

Selective predation by a sculpin and a stonefly on two chironomids in laboratory feeding trials

Anne E. Hershey & Stanley I. Dodson

Dept. of Zool., Birge Hall, University of Wisconsin, Madison, WI 53706

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Abstract

Sculpin and stonefly predators fed selectively on the larvae of the chironomids *Paratendipes* over *Cricotopus* in laboratory stream microcosms. In these experiments, *Cricotopus* were usually tube-dwelling, whereas *Paratendipes* were usually free-living. *Paratendipes* were also bright red, which may have influenced selectivity by visual feeding sculpin, but tactile feeding stoneflies were most likely influenced only by the difference in tube-dwelling behavior of the two prey types. Both chironomids were abundant in the field, but exhibited discrete microhabitat distributions. Field collected sculpin ate mostly *Cricotopus*, probably because *Cricotopus* occurred in a more accessible microhabitat.

Introduction

In aquatic ecosystems, invertebrate and vertebrate predators may feed selectively on benthic invertebrate prey. In lentic systems, some fish select larger insect taxa, thereby affecting the structure of the invertebrate community (Crowder & Cooper, 1982). But sculpin appear to feed selectively on small rather than large chironomids, possibly due to size-specific behavioral differences of prey (Hershey, 1985). In a field enclosure experiment, bluegill had greatest effect on a large, free-living predatory chironomid (Gilinsky, 1984). Bluegill fed on smaller *Chironomus* than predicted by a foraging model because larger *Chironomus* burrow deeper in sediments (Werner *et al.*, 1983).

In streams, as in lentic systems, predator-prey interactions may be determined by prey availability and prey behavior. Some mayflies appear to have behavioral defenses against predatory stoneflies (Peckarsky, 1980), and stoneflies may have a similar defense against trout (Otto & Sjostrom, 1983). Selectivity by stoneflies for mayflies and chironomids has been attributed to a greater availability

of these prey types compared to other taxa (Siegfried & Knight, 1976; Allan, 1982). Stream chironomids have been reported in the diets of most stream predators (Van Vliet, 1964; Davis & Warren, 1965; Brocksen *et al.*, 1968; Stewart *et al.*, 1973; Hildrew & Townsend, 1976; Devonport & Winterbourne, 1976; Siegfried & Knight, 1976; Craig & Wells, 1976; Fuller & Stewart, 1977, 1979; Pidgeon, 1981; Allan, 1982; Walde & Davies, 1984). Chironomids exhibit a variety of behaviors, particularly with respect to the type of tubes they construct (Wiley, 1978). In a stream enclosure experiment, density of the chironomid, *Thienemanniella*, was depressed by predatory stoneflies, but other chironomids were unaffected (Walde & Davies, 1984). This may have been due to *Thienemanniella*'s free-living, as opposed to tube-building behavior (Walde & Davies, 1984).

Thus, evidence from field observations and field enclosure experiments suggested to us that chironomid behavior, particularly chironomid tube-dwelling habits, might be important in determining predator selectivity on chironomids. We tested this hypothesis in laboratory stream microcosms using

2 stream predators, juvenile mottled sculpin, *Cottus bairdii* Girard, and stonefly nymphs, *Acro-neuria lycorias* (Newman). Prey were the larval chironomids, *Paratendipes albimanus* (Meigen), and *Cricotopus* spp. The predator species were suitable for our stream microcosm experiments because congeners of both species are known to feed primarily on larval chironomids (Davis & Warren, 1965; Brocksen *et al.*, 1968). These predators apparently have considerable diet overlap (Davis & Warren, 1965; Brocksen *et al.*, 1968), thus we felt it would be interesting to test whether they selected the same prey under controlled conditions. Prey were chosen for 3 reasons. First, both prey types could readily be collected in large enough numbers to do a replicated experiment. Second, they were similar in size. Third, they naturally occupied different microhabitats (*Paratendipes* was a burrowing mud dweller and *Cricotopus* lived on rocks and macrophytes), and we anticipated their tube-building behavior would differ in our stream microcosms; we wanted to isolate tube-building behavior experimentally.

