EVALUATION OF THE PLANARIAN, *DUGESIA DOROTOCEPHALA*, AS A PREDATOR OF CHIRONOMID MIDGES AND MOSQUITOES IN EXPERIMENTAL PONDS

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ABSTRACT. The predatory effectiveness of the planarian, *Dugesia dorotocephala*, against populations of chironomid midges and mosquitoes in earthen experimental ponds was studied during the summers of 1975, 1976 and 1977.

In 1975, inoculation levels of 10 and 25 planaria/m² of pond surface area produced reductions of 28.5% and 52.3%, respectively, in populations of *Dicrotendipes* sp., *Tanytarsus* spp., *Procladius* spp. and *Cricotopus* spp. midges. In 1976, the midge larvae were reduced by 36.5%, 51.0% and 58.3% at levels of 25, 50 and 100 planaria/m², respectively. In 1977, levels of 25 and 50 planaria/m² produced 37.8% and 47.5% midge control, respectively. Larval populations of *Culex* mosquitoes were reduced in 1976 by 71.8%, 75.2% and 77.0% at inoculations of 25, 50 and 100 planaria/m², respectively. In 1977, *Culex* larvae were reduced 63% with 25 planaria/m² and 73% with 50 planaria/m². The planaria in inoculated ponds persisted throughout each evaluation period, and showed slight population increases, but these increases were inconsistent and non-proportional to their initial inoculation densities.

INTRODUCTION

The turbellarian, *Dugesia dorotocephala* (Woodworth) is a useful biological control organism for larvae of chironomid midges and mosquitoes (Legner and Yu 1975, Legner et al. 1975, Medved and Legner 1974, Yu and Legner 1976). The evaluation of this turbellarian against *Culex* mosquitoes at 2 inoculation rates (10 and 25/m²) in experimental ponds had shown a higher level of suppression of the mosquito larvae at the higher rate of inoculation (Legner 1977). This study was made in experimental ponds to elucidate the predatory effectiveness of *D. dorotocephala* against chironomid midges and mosquitoes when inoculated at rates of 10, 25, 50 and 100 planaria/m².

MATERIALS AND METHODS

Studies were conducted in 6.5 × 4 m and 0.35 m deep earthen experimental ponds at the aquatic research facility (Midgeville) of the University of California, Riverside, CA. These ponds were maintained free of vegetation, and water to these ponds was provided from an irrigation reservoir through underground pipes. The water level in each pond was kept constant by a float valve. The water in the ponds did not flow from one pond into another during the study periods.

Mature *D. dorotocephala* (12–16 mm long) were obtained from laboratory cultures maintained at the University and were evaluated during 3 consecutive summers. In the first experiment, *D. dorotocephala* was introduced on July 12, 1975, at rates of 10 and 25/m² of water surface in each of 3 replicated ponds. Three untreated ponds served as controls. In the second experiment on August 20, 1976, the ponds were inoculated with *D. dorotocephala* at rates of 25, 50 and 100/m² of water surface in 3 replicated ponds for each treatment rate; 3 untreated ponds served as controls. The following year (1977), the rates of 25 and 50 planaria/m² of water surface were repeated and the predator was introduced on July 2 to each of 4 replicates for each treatment. Four control ponds were also maintained. In each experiment, the ponds were flooded ca. 3 wk. prior to the introduction of planaria. The treatments were assigned to ponds in a randomized manner.

Immediately prior to and at intervals after planaria inoculations, midge and mosquito larval densities in the treated and control ponds were assessed. Midge larvae were sampled by taking 3 random mud samples from each pond with a 10 × 8 cm scoop sampler. The mud was processed as in Mulla et al. (1971) to recover the larvae. Mosquito larvae were sampled by using a 400 ml dipper. A composite of 5 dip samples, one from each corner and one from the middle area of the pond, was taken (Fanara and Mulla 1974). Only 3rd and 4th instars (generally 3 mm and longer) of midges and mosquitoes were identified and counted. The percent reduction of midge and mosquito larvae in the ponds after inoculations were calculated as in Mulla et al. (1971). The overall mean reductions at different inoculation rates during an evaluation period were compared for significant difference (P = 0.05) by analysis of variance and Duncan's multiple range test.

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Estimates of *D. dorotocephala* density in each inoculated pond were made by using 16 round rocks of approximately the same size. The rocks were arranged in 4 clusters in each pond with each cluster containing 4 rocks (ca. 400 cm^3 each rock) placed in each corner of an inoculated pond (Yu and Legner 1976). One rock from each cluster in a pond was periodically examined to count planaria that attached, and the rock was immediately returned to the cluster after the planaria were counted. During 1976, the daily water temperature was recorded with a remote thermograph in one of the ponds.

