Invertebrate Composition and Abundance Associated with *Didymosphenia geminata* in a Montane Stream

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ABSTRACT

Didymosphenia geminata, a relatively new aquatic nuisance species that can form extensive, mucilaginous mats on stream substrates, was reported from Rapid Creek, South Dakota in 2002. To examine the association between *D. geminata* and the invertebrate community in Rapid Creek, macroinvertebrates were quantified using three gear types in the fall of 2006. *D. geminata* was present at two of four sites sampled (range = 5.53 to 809.68 g m^{-2} dry mass). At each site, invertebrates were collected using dip nets, Surber samplers, and drift nets. The combined percentage of Ephemeroptera, Plecoptera, and Trichoptera in areas with *D. geminata* was lower (41%) than in areas without *D. geminata* (76%). Diptera abundance was higher at sites with *D. geminata* than in sites where *D. geminata* was absent.

INTRODUCTION

The spread and establishment of *Didymosphenia geminata* has prompted much concern in North America and New Zealand (Branson 2006, Kilroy 2004, Spaulding and Elwell 2007). *D. geminata* is a relatively large diatom historically found in low productivity streams and lakes at northern latitudes (Spaulding and Elwell 2007). It is capable of producing large masses of extracellular stalks that can cover up to 100% of the stream substrata in areas of high infestation, which can make *D. geminata* populations a nuisance in stream ecosystems.

In areas where nuisance blooms of *D. geminata* occur, the stalks can persist for up to two months following peak production and are believed to alter conditions for the colonization of other algae (Spaulding and Elwell 2007). Recent research has focused primarily on the biology and distribution of *D. geminata* (Kawecka and Sanecki 2003, Kilroy et al. 2005, Kilroy et al. 2006, Kirkwood et al. 2007, Spaulding and Elwell 2007, Whitton et al. 2009). Other recent research on invertebrate communities has shown that invertebrate composition tends to shift from larger taxa (i.e., Ephemeroptera, Plecoptera, Trichoptera) to smaller taxa such as Diptera in areas impacted by *D. geminata* (Shelby 2006, Shearer et al. 2007, Larson and Carreiro 2008, Gillis and Chalifour 2009, Kilroy et al. 2009). Moreover, total invertebrate abundance tends to increase in areas where *D. geminata* is present (Gillis and Chalifour 2009, Kilroy et al. 2009).

This recent stream invertebrate work has relied on qualitative assessment (Larson and Carreiro 2008) or use of single gear types to evaluate invertebrate composition in areas impacted by *D. geminata*. The use of quantitative approaches across multiple gears would identify patterns in invertebrate composition associated with *D. geminata* blooms to ensure gear bias is not influencing study results. In this study, we compared invertebrate composition and abundance in areas with and without *D. geminata* in Rapid Creek, South Dakota. We did this using three collection gear types.

MATERIALS AND METHODS

The Rapid Creek watershed drains approximately 1,062 km^2 in western South Dakota. Mean annual discharge below the Pactola Reservoir dam averages about 1.47 $m^3 \cdot s^{-1}$, and mean width of the stream is approximately 11 m throughout the study portion of the stream (USGS 2008). We selected four sites in Rapid Creek to sample – two in areas with high relative abundance of *D. geminata* and two with low relative abundance. Site selection was based upon criteria by Larson and Carreiro (2008). The most upstream sampling location was near Silver City, South Dakota where *D. geminata* had occasionally been observed, but abundances were generally low. A site immediately below Pactola Reservoir and a site about 17 km downstream near Hisega were areas considered to have high levels of *D. geminata*. In these sites, up to 75% of stream substrates had been covered with *D. geminata*. The final site was near Rapid City, where *D. geminata* has not been observed.

When present, *D. geminata* was collected with a Surber sampler (0.085 m^2) from three locations within the study sites. For each sampling, *D. geminata* was removed from all substrate within the sampler and preserved in 70% ethanol. Samples were dried to constant weight (60 °C) and weighed to the nearest 0.001 g to estimate biomass.

At each of the four sites, benthic invertebrates were collected using a D-frame dip net, a Surber sampler, and drift nets. Five invertebrate samples were obtained using D-frame dip nets (500 μm mesh); substrate was agitated for 20 seconds 1 m upstream of each net. This sampling was conducted at 20 m intervals moving upstream in a zig-zag

Table 1. Mean (SE) abundance of ephemeropterans, plecopterans, trichopterans, and dipterans estimated from three sampling gears at four locations in Rapid Creek, South Dakota. Silver City (site 1) and Rapid City (site 2) sampling locations were sites without *Didymosphenia geminata*, whereas Pactola (site 3) and Hisega (site 4) were sites with *D. geminata*. Within a column for any one gear type, values with different superscripted letters are significantly ($P < 0.05$) different.