Methods

To test prey selectivity by stoneflies and sculpin, we used circular stream chambers fashioned after Wiley (1981). In experimental trials, individual predators were offered equal densities of the two chironomid prey types, *Paratendipes* and *Cricotopus* spp. for 24 h. In control trials the same densities of chironomids were present, but no predators were introduced. We collected chironomids and sculpin from Black Earth Creek, Dane Co., WI. Due to the absence of stoneflies or other suitable invertebrate predator in Black Earth Creek, we collected stoneflies from Otter Creek, Sauk Co., WI.

We used slightly different chamber designs for testing the two predators. Stonefly prey selectivity was tested in clear plexiglass circular stream chambers (outer diameter = 13.8 cm, inner diameter = 7.6 cm, area = 104.2 cm²) powered by a single air jet to create a clockwise current (5.5–6.5 cm s⁻¹ at the surface). Sculpin prey selectivity was tested in similar stream chambers, but constructed of white PVC tubing with a grey PVC bottom and a clear plexiglass lid (outer diameter = 15.3 cm, inner diameter = 9.0 cm, area = 120.2 cm²).

Test conditions in both types of chambers were similar. One layer of thoroughly washed cobbles was placed on the bottom of each chamber and each chamber was filled with filtered stream water. We introduced prey into the streams approximately 3 h prior to introduction of predators. Time of prey introduction varied between trials, but all introductions were made during daylight hours. A trial consisted of a single predator foraging in a stream for 24 h. In stonefly predation trials, 25 chironomid larvae of each type were introduced into each chamber, or approximately 2 400 m⁻² of each prey type. In sculpin predation trials, which were performed in slightly larger chambers, 30 chironomids of each type were introduced, or approximately 2 500 m⁻² of each prey type. To terminate a trial, each rock was individually removed, placed in a finger bowl with tap water, and examined carefully using a dissecting microscope to remove clinging chironomids and tubes. Once all rocks had been removed, the inside of the stream was examined for loose and attached chironomids. We scored remaining chironomids of each type. In control trials we scored number of each prey type remaining, recorded whether or not they were found in tubes, and whether they were on the cobble substrate or chamber bottom. All chironomids remaining at the end of a trial were preserved in ethanol, and identifications were confirmed with a compound microscope. The predation rate coefficient, *k* (Dodson, 1975), was calculated for each predator feeding on each chironomid prey type, such that:

$$k = \frac{-\ln(P_T/P_1)}{XT}$$

where *P*₁ and *P*_T are the number of prey initially and at time *T*, and *X* is the number of predators. *P*₁ was determined from control trials. The units of *k* are chambers cleared/day.

For each predator species, predation rate coefficients were compared using t-tests for paired observations (Sokal & Rohlf, 1969). Four replicate experimental trials were conducted with sculpin as predators, and five replicates were conducted with stoneflies. Data on tube dwelling behavior and distribution of larvae in the chambers from control trials were also analyzed with t-tests for paired observations (Sokal & Rohlf, 1969).

We collected 17 juvenile sculpin from the field and preserved them in 95% ethanol for stomach analyses. Stomachs were dissected from preserved fish and all prey items were mounted and identified. Ninety-two percent of chironomids could be identified to genus. Non-chironomid taxa were identified to order.

To determine field microhabitat distribution of chironomids, we qualitatively sampled mud, the macrophyte, *Callitriche*, and cobbles. A dipnet was used to sample mud and macrophyte habitats, and cobbles were simply washed into a bucket. We identified chironomids thus collected to genus or species.

Results

In laboratory microcosms, stonefly predators fed selectively on *Paratendipes* over *Cricotopus* when presented with equal densities of the two chironomid prey types. The predation rate coefficient for the stonefly feeding on *Paratendipes* was 0.30 ± 0.13 (mean \pm S.E.); stoneflies did not eat *Cricotopus* (Fig. 1).

Juvenile sculpin also fed selectively on *Paratendipes* over *Cricotopus*, although they did feed on both prey types. The predation rate coefficients for sculpin feeding on *Paratendipes* and *Cricotopus* were 0.64 ± 0.16 and 0.26 ± 0.19 , respectively (Fig. 1).

The two prey types demonstrated different behaviors with respect to the tube building in the stream microcosms. Of 25 of each prey type introduced in the chambers for 24 h, 15.2 ± 1.7 *Cricotopus* were found in tubes, but 6.2 ± 1.4 *Paratendipes* were found in tubes. These means differed significantly ($t = 4.16$, $p < 0.01$, Table 1). There was no difference in occupation of cobble substrate or the chamber bottom between prey types (Table 1).

