Associations between Aquatic Habitat Variables and *Pyrgulopsis trivialis* Presence/Absence

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ABSTRACT

We evaluated associations between physicochemical aquatic habitat variables and presence/absence of *Pyrgulopsis trivialis*, a hydrobiid snail, in selected springs at Three Forks springs and Boneyard Bog springs in the White Mountains of eastcentral Arizona. Three Forks springs were characterized by more cobble/boulder and gravel/pebble substrates, higher water temperature, lower conductivity, higher pH, and deeper water than Boneyard Bog springs, which were characterized by more silt/sand substrates and watercress. The presence of *P. trivialis* was associated with gravel/pebble substrates, shallower water, higher conductivity, higher pH, and presence of *Physa gyrina*.

INTRODUCTION

Springsnails (Hydrobiidae) of the American Southwest are often endemic to relatively small geographic areas, typically limited in distribution to a few springs. Due to the rarity and vulnerability of these snails, scientists and resource managers have recognized the need to conserve springsnails and their habitats. Recently published studies of hydrobiid habitats have focused on parameters such as substrate, aquatic vegetation, temperature, dissolved carbon dioxide, dissolved oxygen, conductivity, pH, water depth, and total dissolved solids (O'Brien and Blinn 1999, Mladenka and Minshall 2001, Malcom et al. 2005, Martinez and Thome 2006, Tsai et al. 2007).

The Three Forks springsnail (*Pyrgulopsis trivialis*) is known from Three Forks springs and Boneyard Bog springs in the White Mountains in eastcentral Arizona. These spring complexes are situated in open mountain meadows at elevations of about 2,500 m, separated by about 6 km of perennial flowing stream. Each springs complex contains several spring sources that flow into creeks that eventually drain into the North Fork East Fork Black River. Historically, *P. trivialis* has been found inhabiting free-flowing springs, concrete-boxed springheads, rheocrene springbrooks, seeps, and a spring-fed pond on substrates such as cobble, gravel, sand, flocculated silt, and aquatic plants such as watercress (*Rorripa nasturtium-aquaticum*) (Landye 1973, 1981, Taylor 1987). In recognition of the vulnerability of *P. trivialis* to a variety of threats, the species has been designated as a candidate for listing as threatened or endangered under the Endangered Species Act of 1973 (U. S. Fish and Wildlife Service 2006).

This study was initiated in response to field observations indicating the localized elimination of *P. trivialis* at Three Forks springs. Limited information is available on the species' habitat to direct conservation efforts (Landye 1973 and 1981, Taylor 1987, Arizona Game and Fish Department 2002). The objective of our study was to quantitatively evaluate associations between selected aquatic habitat variables and *P. trivialis* presence/absence.

METHODS AND MATERIALS

We used artificial substrate samplers (masonite plate or Saltillo tile) to record presence/absence of *P. trivialis* in selected springheads and springbrooks at Three Forks and Boneyard Bog in 2001 and 2002. We attempted to sample every spring source we could locate. Samplers were placed in the aquatic environment based on a systematic random sampling design starting from the observed origin of a spring source and continuing down stream. Samplers were spaced every 6 m in 2001 and every 5 m in 2002. Samplers were left in the aquatic environment for several weeks before they were collected. In 2001 the colonization periods were May-June and June-August; in 2002, they were February-April, April-May, and May-August. At the end of each colonization period we checked samplers for *P. trivialis* presence/absence and collected habitat measurements.

We measured temperature, pH, dissolved oxygen, and conductivity with a Hydrolab Surveyor II or Quanta. We measured water depth with a ruler. We categorized substrate with a visual estimate of the predominant (> 50%) composition under and adjacent to each sampler following a modified Wentworth classification system for particle size (Cummins 1962, McMahon et al. 1996). Substrate was categorized as silt and sand (< 2 mm), gravel and pebble (2 to 64 mm), or cobble and boulder (64 to 256 mm). We noted the presence/absence of watercress and the sympatric aquatic snail, *Physa gyrina* (Physidae).

We first sought to characterize environmental conditions within spring complexes by analyzing physicochemical data irrespective of *P. trivialis* presence/absence. Because analyses of data collected from Three Forks springs and Boneyard Bog springs yielded different results, we separated data from the two spring complexes. We evaluated differences in continuous variables (temperature, pH, dissolved oxygen, conductivity, and water depth) with Mann-Whitney *U*-tests and differences in discrete variables (substrate and watercress) with cross tabulation contingency tables. We then evaluated habitat associations based on the presence/absence of *P. trivialis* within each springs complex. We evaluated habitat differences between stations where *P. trivialis* was present versus absent. For discrete variables we used cross tabulation contingency tables and for continuous variables we used *t*-tests or Mann-Whitney *U*-tests. NCSS (Hintze 2001) was used for all statistical testing.

