

# Predation by *Hydrophilus triangularis* and *Tropisternus lateralis*<sup>1</sup> in California Rice Fields<sup>2</sup>

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## ABSTRACT

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Gut content examinations of the larvae of *Hydrophilus triangularis* Say and *Tropisternus lateralis* (F.) (Coleoptera: Hydrophilidae) showed that predation was influenced by the relative size of predator and prey and by the availability of prey. The rice seed midges *Cricotopus sylvestris* (F.), an undescribed *Paratanytarsus* sp. (= *Tanytarsus* sp.), and *Paralauterborniella* spp. comprised most of the diet, and were apparently selected with greater frequency than their abundance in the rice field community would indicate. The extent of natural control of midges provided by hydrophilid larvae is unknown.

In California, rice (*Oryza sativa* L.) is grown in paddies that remain flooded throughout most of the production season (late April through late September). These temporary bodies of water are colonized by a variety of aquatic organisms. As several of the colonizing organisms are important disease vectors or pests of rice, the study of their predators becomes especially relevant.

The larvae of Hydrophilidae are well known mosquito predators (e.g., Neilsen and Neilsen 1953, James 1964, Veneski and Washino 1970). Further, Zalom et al. (1978) have shown that chironomid midges are a major part of the diet of hydrophilids in rice fields. Midge larvae, in particular *Cricotopus sylvestris* (F.), an undescribed *Paratanytarsus* sp. (= *Tanytarsus* sp.), and *Paralauterborniella* spp. damage rice by feeding on the roots and leaves of the young seedlings, and burrowing into the germinating seed (Darby 1962, Clement et al. 1977).

In this study we examined the diet of *Hydrophilus triangularis* Say and *Tropisternus lateralis* (F.) larvae collected in northern California rice paddies in relation to the prey types available and to the community diversity of the paddies during the production seasons of 1977 and 1978.

## Methods

The rice invertebrate community was sampled for an entire night at weekly intervals with aquatic light traps consisting of 6v incandescent light sources within glass cylinders (Washino and Hokama 1968). Chloroform fumes served as the killing agent. The traps were deployed 12m apart in 2 rows of 4 traps each. The rows were 5 and 30 m from the levee margin. Vegetation was removed 1m around each trap. A second method of sampling consisted of dragging an aquatic net with an opening of 706.5 cm<sup>2</sup>, 5m through the water column in contact with the substrate. This procedure was repeated 6 times weekly at the 5 and 30 m distances. All organisms captured by both methods were placed in 70% ethyl alcohol. Later, midges and other small aquatic organisms were mounted on slides for identification.

Sampling was conducted in untreated 4 hectare paddies at the California Cooperative Rice Research Foundation field station near Biggs, Butte Co., CA.

*H. triangularis* and *T. lateralis* larvae ingest the entire prey organism after mandibular crushing (Balduf 1935, Wilson 1923), and we could identify prey by searching gut contents for recognizable sclerites. We dissected at least 10 individuals each week of both hydrophilid species and all larval stages when these were present in the aquatic light trap samples. More specimens were dissected at periods of peak abundance (Table 1). Head capsule width was used to determine instar because of the resulting significant regression to 3 instars ( $P < 0.0005$ ;  $r = 0.9945$ ;  $\hat{Y} = 0.4776 + 60.8080x$ ).

Results of the gut dissections were analyzed in terms of the predator's selectivity. The statistic used to measure preference was "electivity" as proposed by Ivlev (1961), where  $E = (r_i - p_i) / (r_i + p_i)$ . In this equation,  $r_i$  is the fraction of the diet compound of species  $i$ , and  $p_i$  is the fraction of the total prey available that is composed of species  $i$ . A value of 0 indicates nonselective feeding; a value between 0 and +1 indicates preference for a prey item; and a value between -1 and 0 indicates avoidance or inaccessibility. It must be remembered that the electivity statistic reflects prey availability or accessibility as much as actual selection or avoidance. The electivity of each instar for each prey type was determined for both years. Weekly electivities were also calculated for larger taxonomic groupings of particular interest.

Diversities of the hydrophilid gut contents and of the aquatic invertebrate community of the rice field were derived using a formula of the Brillouin measure of information provided by Lloyd et al. (1968):

$$\bar{d} = \frac{C}{N} (N \log N - \sum n_i \log n_i),$$

where  $C$  is a constant (3.321928) converting base 10 log to base 2 (bits of information);  $N$  is the total number of individuals in the sample; and  $n_i$  is the total number of individuals in the  $i$ th species. We chose Brillouin's formula as a heterogeneity index based on information theory because of its accuracy when applied to a finite sample in which all members are counted. Pielou (1966) preferred Brillouin's equation to derivations of the Shan-

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**Table 1.**—Number and mean ( $\pm$  SD) size of hydrophilid larvae dissected.

