Didymosphenia geminata in Glacier National Park

Rocky Mountain Network

Resource Brief

Summary

Didymosphenia geminata (didymo) is a freshwater alga native to Glacier National Park (NP). In recent years, large mats of didymo that cover stream beds have become more common. These large blooms can impact water control structures, change the aesthetic appeal of streams, and alter stream community composition and function. We used data from a large stream monitoring project in Glacier NP to determine the distribution of didymo in the park and to explore whether its abundance and distribution are related to climate change and other environmental factors. We found that 64% of the flowing water in Glacier NP had didymo present in 2007-2009. High temperatures, the presence of cobble, and low nitrogen concentrations correlated with high didymo densities. Climate change projections indicate that stream temperatures in Glacier NP will likely increase over the coming decades. Our data suggest that as temperatures warm, didymo abundance will likely increase. Long-term monitoring programs are a critical component of understanding, predicting, and managing for the effects of invasive species in a changing climate.

A didymo bloom covers a stream bed in Glacier NP. A water filter is shown for scale. Photo Credit: B. Schweiger

Climate change and invasive species pose a significant threat to the structure and function of aquatic ecosystems. This is particularly evident in the western United States where climate change has caused large alterations in hydrology over the past fifty years. The timing of peak streamflows has advanced by several days to weeks, due to more precipitation falling as rain rather than snow and earlier snowmelt. Water temperatures have also begun to increase in western mountain landscapes. Concurrent with these changes in hydrology, aquatic invasive species have increased in distribution and abundance. An estimated 25% of the fish species in streams of the western US are exotic and many are directly linked to a decline in the abundance of native fishes. Climate change is generally expected to increase the spread of invasive species through direct effects on habitat suitability and the indirect effects of altered nutrient availability and disturbance regimes. Warmer temperatures and earlier snow melt can also change human behavior and visitation to natural areas, which in turns influences the distribution of species. However, the link between climate change and invasion is still poorly understood and often hard to document. Adding to this challenge, climate change has driven range shifts and altered the ecology of some native species causing a change in the fundamental composition of communities. Ecologists and managers have begun to redefine invasive species to include native species that are expanding their range and negatively impacting ecosystems. In this Resource Brief, we present preliminary analyses and discuss potential causes and consequences of the spread of one such aquatic nuisance species, *Didymosphenia geminata* (didymo), in Glacier National Park (NP) and examine if and how climate change may be driving invasion dynamics.

> *Scientists and managers are concerned about nuisance blooms of didymo in western waters.*

Didymo is a freshwater diatom native to the pristine mountain habitats of North America and Europe. The diatom grows attached to solid surfaces, such as cobbles, with polysaccharide stalks extruded from individual cells. When conditions are favorable these stalks can come together to form thick mats or blooms. Mats can be several centimeters thick and cover kilometers. Paleological and historic records suggest that didymo has been part of the North American diatom community for at least 150 years. However, in recent years, didymo has expanded into lower altitudes, latitudes, and new continents. Moreover, in its native range it increasingly forms large mats that cover streambeds. This change in abundance and distribution and its potential to effect stream food webs has led didymo to be recognized as a nuisance aquatic species. Blooms may inhibit the growth of other algae, change the composition of aquatic invertebrate communities, decrease the area of suitable spawning locations for fish, and cause significant diurnal fluctuations in available oxygen. Didymo blooms may also impact the functioning of water control structures and often greatly decrease the aesthetic appeal of a stream (very important in a system like Glacier NP). As such, understanding the causes and consequences of didymo outbreaks is a priority to predict and where possible, prevent its spread.

There is much speculation and not much data on why there has been a change in didymo distribution and ecology. Some evidence suggests fishing with felt waders may have played a role in the spread of didymo to new localities. However, whether climate change has been a significant factor remains unknown.