RESULTS AND DISCUSSION

We found statistically significant differences in environmental conditions between sampled portions of Three Forks springs and Boneyard Bog springs. Springs at Three Forks exhibited higher water temperature, lower conductivity, higher pH, and deeper water than springs at Boneyard Bog (Table 1). Silt/sand substrates and watercress occurred more frequently in springs sampled at Boneyard Bog whereas cobble/boulder and gravel/pebble substrates occurred more frequently in springs at Three Forks (Table 2).

Table 1. Descriptive statistics for habitat variables at Boneyard Bog springs and Three Forks springs in the White Mountains, Arizona, 2001-2002.

		Boneyard Bog	Three Forks	P
Temperature (°C)	n	113	201	
	$\bar{x} \pm$ SE	14.934 ± 0.28	17.651 ± 0.13	< 0.001
Dissolved Oxygen (mg/L)	n	113	201	
	$\bar{x} \pm$ SE	9.548 ± 0.374	9.387 ± 0.184	= 0.348
Conductivity (µS/cm @ 25°C)	n	112	200	
	$\bar{x} \pm$ SE	164.232 ± 1.98	129.93 ± 0.796	< 0.001
pH	n	112	201	
	$\bar{x} \pm$ SE	7.88 ± 0.053	8.55 ± 0.035	< 0.001
Water depth (cm)	n	109	204	
	$\bar{x} \pm$ SE	4.87 ± 0.419	9.533 ± 0.685	< 0.001

Table 2. 3X2 and 2X2 contingency tables of observed frequencies of substrate type ($P < 0.001$) and watercress presence/absence ($P < 0.001$) between Boneyard Bog and Three Forks springs, 2001-2002. Expected counts in parentheses.

	Boneyard Bog	Three Forks	Total
Cobble/Boulder	0 (19.7)	55 (35.3)	55
Gavel/Pebble	25 (50.9)	117 (91.1)	142
Silt/Sand	88 (42.3)	30 (75.7)	118
Total	113	202	315
Watercress Absent	30 (53.5)	119 (95.5)	149
Watercress Present	83 (59.5)	83 (106.5)	166
Total	113	202	315

Over the entire study, our effort yielded 317 samples of *P. trivialis* presence/absence data for analysis, 113 from Boneyard Bog springs and 204 from Three Forks springs. Samplers were sometimes unrecoverable. *P. trivialis* were found associated more frequently with gravel/pebble substrates and less frequently with silt/sand at both Boneyard Bog springs and Three Forks springs (Table 3). Even in Boneyard Bog springs, where silt/sand substrates were more common than other substrates, the species was more often associated with gravel/pebble substrates. Hard larger substrates have been documented as providing more suitable surfaces for egg-laying by hydrobiids than other substrates (Mladenka 1992, Hershler 1998).

Cobble/boulder substrates were associated with absence of *P. trivialis* at Three Forks (Table 3). However, cobble/boulder did not occur at Boneyard Bog, and most of the cobble/boulder data came from concrete-boxed springheads at Three Forks where the species previously occurred but was not detected during our study. In fact, it was the disappearance of *P. trivialis* from the concrete-boxed springheads that prompted this study. If we had sampled prior to the disappearance, the association between cobble/boulder and *P. trivialis* presence/absence may have yielded different results.

Watercress presence/absence exhibited no association to *P. trivialis* presence/absence at Boneyard Bog ($P = 0.201$) or at Three Forks ($P = 0.501$). However, our sampling of watercress was likely inadequate to detect its influence on *P. trivialis*. We often could not recover samplers covered by mats of watercress, and we did not investigate potential habitat changes due to watercress growth. Also, watercress always co-occurred with some other substrate, thus confounding any potential associations with *P. trivialis* presence/absence.

Within both spring complexes, water was shallower where *P. trivialis* was present (Fig. 1). Martinez and Thome (2006) found that *Pyrgulopsis morrisoni* distribution was associated with shallow water. However, prior to this study *P. trivialis* occurred in areas

Table 3. 3X2 and 2X2 contingency tables of observed frequencies of substrates at Three Forks springs ($P < 0.001$) and Boneyard Bog springs ($P < 0.001$) in relation to *P. trivialis* presence/absence, 2001-2002. Expected counts in parentheses. CB=Cobble/Boulder, GP=Gravel/Pebble, and SS=Silt/Sand.