RESULTS AND DISCUSSION

Four genera of Chironomidae, *Dicrotendipes* sp., *Tanytarsus* spp., *Procladius* spp. and *Cricotopus* spp., and 3 species of Culicidae, *Culex peus* Speiser, *Cx. tarsalis* Coq., and *Cx. quinquefasciatus* Say, were present during the study periods. The mosquito data for the July–September 1975 evaluation were reported by Legner (1977). *Culex* larvae were reduced proportional to the number of prevailing planaria. Table 1 shows that the rate of 10 planaria/m^2 produced an overall mean reduction of 28.5% and 25 planaria/m^2 produced a significantly (5% level) higher control (overall mean 52.3%) of midge larvae in the 55 days of post-inoculation period. The reductions of midge larvae ranged from 16–36% with 10 planaria/m^2 and 37–62% with 25 planaria/m^2 in the 55 days.

In August–October 1976, the overall mean reduction of midges ranged from 36.5% at 25 planaria/m^2 to 58.3% at 100 planaria/m^2. Although there was a progressive increased reduction of midge larvae with the increasing rate of inoculation, the overall reductions produced by the 2 higher rates (50 and 100/m^2) were not significantly different ($P = 0.05$) from each other. The same trend was true for the July–August 1977 evaluations when the rate of 25 planaria/m^2 produced an overall 37.8% reduction, and 50 planaria/m^2 resulted in 47.5% control of midge larvae, but these 2 reduction levels did not differ from each other at the 5% level of probability.

Table 2 shows the levels of reduction of *Culex* larvae. In 1976, inoculation of 25 planaria/m^2

Table 1. Evaluation of the planarian, *Dugesia dorotocephala,* against chironomid midge larvae[a] in experimental ponds at Midgeville, University of California, Riverside, CA, 1975–77.

Inoculation no. planaria/m^2	Mean no. larvae/0.09 m^2 pre, and post-inoculation (days)					
	Pre-	9–20	16–33	30–45	45–56	$\bar{x}$[d]
		July–September 1975 evaluation				
10	76	154	366	199	293	
		(16)[b]	(29)	(33)	(36)	(28.5) a
25	130	197	382	239	300	
		(37)	(57)	(53)	(62)	(52.3) b
0	66	159	446	259	396	
		August–October 1976 evaluation[c]				
25	207	160	144	56	42	
		(27)	(40)	(42)	(37)	(36.5) a
50	203	145	112	37	27	
		(32)	(52)	(61)	(59)	(51.0) b
100	258	110	130	52	33	
		(60)	(56)	(57)	(60)	(58.3) b
0	229	242	265	107	74	
		July–August 1977 evaluation				
25	248	250	159	73	80	
		(25)	(29)	(56)	(41)	(37.8) a
50	197	185	105	55	54	
		(31)	(41)	(58)	(60)	(47.5) a
0	179	242	162	120	98	

[a] Third and 4th instar (2-3 mm and longer); mostly *Procladius* spp., *Tanytarsus* spp., *Dicrotendipes* sp. and *Cricotopus* spp.

[b] Numbers in parentheses represent mean percent reduction calculated as in Mulla et al. 1971.

[c] Daily maximum and daily minimum water temperatures ranged from 18–32°C during August 20 to October 15, 1976.

[d] Overall mean percent reduction. Overall means in a column under each evaluation followed by a different letter are significantly different ($P < 0.05$); Duncan's multiple range test.

produced 61–80% reduction in the 56 days of evaluation while 50 planaria/m² caused 64–86% reduction. The highest rate produced 71–81% reduction. The overall mean reductions for the 3 ascending rates were 71.8%, 75.2% and 77.0%, respectively; the lowest rate was as effective as the highest rate (Table 2). In July–August 1977, 25 and 50 planaria/m² produced 57–67% control of mosquito larvae at 25, and 63–78% at 50 planaria/m² (Table 2). The overall mean reduction of 63% given by 25 planaria/m² was not significantly different from that of 73% produced by 50 planaria/m².

It is apparent from Table 3 that the planaria in the inoculated ponds persisted throughout the study periods of 1976 and 1977 and their mean density from August 20 to October 15, 1976, increased by 36% in ponds inoculated at 25 planaria/m², 18% at 50/m² and 11% at 100/m². From July 2 to August 15, 1977, increases of 22% and 28% in the mean density of planaria inoculated with 25 and 50/m², respectively, were recorded.