Models suggest that the presence of didymo is associated with warmer summer temperatures and while the diatom appears to be largely restricted to cold areas, it reaches its highest biomass and growth rates at higher water temperatures. Changes in hydrology may also play a role. Higher peak flows in spring have increased the occurrence of floods, and didymo can withstand stronger floods than many other algae. It has been suggested that low flows in the summer and high flows in the winter favor its growth in the subsequent winter. On the other hand, didymo needs a stable substrate to grow and in Colorado higher didymo densities have been correlated with low discharge and a low variation in discharge. Other factors that are largely unrelated to climate change, such as new genetic strains may be driving the mat forming behavior but again there is a lack of data and agreement in the literature. For instance, blooms have been correlated with changes in nutrient concentrations. On the one hand, the diatom tolerates a wide range of nutrient conditions, eutrophication is not tied to blooms, and continental scale patterns can be predicted without water chemistry information. On the other hand, didymo responds quickly to phosphorus fertilization and total dissolved phosphorus correlates with abundance. One of the largest challenges to understanding the environmental factors that influence the spread of didymo has been acquiring data on the appropriate spatial scale. Much of the work to date has focused on detailed descriptions or experiments in a small area (one or two streams) or has been continental or global in scope and simply looked at presence/absence data.

From 2007-2009, we undertook a large project in Glacier National Park to develop the Rocky Mountain Network's long term monitoring protocol for streams and rivers. By using a survey design to locate most sites, we were able make statistically-valid inferences at the scale of the whole park. At each site, we assessed numerous physical, biological, and chemical attributes including the density and bloom state of didymo. As a result, we have a robust dataset that is uniquely suited to understanding the spread of didymo and possible drivers that, given the pristine state of most Glacier streams, relatively free from the confounding factors of human disturbance. Using these data, we ask:

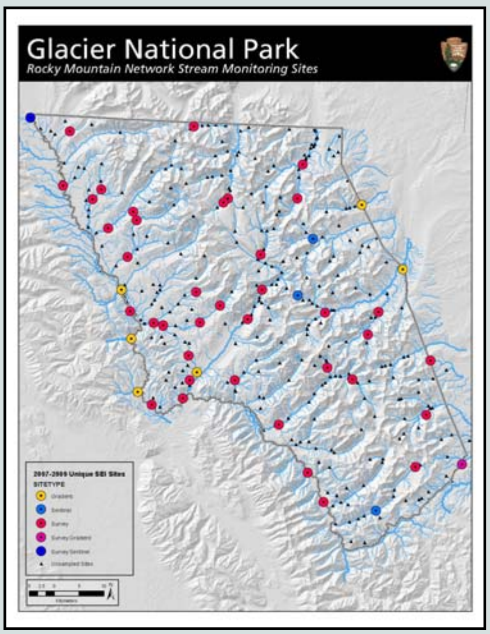
What is the current distribution of didymo within Glacier NP?

Is didymo increasing at specific sites in Glacier NP?

Are current patterns of didymo density and distribution correlated with climate change factors (i.e., temperature and flow) or other factors such as nutrient concentrations or substrate?

Methods

We visited and sampled 46 stream sites within Glacier NP between 2007 and 2009. At each site, we measured a suite of biological, physical, and chemical variables including: over 30 water chemistry parameters, stream flow, temperature, riparian vegetation structure, stream substrate and geomorphology, macroinvertebrate and periphyton diversity and abundance, and an index of human disturbance. In some cases, sites were visited multiple times within and across seasons. Describing the detailed methods is beyond the scope of this brief; more information can be found in the protocol and pilot report (forthcoming). Many of our methods were based on the EPA Environmental Monitoring and Assessment Program.



