Publications of the Oklahoma Biological Survey
2nd Series
Volume 9:13-15, 2009

OCCURRENCE OF THE INVASIVE DIATOM *DIDYMOSPHENIA GEMINATA* IN SOUTHEAST OKLAHOMA

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ABSTRACT.—Diatoms are a major food source for aquatic grazing snails and insects, thereby contributing to aquatic food webs. Diatoms are microscopic and are seldom visible; an exception is colonies of *Didymosphenia geminata*. *Didymosphenia* secrete long extracellular stalks that can form mats several centimeters thick. Mats occur on single rocks or may cover areas of a streambed. Recently, this species has expanded from its original boreal or alpine, oligotrophic habitat and is appearing in blooms on rocky habitats below dams in regulated rivers. In April 2009, *Didymosphenia geminata* was collected in the Mountain Fork downstream of Broken Bow Lake, where colonies up to 13 cm in diameter were observed. This is the first record of this species in Oklahoma and is the southernmost known occurrence in the United States. Oklahoma is outside the modeled area of potential occurrence and the artificially low temperature maintained for the trout fishery likely enabled the establishment of *Didymosphenia*. *Didymosphenia* mats are unsightly, alter benthic communities, and may affect fish growth, condition, and spawning. In response to the establishment of *Didymosphenia*, public education, a surveillance program, and local ecological studies are recommended.

Diatoms are a taxonomically rich group of algae that are an important component of both marine and freshwater food webs (e.g., Fry and Wainwright 1991, Hughes et al. 2000, Hart and Lovvorn 2003, Torres-Ruiz et al. 2007). Diatoms are highly nutritious because they store excess energy as energy-rich oil. Because diatoms are microscopic, their ecological role is often underappreciated.

Although generally considered highly beneficial, certain diatom species may be problematic. Among these is *Didymosphenia geminata* (Lyngbye) Schmidt. During blooms, this species forms mat-like colonies on hard substrates in rivers, streams, and sometimes lakes. The diatom initially attaches to a substrate and then secretes a stalk that elevates the diatom off the substrate. Mats are composed mostly of stalks and associated organisms, sediment, and detritus and can be several cm thick (Spaulding and Elwell 2007), although individual *Didymosphenia* cells are less than 0.2 mm long. Mats visually and texturally resemble dirty cotton (Spaulding and Elwell 2007) and are commonly called 'didymo' or 'rock snot'. Stalks decay slowly and may remain after the *Didymosphenia* cells are gone (Larned et al. 2007).

A bloom of *Didymosphenia geminata* was confirmed in the Mountain Fork downstream of Broken Bow Lake in Beavers Bend State Park (McCurtain County, Oklahoma) from a sample collected on 23 April 2009 (Fig. 1). The bloom was initially noticed by a fisherman and subsequently confirmed as *Didymosphenia geminata* by EAB and JTC. The diameter of observed colonies ranged from 1 to 13 cm.

In addition to the river below the dam, colonies were observed in the Lost Creek side channel and the Evening Hole area - both of which have been recently renovated to provide improved trout habitat by water diversion into a previous dry side channel (Lost Creek), narrowing of the river, supplementation of logs and boulders in the river, and tree planting in the newly created riparian zone (LMFRF 2009).

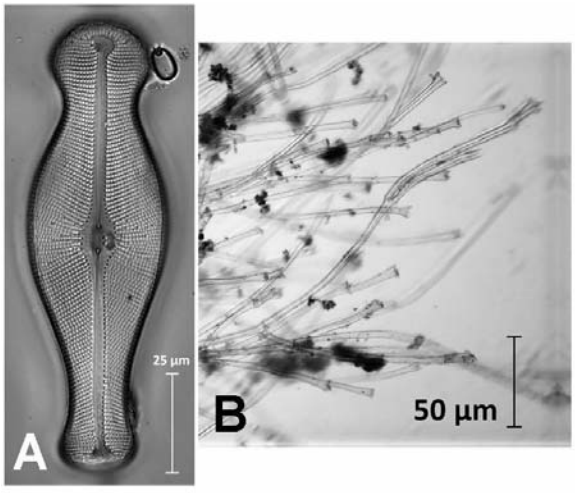

Figure 1. Photographs of Didymosphenia geminata collected in April 2009 in Mountain Fork, McCurtain County, Oklahoma. A = valve, B = stalks. Note the difference in magnification.