Type of larva	N (1977)	N (1978)	Head capsule width (mm)	Length of larva (mm)
<i>H. triangularis</i>				
3rd instar	120	165	6.06 $\pm$ 0.09	41.35 $\pm$ 4.38
2nd instar	60	60	3.63 $\pm$ 0.14	19.85 $\pm$ 3.13
1st instar	40	100	1.97 $\pm$ 0.09	11.73 $\pm$ 1.03
<i>T. lateralis</i>				
3rd instar	155	175	1.88 $\pm$ 0.09	13.97 $\pm$ 1.08
2nd instar	95	60	1.25 $\pm$ 0.05	7.03 $\pm$ 0.72
1st instar	120	120	0.96 $\pm$ 0.03	6.10 $\pm$ 0.83

non formula because the latter does not reflect sample size.

All 29 prey types identified from gut dissections were present in the aquatic light trap samples, while only 17 of the 29 were captured in the aquatic nets. We defined the 29 prey types representing 23 different species as the universe of total prey available to *H. triangularis* and *T.*

*lateralis* larvae, and used data from the aquatic light trap samples in calculations of electivity and diversity. A sampling error could result from variation in attraction to light by the potential prey species.

### Results

We measured the selection of a prey item by each instar of *H. triangularis* and *T. lateralis* in terms of the electivity of larvae for each prey type, and the percentage of the total diet composed of each prey type during both years (Table 2). It was apparent that Chironomidae as a group comprised the greatest numerical fraction of the total diet of all instars of *H. triangularis*, accounting for over 50% of all prey items. In most cases, the electivity for each midge species was also high, indicating possible preferential feeding by both hydrophilid species. *Tanytarsus* sp. was the most commonly identified prey item in the gut dissections of both species. The rice seed midges *C. sylvestris* and *Paralautborniella* spp.,

**Table 2.**—Electivity rates of the larvae of *H. triangularis* and *T. lateralis* during 1977–78. Number in parentheses indicates the percent composition of the diet.

ORGANISM	<i>H. triangularis</i>			<i>T. lateralis</i>	
	1st	2nd	3rd	2nd	3rd
CRUSTACEA					
Copepoda					
<i>Cyclops</i> sp.	-0.906(2.73)	—	-0.921(2.48)	-0.320(41.25)	-0.336(22.98)
Ostracoda					
<i>Candona</i> sp.	-0.242(1.36)	-0.776(0.95)	0.601(6.95)	—	0.290(2.41)
<i>Stenocypris</i> sp.	0.058(5.02)	-0.487(4.96)	0.539(11.59)	0.368(10.00)	0.628(11.69)
Cladocera					
<i>Ilyocryptus spinifer</i>	0.925(4.10)	0.433(1.34)	0.929(3.53)	0.913(3.75)	0.981(10.08)
INSECTA					
Hemiptera					
Corixidae					
<i>Corisella decolor</i> (adult)	—	-0.933(0.76)	-0.244(3.21)	—	—
<i>C. decolor</i> (nymph)	0.030(2.73)	-0.390(3.62)	0.087(2.37)	-0.359(1.35)	0.597(6.04)
Belostomatidae					
<i>Belostoma</i> sp. (nymph)	—	—	0.516(0.47)	—	—
Coleoptera					
Halplidae					
<i>Halipus</i> sp. (adult)	—	—	-0.874(0.16)	—	—
Dytiscidae					
<i>Hygrotus medialis</i> (adult)	—	-0.929(0.19)	0.150(1.69)	—	—
<i>H. medialis</i> (Larva)	—	—	0.222(0.11)	—	—
<i>Laccophilus mexicanus</i> (adult)	—	—	-0.255(3.64)	—	—
<i>L. mexicanus</i> (larva)	0.845(2.73)	0.219(1.14)	0.807(1.69)	—	0.893(2.41)
<i>Liodes affinis</i> (adult)	—	—	-0.670(0.79)	—	—
<i>Thermonectus basilaris</i> (larva)	—	—	0.926(0.26)	—	0.943(0.40)
Hydrophilidae					
<i>Berosus styliferus</i> (larva)	0.717(0.91)	-0.106(0.38)	0.585(0.42)	—	—
<i>Hydrophilus triangularis</i> (2nd)	—	—	0.103(0.16)	—	—
<i>H. triangularis</i> (1st)	—	—	0.660(0.53)	—	—
<i>Tropisternus lateralis</i> (3rd)	—	—	-0.222(1.37)	—	0.742(0.80)
<i>T. lateralis</i> (2nd)	0.640(0.91)	0.407(1.52)	0.712(0.95)	—	0.547(6.04)
<i>T. lateralis</i> (1st)	0.257(5.02)	-0.150(7.06)	0.584(8.75)	-0.421(1.25)	—
Curculionidae					
<i>Lissorhoptrus oryzophilus</i> (adult)	—	—	0.333(0.16)	—	—
Diptera					
Chironomidae					
<i>Chironomus</i> sp. (larva)	—	0.652(0.19)	0.680(0.21)	—	0.838(0.40)
<i>Cricotopus sylvestris</i> (larva)	0.717(5.46)	0.314(5.53)	0.727(4.43)	0.147(4.43)	0.742(3.62)
<i>Paralautborniella</i> spp. (larva)	0.927(11.47)	0.721(8.39)	0.884(5.37)	—	0.871(3.62)
<i>Procladius culiciformis</i> (larva)	0.993(2.73)	0.869(0.57)	0.667(0.05)	—	—
<i>Tanytarsus</i> spp. (larva)	0.747(56.16)	0.411(62.78)	0.710(37.25)	0.661(41.25)	0.699(27.41)
<i>Tendipes attenuatus</i> (larva)	—	-0.314(0.19)	0.782(0.90)	—	0.812(0.80)
Culicidae					
<i>Aedes melanimon</i> (larva)	—	—	-0.508(0.16)	—	—
<i>Culex tarsalis</i> (larva)	0.385(0.45)	0.689(0.38)	0.897(0.37)	—	0.980(1.20)