Gear type	Site (*D. geminata* presence)	Order			
		Ephemeroptera	Plecoptera	Trichoptera	Diptera
Dip net (number/net)	1 (absent)	26.6 (6.6)	7.6 (3.5)	16.2 (6.4)^{a}	4.4 (1.4)^{a}
	2 (absent)	161.6 (114.6)	19.6 (15.2)	16.0 (9.1)^{ab}	25.4 (18.8)^{ab}
	3 (present)	95.6 (52.7)	21.6 (14.8)	0.2 (0.2)^{b}	125.2 (44.5)^{b}
	4 (present)	38.2 (18.6)	8.6 (4.4)	10.8 (5.4)^{ab}	35.6 (29.9)^{ab}
Surber (number/m^2)	1 (absent)	261.2 (120.5)	153.0 (85.7)	204.7 (64.3)^{a}	51.8 (32.1)^{a}
	2 (absent)	1505.9 (800.0)	174.1 (121.0)	150.6 (94.7)^{a}	249.4 (130.8)^{ab}
	3 (present)	331.8 (177.1)	145.9 (51.8)	0 (0)^{b}	845.5 (388.7)^{b}
	4 (present)	458.9 (182.3)	1320 (774.2)	61.2 (24.0)^{a}	696.5 (201.4)^{b}
Drift net (number/m^3)	1 (absent)	42.3 (19.0)	12.0 (2.4)	15.4 (7.2)	4.6 (2.6)^{a}
	2 (absent)	112.8 (43.6)	0.3 (0.3)	1.95 (1.03)	6.18 (4.6)^{ab}
	3 (present)	39.6 (32.0)	4.2 (4.0)	0.96 (0.7)	74.8 (59.2)^{ab}
	4 (present)	100 (14.0)	43.3 (42.1)	1.7 (0.8)	134.2 (39.0)^{b}

pattern. A Surber sampler was also used to collect invertebrates (n = 5) at each site; invertebrates were collected near the left stream margin, across the middle channel, and near the right stream margin at each site. Three drift nets were set after sunset for a minimum of 2 hr at each location. Drift nets were staggered about 10 m apart and set near the left bank, center channel, and right bank of the stream. Water velocity was measured at the mouth of each net using a Marsh-McBirney flowmeter. Invertebrate sampling was conducted in September and October 2006.

Invertebrates were removed and identified to family (Merritt and Cummins 1996, Smith 2001, Thorp and Covich 2001, Voshell 2002). For high-density samples (i.e., >1 hr processing time), a random 20% subsample was examined. For each location (n = 4), we calculated invertebrate abundance as 1) number per sweep (dip nets), 2) number per m^{-2} (Surber), and 3) number per m^{-3} (drift nets). Invertebrate abundance data were $\log_{10}(x+1)$ transformed prior to analysis, and we tested for differences among the four sites using multivariate analysis of variance (MANOVA; SAS 9.1 SAS Institute 2007). We did a post-hoc comparison of means using a Tukey test.

We calculated the proportion of Ephemeroptera, Plecoptera, and Trichoptera (EPT) for each sampling gear at each site by dividing the total numbers of each of these groups by the total number of invertebrates collected at each site. Similarly, the proportion of dipterans was calculated. Community composition data (proportions of EPT and Diptera) were arcsin $\sqrt{p}$ transformed prior to analysis, where p is the observed proportion (ranging from 0 to 1.0). We tested for differences among sites for EPT and Diptera using analysis of variance; a Tukey test was used to evaluate differences between sites.

RESULTS

Quantitative estimates of *D. geminata* dry mass ranged from 5.53 to 809.68 g m^{-2}. Dry mass averaged 47.33 g m^{-2} at the Pactola site and 267.67 g m^{-2} at Hisega.

Representatives were collected from several orders of insects including Ephemeroptera, Plecoptera, Trichoptera, Diptera, Odonata, Lepidoptera, and Heteroptera. Molluscs and decapods were not frequently encountered and represented less than 1% of the total number of invertebrates collected. Because Ephemeroptera, Plecoptera, Trichoptera, and Diptera represented 72 to 94% of the insects collected at each site, we focused our analysis on those four orders.

