USE OF OCCUPIED *GLOSSOSOMA VERDONA* (TRICHOPTERA: GLOSSOSOMATIDAE) CASES BY EARLY INSTARS OF *BAETIS* SPP. (EPHEMEROPTERA: BAETIDAE) IN A ROCKY MOUNTAIN STREAM[1]

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ABSTRACT: Collections of individual, occupied *Glossosoma verdona* larval cases from the upper surfaces of rocks in the Colorado River revealed that *Baetis* spp. nymphs occurred in the interstices between the mineral particles comprising the cases, or on the outer surface of the cases, at significantly higher densities than they did on the adjacent rock surfaces. Also, early instar nymphs of *Baetis* tended to occur at a higher proportion in and on the cases than did later instars. Such positive spatial associations may be common among the species of these two widely-distributed and frequently sympatric aquatic families.

The spatial microdistribution of aquatic insects in streams has been extensively investigated with respect to a variety of biotic and abiotic factors (e.g., Resh and Rosenberg 1984). Frequently, interspecific interactions result in negative spatial associations because of predation (Peckarsky 1982), exploitative competition (McAuliffe 1984) or interference competition (Hart 1985). Positive associations have been found, however, both for phoretic species (Steffan 1967; Dosdall *et al.* 1986) and for species that reside in the cases (Vinikour and Anderson 1981) or retreats (Diamond 1986) of various trichopteran larvae. From the point of view of the smaller species involved, the former of these associations (phoresy) may be considered as obligatory, the latter as facultative. Observations of positive associations for species of either the Glossosomatidae or the Baetidae are few. Vinikour and Anderson (1981) reported the variable occurrence of dipteran larvae within the pupal cases of *G. intermedium* (Klapalek), while Müller-Liebenau and Heard (1979) described an apparently obligatory ectosymbiosis between a tropical baetid mayfly and its unionid clam host. However, no previous record of a positive association between species of these two aquatic insect families has been documented.

During a study of factors determining microdistributional patterns of glossosomatid caddisflies in the upper Colorado River, the observation was made that *Baetis* spp. nymphs often occurred in association with occupied cases of *Glossosoma verdona* Ross. When such a case was placed in formalin, one to several nymphs could be seen to abandon the case immediately by swimming from the interstices between the mineral

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particles. A simple protocol was then devised to determine what proportion of *G. verdona* cases was occupied by *Baetis* nymphs and to evaluate whether mayfly densities on caddisfly cases differed from mayfly densities on adjacent rock surfaces.

At this location, *G. verdona* eggs hatch in late summer and pass through five instars during the fall (and possibly winter) months. Pupation and emergence occur in early spring. Three of the five instars (II, III and IV) were present at the time of this study. The cases constructed by the largest of these larvae can range up to about 6 mm in length, 5 mm in width and 4 mm in height and are composed of small mineral particles usually less than 2 mm in diameter. *Baetis* species present at this site, in order of decreasing abundance, are *B. tricaudatus* Dodds, *B. bicaudatus* Dodds, *B. insignificans* McDunnough, and *B. hageni* Eaton. Species of this genus are typically multivoltine and early instars cannot be reliably identified to species.

MATERIALS AND METHODS

On 5 October 1986, six stones were individually removed from a low velocity (<25 cm sec^{-1}) zone of a single riffle in the Colorado River about seven km below Granby Reservoir in Grand County, CO (2400 m a.s.l.). Individual *G. verdona* larvae in their cases were collected from each rock and stored separately in 5% formalin. The upper surface of each rock was then brushed into a pan with a toothbrush to dislodge and retain *Baetis* nymphs associated with the rock surface. (Nymphs typically do not drift from a rock when it is lifted gently from the water: NLP, pers. obs) Rock area was determined by placing variously-sized pieces of hardware cloth over the brushed surface. A total of 49 *G. verdona* larvae was collected from the six rocks. An additional 39 larvae were individually taken from several other rocks in the riffle for further comparison.

In the laboratory, individual *G. verdona* and their cases were placed in watch glasses and the number of *Baetis* spp. nymphs present counted. Maximum head capsule widths (HCW) of all mayfly nymphs and caddisfly larvae were measured with a stage micrometer. In addition, length, width, height and weight of the caddisfly cases were determined. The surface area of each case was estimated by assuming the exposed upper surface to approximate a hemi-ellipsoid. The density of *Baetis* on *G. verdona* cases for each rock was calculated as the number of nymphs on cases divided by the total case surface area. Density of *Baetis* on each of the rock surfaces was calculated as the number of nymphs not on caddisfly cases divided by the total area of the upper rock surface.