*T. lateralis* larvae, and various crustaceans also comprised large proportions of total prey. Chironomid larvae and crustaceans were found in similar proportions in the guts of 2nd and 3rd instars of *T. lateralis*. Again, electivity for each midge species was high. We found no identifiable prey items in the guts of 1st instars of *T. lateralis*.

It was obvious (Table 2) that 3rd instars of *H. triangularis* feed upon more kinds of prey than the other instars of *H. triangularis* or *T. lateralis*. Interestingly, we found a significant ( $P < 0.001$ ;  $r = 0.9288$ ) regression line which described the relationship between the total number of different prey species in the gut dissections of each instar during a season, and the mean head capsule width of that instar (Fig. 1). The regression line  $\hat{Y} = 0.8651 + 1.3528x$  estimated the relationship of width of the hydrophilid head capsule and total number of midges in the gut ( $P < 0.025$ ;  $r = 0.3252$ ;  $n = 43$ ).

Figures 2 and 3 show the weekly electivities of hydrophilids for larger taxonomic groupings that represented a total of over 80% of the diet of each hydrophilid species. For most prey species, there was little weekly change from the total electivity for both years. Weekly electivity for *Cyclops* sp. changed markedly, possibly due to the tremendous population fluctuations recorded. However, we found no significance ( $P > 0.25$ ) between the weekly trap catch and electivity for *Cyclops* sp.

We found a highly significant ( $P < 0.0005$ ;  $r = -0.9428$ ;  $n = 19$ ) negative correlation between the weekly electivity for chironomids by *H. triangularis* and the corresponding weekly diversity (Fig. 4) of the aquatic invertebrate community. A negative correlation ( $P < 0.001$ ;  $r = -0.6784$ ;  $n = 18$ ) also existed for *T. lateralis* preying on midges and the diversity of rice field invertebrates.

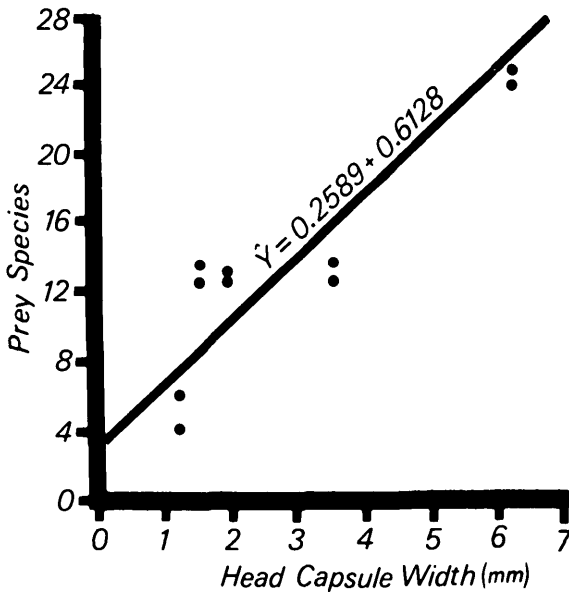


FIG. 1.—Graphical estimation of the effect of hydrophilid larval head capsule width on the total number of prey species taken during a season.

