae moved slowly and remained on the bottom where contacts with planaria were more frequent. *Culex* larvae moved actively in the dishes, but fed on the bottom surface where contacts with planaria occurred. *Gammerus* swam actively in the dishes for relatively longer periods so contacts were fewer. It seems evident that in sites where organisms less mobile than mosquitoes occur on the substrate the planaria may do little to regulate the mosquito population.

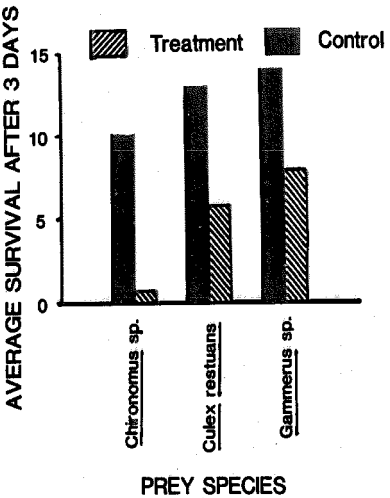

Fig. 3. Numbers of prey species consumed by *Dugesia tigrina* in 3 days.

There was a significant difference ($p = 0.05$) in the number of larvae at each instar eaten per planarian in 7 days. Second and 3rd instar larvae were most preferred and did not differ significantly from each other. First instar larvae were preferred over pupae and 4th instar larvae (Table 2). Pupae and 4th instar *Culex pipiens* were probably able to escape more encounters

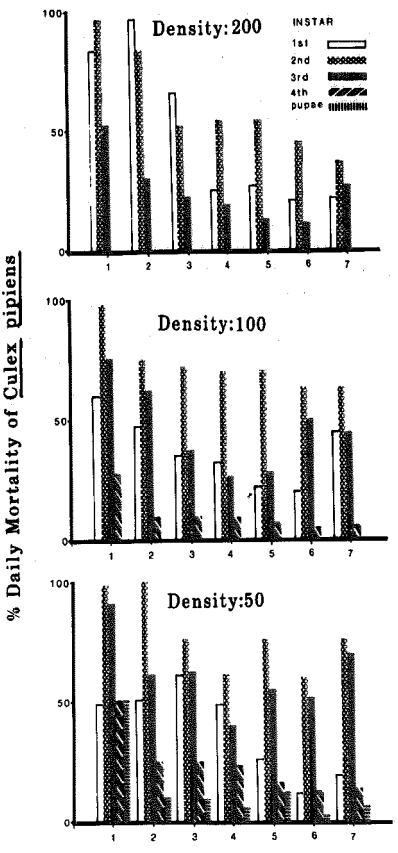

Fig. 2. Percent mortality of larvae and pupae of *Culex pipiens* at densities of 200 (top), 100 (middle) and 50 (bottom) added daily to dishes with 25 *Dugesia tigrina*.

Table 2. Mean number of *Culex pipiens* larvae consumed per *Dugesia tigrina* in 7 days.

Instar	Larvae consumed/planarian
2nd	2.543 a
3rd	2.267 a
1st	1.480 b
pupae	0.653 c
4th	0.533 c

Means followed by common letters did not differ significantly from each other using Duncan's New Multiple Range Test ($p = 0.05$).

with planarians, and 1st instar larvae appeared too small to be readily detected. The larger planarian, *Dugesia dorotocephala*, showed a preference for 4th instar larvae and pupae (Yu and Legner 1976).

EFFECT OF *D. tigrina* MUCOUS SECRETIONS ON MOSQUITO LARVAE. There was no significant difference ($p = 0.05$) in mortality between larvae in control and mucous coated dishes. Legner and Yu (1975) reported the secretions of *D. dorotocephala* had an anethestizing effect on mosquito larvae in addition to an ability to physically smother them. This was not the case with *D. tigrina* secretions; however, secretions acted as a mechanical aid to subdue and hold larvae for short periods. No toxic effects from the secretions were observed and entrapped larvae were able to free themselves. Even 4th instar larvae and pupae were temporarily entrapped by the mucous; in dishes with planaria these larvae were usually fed on before they could escape.

Feeding planaria secreted large amounts of mucous which would entrap additional larvae. Subsequently, several planaria gathered to feed on these entrapped groups.

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