MANOVA showed that invertebrate abundance varied significantly among locations for each of the gear types used (dip nets, $F_{12,35}$ = 2.05, P = 0.04; Surber, $F_{12,13}$ = 4.32, P = 0.006; drift nets, $F_{12,34}$ = 4.25, P = 0.004). Analysis of individual taxa revealed that the abundance of Diptera and Trichoptera were responsible for most of the variation in insect abundance. For each gear type used, Diptera abundance varied significantly among locations and was generally higher at locations with *D. geminata*. In contrast, the abundance of Trichoptera was generally lower at locations with *D. geminata* than areas without *D. geminata* (Table 1).

The proportion of EPT varied among locations and was generally higher at sampling locations without *D. geminata* (Fig. 1). Differences in EPT were most pronounced for Surber samples ($F_{3,17}$ = 4.41, P = 0.018) and drift nets ($F_{3,8}$ = 6.85, P = 0.013). In contrast, the percentage of Diptera was higher at sites with *D. geminata* as indexed by Surber samples ($F_{3,17}$ = 14.2, P < 0.0001) and drift nets ($F_{3,8}$ = 14.46, P = 0.0014; Fig. 2). Although similar patterns in EPT and Diptera were observed from the dip net samples, we found no evidence that they varied significantly among locations, potentially owing to small sample size and the variable nature of dip net samples.

DISCUSSION

Overall, we observed higher abundance of Diptera and a lower percentage of EPT in *D. geminata* impacted areas of Rapid Creek. Similar results were reported from the

White River, Arkansas, USA (Shelby 2006), and several New Zealand rivers (Larned et al. 2007, Shearer et al. 2007, Kilroy et al. 2009). Kilroy et al. (2005) reported an increase of invertebrates overall, particularly for dipterans. In a separate study in Rapid Creek, lower EPT percentage and higher Diptera percentage were observed by Larson and Carreiro (2008) using a "semi-quantitative" sampling approach (kicknets). The observed differences of invertebrate community metrics seen in Rapid Creek may be due primarily to differences in the abundance of dipterans. The percentage of EPT abundance could be lower because of an increase in Diptera abundance and not necessarily a decrease in the number of EPT individuals. Although Trichoptera abundance was lower at sites with *D. geminata*, neither Ephemeroptera nor Plecoptera abundance varied significantly among sites.

Differences in invertebrate community composition observed in areas with and without *D. geminata* may be attributable to the colonization dynamics of different invertebrate taxa. *D. geminata* has mucilaginous stalks, which comprise a majority of the diatom's biomass. The stalks can remain on the stream benthos for up to two months following peak *D. geminata* production, can trap fine sediments in the matrix, and can alter stream substrates (Spaulding and Elwell 2007). The dense stalks secreted by *D.*