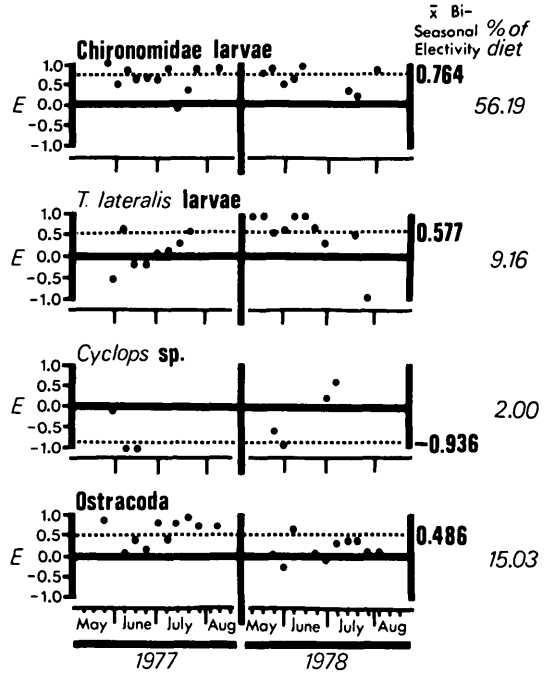


FIG. 2.—Weekly electivity rates of *H. triangularis* larvae for selected prey. Dashed line indicates total electivity for 1977-78.

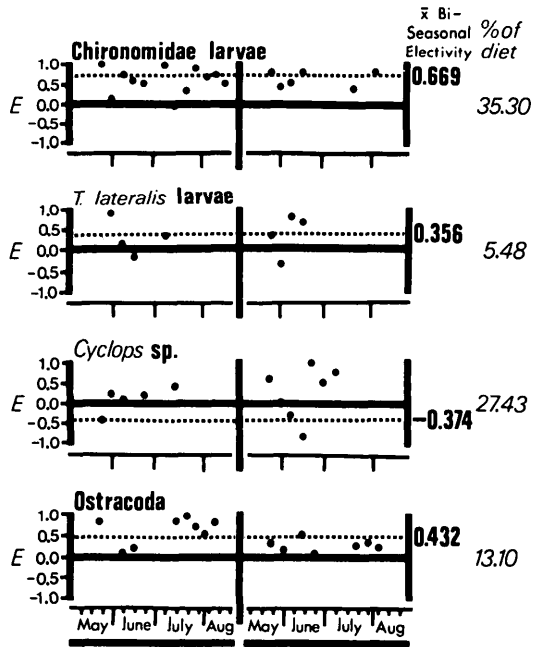


FIG. 3.—Weekly electivity rates of *T. lateralis* larvae for selected prey. Dashed line indicates total electivity for 1977-78.

When the weekly gut content diversity for each instar of *H. triangularis* and *T. lateralis* was compared to the corresponding weekly diversity of the rice field invertebrate community (Fig. 4), no significant ( $P > 0.10$ ) correlation existed. Further, no correlation appeared when the mean number of midges per hydrophilid gut