Gut contents of juvenile sculpin revealed that they were eating predominantly *Cricotopus* in the field. Of 14 juvenile sculpin with non-empty guts examined, 33 prey items were found: 25 Chironomidae, 1 Ostracoda, and 7 Isopoda. Of the 25 Chironomidae, 21 were *Cricotopus*, only 2 were *Paratendipes*, and the other two could not be identified (Table 2).

Microhabitat sampling revealed that the *Cricotopus* and *Paratendipes* had remarkably discrete

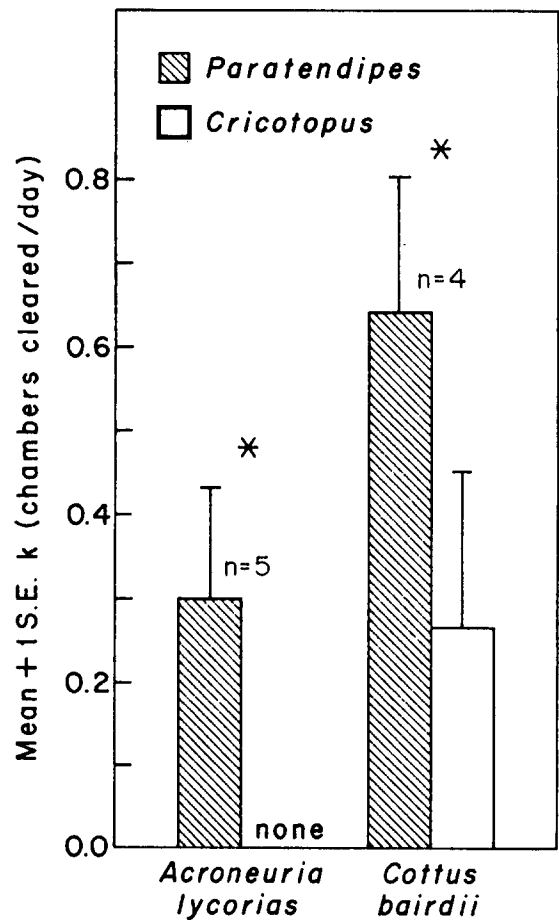


Fig. 1. Predation rate coefficients, k , for the sculpin, *Cottus bairdii* and the stonefly, *Acroneuria lycorias*, preying on *Paratendipes* and *Cricotopus*. Vertical bars show \pm S.E. of the mean. Asterisks indicate significance of $p < 0.05$ in a t -test for paired data.

Table 1. Mean \pm S.E. number of *Paratendipes* and *Cricotopus* found in tubes and on cobbles in control trials.

	<i>Paratendipes</i>	<i>Cricotopus</i>	df	P-value
Total	22.4 ± 0.8	22.6 ± 1.2	4	n.s.
Tube-dwelling	6.2 ± 1.4	15.2 ± 1.7	4	$p < 0.01$
Cobbles	5.6 ± 1.6	8.8 ± 1.0	4	n.s.

field distributions and that both were abundant (Table 3). *Cricotopus* were restricted to *Callitriche* and cobbles. Conversely, *Paratendipes* was restricted to the mud habitat (Table 3). Other chironomid taxa sampled are also presented in Table 3.

Table 2. Summary of stomach contents of 14 juvenile sculpin with non-empty stomachs from Black Earth Creek on 17, 18, and 19 June 1983.

Prey taxon	# observed	# sculpin guts with taxon	% total prey items
Chironomidae	25	11	76
<i>Cricotopus</i>	21	10	84
<i>Paratendipes</i>	2	2	8
Unidentified			
Orthoclaadiinae	1	1	4
Unidentified			
Chironomidae	1	1	4
Ostracoda	1	1	3
Isopoda	7	4	21

Table 3. Numbers of chironomid larvae collected from Black Earth Creek, Dane Co., WI, in three different habitat types: mud, the macrophyte, *Callitriche*, and cobbles.