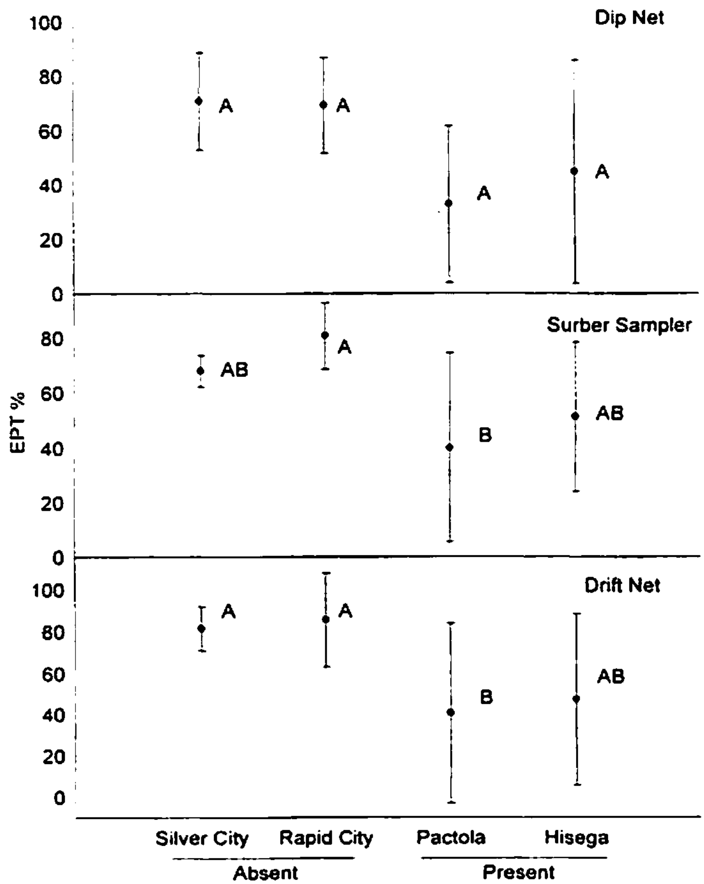

Figure 1. Means and 95% confidence limits for percentage of EPT at four sites in Rapid Creek, South Dakota, collected with three different gear types (dip net, Surber sampler, and drift net). Dissimilar letters adjacent to means indicate significant differences. Absent or Present on the x-axis indicates presence or absence of *Didymosphenia geminata*.

geminata cells may provide a habitat that favors the colonization of clinging and burrowing invertebrate taxa. Numerous chironomids and ephemeropterans (Baetidae) were often observed within the *D. geminata* matrix while collecting samples.

Relatively high dipteran abundance is often associated with poor water quality (Barbour et al. 1999, Chipps et al. 2006). Dipterans were more abundant in the presence of *D. geminata* in Rapid Creek. This may be of concern because Rapid Creek is the municipal drinking water supply for Rapid City. However, Rapid Creek water quality typically ranges from good to satisfactory in its upper reaches, and water quality is not of concern according the South Dakota Department of Environment and Natural Resources (Pirner 2008).

Our results add to the growing knowledge of how *D. geminata* impacts aquatic ecosystems. Our findings are consistent with previous studies in the United States and New Zealand. In the presence of *D. geminata*, total invertebrate abundance, and particularly Diptera abundance, are higher than in areas without *D. geminata*. We found these patterns with each of our three gear types, which further support the findings of previous studies. Gear type likely has little bias when sampling invertebrates in *D. geminata* impacted streams.

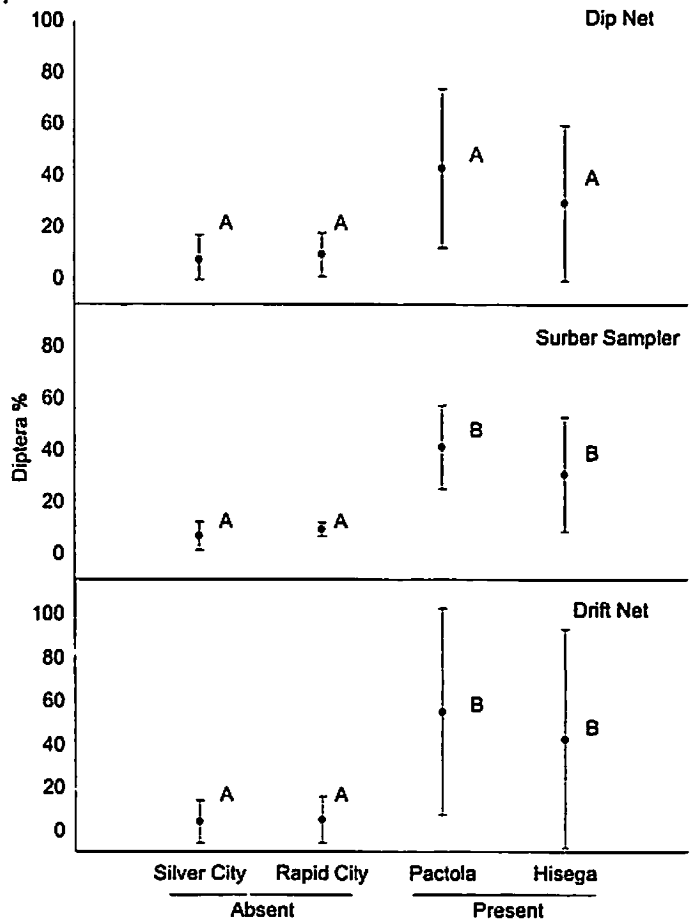

Figure 2. Means and 95% confidence limits for percentage of Diptera at four sites in Rapid Creek, South Dakota, collected with three different gear types (dip nets, Surber samplers, and drift nets). Dissimilar letters adjacent to means indicate significant differences. Absent or Present on the x-axis indicates presence or absence of *Didymosphenia geminata*.

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