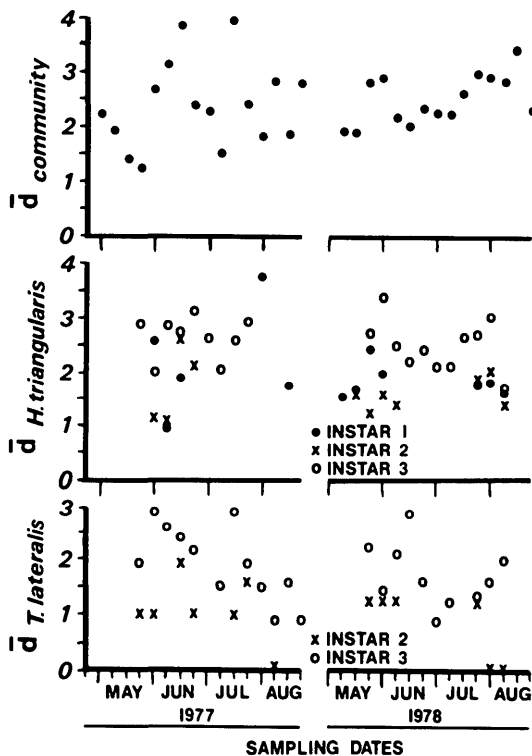


FIG. 4.—Weekly measurements of diversity for the aquatic invertebrate community, and for the larvae of *H. triangularis* and *T. lateralis*.

was compared to either the mean number of other organisms per hydrophilid gut ( $P > 0.25$ ) or the mean number of midges per aquatic light trap ( $P > 0.10$ ) for each weekly sampling date.

### Discussion

The diet of a predator is influenced by factors including the relative size of predator and prey and the availability of a prey organism to the predator. Prey availability can be a function of the ecology and behavior of both predator and prey, of the numerical abundance of prey organisms, and of competition between predators.

We have shown that there was a direct relationship between the size of the predaceous larvae of *H. triangularis* and *T. lateralis*, and the number of species of rice field invertebrates found in their gut contents. The narrow head capsule width of 1st instar *T. lateralis* probably precluded predation upon whole organisms with sclerotized structures. We have also demonstrated that some prey types were apparently selected in greater proportion than their relative abundance in the general rice field community. The measure of electivity could not be considered absolute due to the difficulties in assessing the availability of prey organisms to a given predator, and in accurately sampling that component of the community. The percent composition of the gut contents was an absolute measure and was indicative of foraging habits, but not of relative prey selection.

Chironomidae, *T. lateralis* larvae, copepods and ostracods accounted for the greatest fraction of the diet of

*H. triangularis* and *T. lateralis* larvae. The copepod *Cyclops* sp. comprised a much higher proportion of the diet of *T. lateralis* (27.43%) (Fig. 3) than of *H. triangularis* (2.00%) (Fig. 2). Mosquito larvae represented an average of less than 1% of all prey found in the gut contents, and did not appear to be controlled by hydrophilid larvae in rice fields.

We have often observed *H. triangularis* larvae gleaning food on the substrate and plants. *T. lateralis* divided its foraging time between the substrate, plant surfaces, and open water. Bay (1972) described this *T. lateralis* activity as "diving to the bottom of shallow ponds to seize chironomid larvae from their tubes, and then ascending to a perch on a plant near the surface to consume their quarry." Both species seemed to occupy similar feeding habitats where the availability of chironomids and hydrophilids for prey was greater than other prey, and this similarity may explain our measurement of positive electivity toward those food items by *H. triangularis* and *T. lateralis* larvae. Preferential predation upon midges by hydrophilid larvae was also enhanced by our conclusion that no significant correlation existed between the weekly gut content diversities of *H. triangularis* and *T. lateralis*, and the weekly diversities of the rice field invertebrate community.

We have also demonstrated significant negative correlations between the weekly electivities of *H. triangularis* and *T. lateralis* larvae for midge larvae, and the corresponding weekly diversities of the rice field invertebrate community. One reasonable explanation would be that seasonal changes in food abundance varied with the intensity of competition between the hydrophilid larvae and other rice field predators for available food. In times of low seasonal diversity, hydrophilid larvae best compete by preying upon available Chironomidae. Zaret and Rand (1971) predicted a similar change in feeding patterns by tropical stream fishes.

In conclusion, predation by *H. triangularis* and *T. lateralis* larvae was directly influenced by the relative size of predator and prey, by the availability of prey (especially Chironomidae) where the hydrophilids typically forage, and possibly by competition with other predators resulting from changes in the seasonal abundance of potential prey species. The rice seed midges *C. sylvestris*, *Paratanytarsus* sp. (= *Tanytarsus* sp.) and *Paralauterborniella* spp. comprised the largest proportion of the diet of both hydrophilid species, and were apparently selected more frequently with respect to their abundance in the rice field community. It is difficult to assess the economic impact of hydrophilid predation upon midge larvae, as they damage rice early in the season, before the peak abundance of larval hydrophilids occurs. However, the larvae of *H. triangularis* and *T. lateralis* undoubtedly provide some measure of natural control upon chironomids throughout the rice production season, and may regulate the numbers that survive to the beginning of the next year (Fretwell 1972).

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