		Absent	Present	Total
Three Forks	CB	47 (35.9)	8 (19.1)	55
	GP	64 (76.5)	53 (40.5)	117
	SS	21 (19.6)	9 (10.4)	30
	Total	132	70	202
Boneyard Bog	GP	7 (15.9)	18 (9.1)	25
	SS	65 (56.1)	23 (31.9)	88
	Total	72	41	113

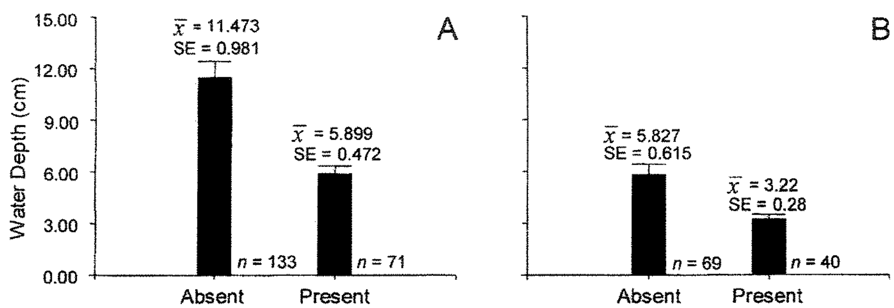

Figure 1. Mean water depth between stations where *P. trivialis* was present versus absent at (A) Three Forks springs ($P < 0.001$) and (B) Boneyard Bog springs ($P < 0.001$), 2001-2002.

characterized by deeper water, such as the spring-fed pond (Taylor 1987) and concrete boxed springheads (mean depth = 30.03 ± 5.58 cm, $n = 16$) at Three Forks. The disappearance of *P. trivialis* from these deeper habitats may suggest that other factors influence the distribution of the species.

Water chemistry exhibited inconsistent associations with *P. trivialis* presence/absence. Within Three Forks springs, conductivity was higher where *P. trivialis* were present (Fig. 2), but no such association was observed at Boneyard Bog ($P = 0.659$) even though the range of conductivity at both spring complexes exhibited some overlap. Additionally, within Boneyard Bog, pH was higher where *P. trivialis* was present, yet this association was not detected at Three Forks (P = 0.378). We found no association between temperature or dissolved oxygen and the presence/absence of *P. trivialis* at either springs complex (P > 0.05).

These inconsistent associations may indicate the species is not greatly influenced by the parameters we selected for analyses. Particularly when considering the miniscule differences we observed for pH and conductivity. Or maybe our sample sizes were too small to detect important associations. Nevertheless, the distribution of hydrobiids is often linked to environmental conditions provided by spring water (Hershler 1984 and 1998, O'Brien and Blinn 1999, Mladenka and Minshall 2001, Malcom et al. 2005, Martinez and Thome 2006, Tsai et al. 2007).

Physa gyrina occurred more frequently where *P. trivialis* was present in both spring complexes (Table 4). This may suggest these two snail species are similarly influenced by habitat, though how they interact is not known. Tsai et al. (2007) found that *Pyrgulopsis thompsoni* may compete with a *Physa* sp. in habitats where they are

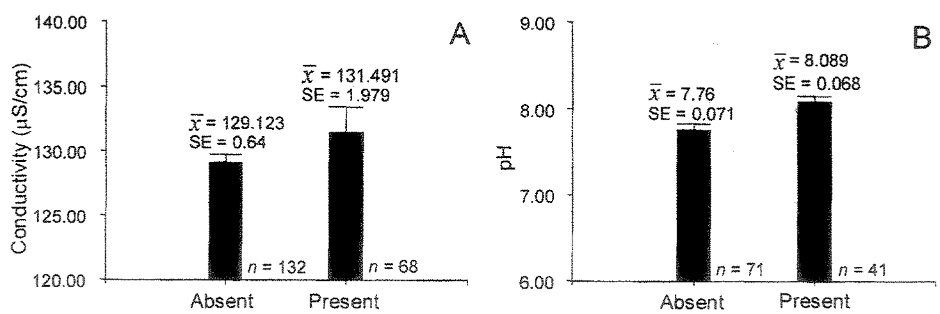

Figure 2. Means for water quality variables that differed between stations where *P. trivialis* wase present versus absent at (A) Three Forks springs ($P < 0.001$) and (B) Boneyard Bog springs ($P = 0.001$), 2001-2002.

sympatric. An analysis that compares relative abundance may help clarify the nature of the relationship between *P. trivialis* and *Physa gyrina*.

The results presented here should be useful in addressing conservation and research issues related to *P. trivialis*. However, these results should be applied carefully because we did not sample all potential habitats or aquatic habitat variables, and the distribution of the species during our study did not entirely match historical observations. Importantly, the invasion of these springs by non-native crayfish (*Oronectes virilis*) just prior to our study may have influenced the distribution of *P. trivialis* through predation and/or alteration of habitat characteristics.

Table 4. 2X2 contingency tables of observed frequencies of *Physa gyrina* presence/absence compared to *P. trivialis* presence/absence at Three Forks springs ($P < 0.001$) and Boneyard Bog springs ($P < 0.001$), 2001-2002. Expected counts in parentheses.

		P. trivialis Absent	*P. trivialis* Present	Total
Three Forks	*Physa gyrina* Absent	76 (61.9)	8 (19.1)	95
	Physa gyrina Present	57 (71.1)	53 (40.5)	109
	Total	133	71	204
Boneyard Bog	*Physa gyrina* Absent	69 (62.4)	29 (35.6)	98
	Physa gyrina Present	3 (9.6)	12 (5.4)	15
	Total	72	41	113

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