RESULTS

Of the total 83 *G. verdona* cases collected, 44 (53%) contained from one to six *Baetis* nymphs. On the six individually collected rocks, a significantly higher mean density of *Baetis* nymphs was found in association with *G. vedona* cases than on the adjacent rock surfaces (paired t-test, $t=3.60$, $p=0.015$). The mean density of *Baetis* spp. on cases was regularly one to two orders of magnitude greater than on rocks (Table 1). Even if case surface area were increased by a factor of 10 to allow for the additional area in the interstitial spaces, *Baetis* nymphs would still be significantly more dense on cases than on the rock surfaces ($p=0.04$).

Mayfly sizes ranged from 0.1 - 0.6 mm HCW, though the difference in mean size between nymphs on cases vs. rocks was not significant ($p=0.19$). However, 97% of all mayflies collected from cases were <0.3 mm HCW, whereas only 83% of those collected from rock surfaces were <0.3 mm HCW. This difference probably reflects the physical size limitations imposed on *Baetis* nymphs by the small interstitial spaces between the mineral particles comprising the *G. verdona* cases. Other statistically significant patterns of *Baetis* use of *G. verdona* cases were not found. For example, *Baetis* density on rocks was independent of *G. verdona* case density. When all 83 *G. verdona* larvae were combined into one sample, the number of *Baetis* per *G. verdona* case was not significantly predicted by *G. verdona* size (HCW), case area or case weight. Similarly, *Baetis* size on cases was unrelated to case area.

Table 1. Comparison of densities of *Baetis* spp. nymphs associated with rock surfaces vs. with *G. verdona* cases for six rocks collected from the Colorado River on 5 October 1986. Means ($\bar{x}$) and standard errors (s.e.) are given both for rock and case densities and for the differences between them. The t-statistic for the paired t-test is also provided and shows that *Baetis* densities are significantly higher on cases vs. rocks ($p=0.015$).

Rock	Rock Surface Area (cm^2)	Case Surface Area (cm^2)		# *Baetis* per cm^2 Rock	# *Baetis* per cm^2 Case	Case Density - Rock Density
1	145	0.9		0.04	3.30	3.26
2	185	1.6		0.02	0.48	0.46
3	201	0.8		0.06	3.61	3.55
4	210	1.8		0.07	7.98	7.91
5	219	1.6		0.20	2.60	2.40
6	227	5.0		0.08	4.23	4.15
			$\bar{x}$	0.08	3.70	3.62
			s.e.	0.03	1.00	1.00
			t			3.60

DISCUSSION

The observation of *Baetis* spp. utilizing *G. verdona* cases as habitat is particularly interesting given that *Glossosoma* larvae have elsewhere been shown capable of competing exploitatively with *Baetis* nymphs when both graze algae on artificial substrate surfaces (McAuliffe 1984). However, the significance of *G. verdona* cases as habitat for early instars of *Baetis* cannot at this time be adequately evaluated. The cases do possess features that appear to make them attractive to *Baetis* nymphs. For example, they probably provide some refuge from potential predators because of their small interstitial spaces. If this is so, then individual *Baetis* nymphs utilizing the case habitat may have a higher probability of surviving, at least to a size where case habitat is no longer available to them. The mineral cases also trap detritus and algal cells and serve as a substrate for periphyton (NLP, pers. obs.). The *Baetis* nymphs can use these food resources, presumably without expending much energy to forage. Depending on the availability of food resources on the cases, the possibility exists that early instar *Baetis* residing on *G. verdona* cases could avoid exploitative competition with the larger caddisfly larvae.

It is unclear what, if any, benefit the *G. verdona* larvae derive from this arrangement. Possibly, the *Baetis* nymphs serve to prevent detrital accumulations from clogging the interstitial spaces of the case, thereby enhancing water circulation and gaseous exchange. In this instance, the association would be more mutualistic than commensalistic. However, the association seems to be only facultative and opportunistic, given the absence of *Baetis* from many cases and the apparent size limitations placed on *Baetis*' utilization of the case habitat. Moreover, larval glossosomatids in the upper Colorado River do not always overlap temporally with early instar baetids (NLP, pers. obs.).

Species of these two insect families are widespread across North America and often occur sympatrically. The possibility therefore exists that this positive association is also widespread. However, depending on the oxygen requirements of the various species of *Baetis* nymphs in the interstitial spaces of glossosomatid cases, such an association may be restricted geographically or seasonally to streams characterized by high dissolved oxygen content, or to microhabitats in streams where dissolved oxygen is high.

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