The results of this study are in general agreement with those of Legner (1977), and Yu and Legner (1976). However, the extent of midge larval reductions (64–82%) during the 3–5 months of post-inoculation of 5 mature planaria/m² of water surface in flood control basins (Yu and Legner 1976) were proportionally much higher than those produced by the higher rates of 10–100 planaria/m² presently employed. The 75–79% reduction of *Culex* larvae produced by a rate of 25 planaria/m² in rice paddy habitats (Yu and Legner 1976) is compatible with comparable mosquito data obtained here. This study showed that doubling or quadrupling the inoculation rates of the planarian from 25 to 50 or 100/m² produced only 9.7–14.5% more reduction of midges by doubling (i.e. 50 planaria/m²) and 21.8% more reduction by quadrupling (i.e. 100 planaria/m²) the rates of planaria inoculation. Similarly, only 3.4–10% more reduction of mosquito larvae was achieved by doubling the inoculation rate from 25 to 50 planaria/m² and 6.2% more at 4 times the rate of 25 planaria/m². Some of these increases of reductions achieved with higher rates of inoculations were not significant at the 5% level of probability. This suggests that a threshold level of inoculation rate for a given habitat exists above which the reductions of midges and mosquitoes are negligible. Perhaps complete (100%) control of these aquatic pests and vector insects in field situations cannot be achieved by increasing the inoculation rate above the threshold level. However, appreciable reductions of midges and mosquitoes can be achieved by this predator at certain rates employed in this study and in the previous studies (Legner 1977, Yu and Legner 1976).

This study also showed increases of planaria density in the inoculated ponds but these increases were inconsistent and were not proportional to the initial inoculation densities, con-

Table 2. Evaluation of the planarian, *Dugesia dorotocephala*, against *Culex* spp.[a] mosquitoes in experimental ponds at Midgeville, University of California, Riverside, CA, 1976–77.

Inoculation no. planaria/m²	Mean no. larvae/5 dips[b] pre-, and post-inoculation (days)					
	Pre-	9–20	16–33	30–45	45–56	$\bar{x}$[e]
		August–October 1976 evaluation[c]				
25	67	6	4	4	4	
		(80)[d]	(69)	(77)	(61)	(71.8) a
50	37	3	1	3	2	
		(82)	(86)	(69)	(64)	(75.2) a
100	69	9	3	4	2	
		(71)	(78)	(78)	(81)	(77.0) a
0	46	21	9	12	7	
		July–August 1977 evaluation				
25	164	15	14	7	12	
		(65)	(57)	(63)	(67)	(63.0) a
50	184	12	8	8	12	
		(75)	(78)	(63)	(76)	(73.0) a
0	120	31	24	14	27	

[a] Third and 4th instar *Culex peus, Cx. tarsalis* and *Cx. quinquefasciatus.*
[b] Two liters water.
[c] Daily maximum and daily minimum water temperatures ranged from 18–32°C during August 20 to October 15, 1976.
[d] Numbers in parentheses represent mean percent reduction calculated as in Mulla et al. 1971.
[e] Overall mean percent reduction. Overall means in a column under each evaluation followed by the same letter are not significantly different ($P > 0.05$); Duncan's multiple range test.

Table 3. Population density of the planarian, *Dugesia dorotocephala,* as measured by their numbers on uniform rock substrates in replicated experimental ponds at Midgeville, University of California, Riverside, CA, 1976–1977.

Inoculation no. planaria/m²	Mean no. *D. dorotocephala*/rock[a] sample post-inoculation (days) Pre-	2	16–20	30–33	45	56	$\bar{x}$[c]
			August–October 1976 evaluation[b]				
25	0	4.75	3.25	8.75	9.25	6.25	6.45 (36)
50	0	9.25	11.25	13.50	12.25	8.25	10.9 (18)
100	0	15.75	21.75	18.50	17.50	14.25	17.55 (11)
			July–August 1977 evaluation				
25	0	6.5	7.5	8.5	9.25	—	7.94 (22)
50	0	9.25	9.75	13.75	14.75	—	11.88 (28)

[a] A total of 16 uniform rocks (each ca. 400 cm^3) per pond were placed in 4 clusters of each with 4 rocks in each corner of a pond inoculated with *D. dorotocephala.*

[b] Daily maximum and daily minimum water temperatures ranged from 18–32°C during August 20 to October 15, 1976.

[c] Numbers in parentheses represent mean percent increase of *D. dorotocephala* during the 56 and 45 days post-inoculation periods; the 2 days post-inoculation density was considered as the initial *D. dorotocephala* density in the inoculated ponds in each test.

trary to the observations of Legner (1977). Also, the amount of increases were not as great as reported previously by Yu and Legner (1976) in rice paddy habitats where apparently a quadrupling of the planarian population had occurred in the 4 months post-inoculation period. Certain environmental stimuli affect asexual reproduction of the planaria (Legner et al. 1976). These stimuli may differ from habitat to habitat resulting in differential growth of the planarian among habitats. The predator-prey proportions in a habitat and the time of the year might also affect growth of the planarian.

This study confirms that *D. dorotocephala* offers some potential for controlling freshwater mosquitoes and chironomid midges in certain situations. The rearing of this predator, although not easy, is feasible (Tsai and Legner 1977). Further research on the mass rearing techniques of *D. dorotocephala* is needed. The inoculation of this predator at practical mosquito control rates did not affect densities of other natural predators of midges and mosquitoes in the ponds as shown by Legner (1977). Also, unlike chemical larvicides, *D. dorotocephala* produces and maintains long-term control.

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