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The Mountain Fork occurrence of *Didymosphenia geminata* in southeast Oklahoma is the southernmost record known to date in the United States (Sarah Spaulding, personal communication). Among states neighboring Oklahoma, blooms have been found in four locations in Arkansas, where it occurs primarily below dams, and multiple sites in Colorado, mostly in rivers in the Rocky Mountains (Spaulding and Elwell 2007). The worldwide range of *Didymosphenia* includes the British Isles and Europe, where blooms occurred historically, and the United States, where records before the 1990s are much less common and blooms were not noted (reviewed in Spaulding and Elwell 2007, Blanco and Ector 2009). *Didymosphenia* was previously considered a diatom inhabiting cool, oligotrophic waters in boreal and alpine areas (Krammer and Lange-Beralot 1997, Blanco and Ector 2009). The species is expanding its spatial and ecological range and is now occurring as blooms in the United States (Spaulding and Elwell 2007).

Kumar et al. (2009) predicted the occurrence of *Didymosphenia* in the United States, based on four different models (logistic regression, classification and regression tree, maximum entropy model, and genetic algorithm for rule-set production) using extensive presence/absence occurrence and environmental variable data. None of these models predicted that Oklahoma would support *Didymosphenia*. The strongest predictor of potential sites in the models was air temperature, with *Didymosphenia* able to colonize cool (including high elevation) sites (Kumar et al. 2009). The failure of the models for Oklahoma resulted from the use of air temperature as a surrogate for water temperature, combined with the uncoupling of air and water temperatures in the Mountain Fork, where cool, hypolimnetic water is released from Broken Bow Lake. This cool water sustains a year-around trout fishery for approximately 20 km downstream of the dam.

The location of the bloom in the Mountain Fork is consistent with the species' characteristic habitat of regulated rivers below dams (e.g., Kawecka and Sanecki 2003, Kirkwood et al. 2007). In addition to the cool water temperatures, water regulation reduces the magnitude of downstream floods. The reduction of floods in below-dam habitats may (1) promote new colonization, because *Didymosphenia* establishes on rocks with intact biofilms (Bergey et al. 2009), and (2) reduce scouring of existing colonies.

Didymosphenia is mainly found in rivers that support trout or salmon, and studies of the effects of blooms on these fishes are ongoing. Because *Didymosphenia* is benthic, the dense mats that occur during blooms may negatively impact fish by influencing aquatic macroinvertebrates or by altering the habitat and affecting spawning success (Larned et al. 2007). In some areas, mats result in higher macroinvertebrate densities, with a greater abundance of certain taxa, such as diptera, oligochaetes, and nematodes (Kilroy et al. 2006) – smaller taxa that live within the mats. In a limited study of macroinvertebrate drift in New Zealand, there were no differences in drifting biomass or density in areas with *Didymosphenia* blooms, compared to areas without blooms (Shearer et al. 2007). A reduction in brown trout coincided with the initial *Didymosphenia* blooms in Cedar Creek, South Dakota (reported in Shearer et al. 2007) and reductions have been reported elsewhere (reviewed in Blanco and Ector 2009). Effects on other fishes have but little reported. In New Zealand, Larned et al. (2007) found that a *Didymosphenia* bloom had little effect on native fish species.

Although trout are normally maintained in the Mountain Fork by frequent year-around stocking, trout spawning also occurs (ODWC 2006; Jared Vanderpool, personal communication). *Didymosphenia* blooms did not affect the hydraulics within spawning redds in New Zealand (e.g., Bickel and Closs 2008). Biological effects of blooms on redds have not been investigated; and diurnal reductions in dissolved oxygen during blooms may be a concern (Kilroy 2004).

Didymosphenia blooms are unsightly, have ecological impacts within streams, and have resulted in new regulations for river use, especially in New Zealand (e.g., a country-wide ban on the use of felt-bottomed waders for fishing; MAF Biosecurity New Zealand 2007). Although only one invasion site is known in Oklahoma, further spread into cooler waters, such as the Blue and Illinois Rivers, is possible. A surveillance program, a public education program, and studies of local ecological effects within the state are recommended.

ACKNOWLEDGMENTS

Matt Mauck first noticed *Didymosphenia* in the Mountain Fork River. Paul Balkenbush and Jay Barfield provided site access and assisted in field sampling. Funding for sampling and verification was provided by Oklahoma EPSCoR and NSF grant DEB-0447449 to EAB, and federal aid grant T-44-P2 to CRT.

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