	Habitat		
	Mud	<i>Callitriche</i>	Cobbles
<i>Cricotopus</i> sp 1	1	41	0
<i>Cricotopus</i> sp 2	2	18	5
<i>Cricotopus</i> sp 3	0	1	0
<i>Cricotopus</i> sp 4	1	0	16
<i>Cricotopus</i> sp 5	1	0	10
<i>Paratendipes albimanus</i>	81	2	0
<i>Dicortendipes</i>	2	1	1
<i>Paraphenocladus</i>	1	0	0
<i>Cladotanytarsus</i>	0	28	1
<i>Corynoneura</i>	0	1	0
<i>Prodiamesa divacea</i>	3	1	0
<i>Rheotanytarsus</i>	0	1	0
<i>Tanytarsus</i>	0	3	1
Total N	92	96	34

Discussion

In our experiments, both stoneflies and sculpin selected *Paratendipes* over *Cricotopus*. Observations of chironomids in control trials showed that *Paratendipes* occupied tubes significantly less often than *Cricotopus*. In field enclosure experiments, a stonefly had greatest effect on the free-living chironomid *Thienemanniella*, and little effect on other chironomids which built tubes (Walde & Davies, 1984). In our stream microcosms, prey had similar distributions; tube-building behavior was the most likely factor in the chambers which could have con-

tributed to stonefly selectivity. Thus, our laboratory data support the hypothesis of Walde & Davies (1984) that differences in effects of stoneflies on chironomids can be attributed to differences in tube-building behavior.

For sculpin, there was one other factor we can identify which may have contributed to prey selectivity: Bright red *versus* drab coloration. In laboratory feeding trials, where chironomids could not build tubes and had no spatial refuge, slimy sculpin selected red chironomids over brown chironomids (Cuker, 1981). Thus, bright red coloration may have attracted sculpin to *Paratendipes*.

The field situation is quite different. Gut analysis of sculpin indicated that 84% of their chironomid prey were *Cricotopus*, and only 8% of chironomid prey were *Paratendipes*. In streams, *Paratendipes* burrows in silty sediments and *Cricotopus* lives on rocks and *Callitriche* (Table 3). Its burrowing behavior may make it even less available to sculpin than *Cricotopus*; burrowers rarely come out of the sediment, but tube builders on surfaces frequently come out of tubes to graze (Wiley, 1978). In our laboratory control trials, some *Cricotopus* were not found in tubes, and in experimental trials, some *Cricotopus* were eaten. Depth of burrowing appears to influence bluegill predation on *Chironomus* in a temperate pond (Werner *et al.*, 1983). In an arctic lake, slimy sculpin fed on chironomids in soft sediments, but ate proportionately few burrowers even though they were more common than other prey types (Hershey, 1985). Thus, it is probably not the soft sediments that prevented sculpin from feeding on *Paratendipes* in Black Earth Creek, but rather prey burrowing behavior.

In the laboratory, either tube-dwelling behavior or bright coloration could have affected prey selection by sculpins. In nature, tube-building (or burrowing behavior) is probably the only factor affecting prey selection, because bright coloration of prey is concealed by the mud. The red color is due to hemoglobin which aids in oxygen storage and transport (Walshe, 1950). Less cryptic habitats in streams are usually well-oxygenated. In these habitats, red coloration, which is advantageous in low oxygen conditions (Walshe, 1950) would probably be disadvantageous; it would attract visual predators, and the energy used in hemoglobin production would be wasted in a well-oxygenated environment. It is not surprising, therefore, that red chi-

ronomids are not usually found in exposed, well-oxygenated stream habitats. It follows that bright coloration would not be an important factor determining chironomid availability to predators in nature.

Chironomid tube-building behavior is considered to be an adaptation for feeding and respiration (Walshe, 1951). It is clear that the feeding and respiratory behaviors of tube-building chironomids are inseparable from their ecology. We have shown that tubes also function as anti-predator devices from predatory stoneflies, and may be important in protection from sculpin and other stream predators.

Summary

In laboratory stream microcosms, sculpin and stonefly predators fed selectively on the chironomid larva *Paratendipes* over *Cricotopus*. For stoneflies, selectivity could be attributed to the fact that *Paratendipes* was found in tubes less often than *Cricotopus*. For sculpin, either tube-dwelling behavior or bright coloration could have contributed to the selectivity. *Paratendipes* and *Cricotopus* exhibited discrete field distributions, with *Cricotopus* on cobbles and in macrophytes, and *Paratendipes* beneath the mud surface. Burrowing in the mud probably protected *Paratendipes* from sculpin, since sculpin ate mostly *Cricotopus* in the field.

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