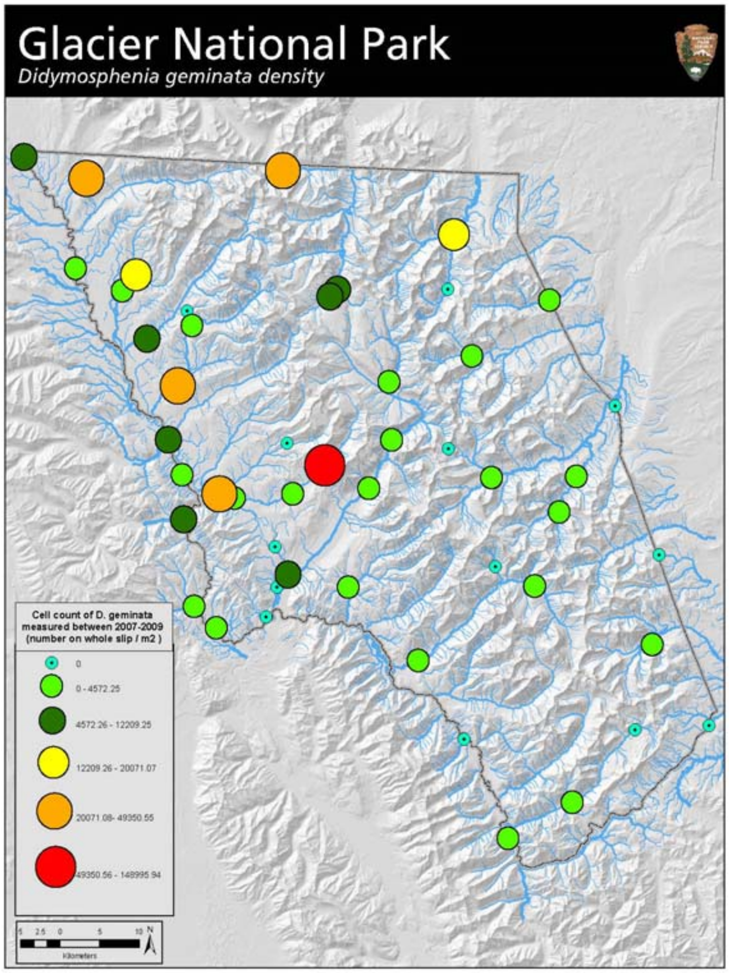
Stream sites visited in Glacier NP between 2007-2009 by the Rocky Mountain Network as part of the stream ecological integrity protocol .

Billy Schweiger sampling Hudson Creek in Glacier NP. Photo Credit: I. Ashton

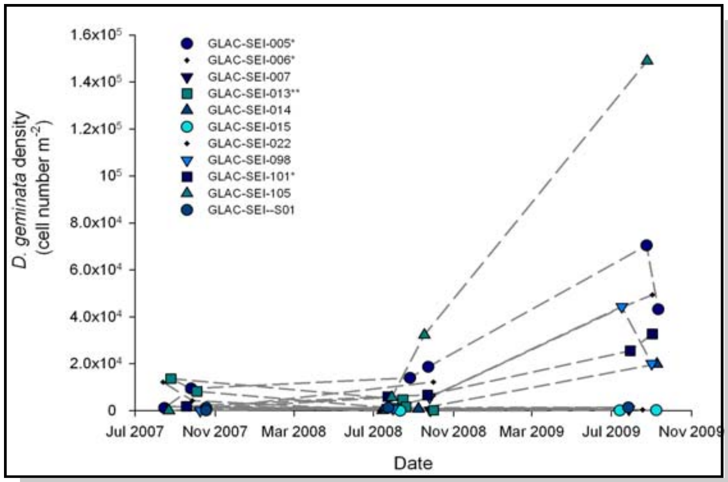
A cobble used to collect periphyton. The algae is scrubbed using a metal brush and rinsed into a collection container. Photo Credit: B. Schweiger

We sampled the diatom community at all sites in two ways. First, we took 11 sub-samples from the surface of rocks, wood, and other substrates on the stream bottom. These samples were composited and were processed in the lab using standard methods that generated species level identifications and cell counts, including a whole slide count of didymo (to account for the larger cell size of didymo). Second, we visually estimated thickness and abundance of didymo at the same 11 sites along the stream to describe potential bloom extent (the Killroy Index). We standardized didymo cell count across samples to a per unit area of stream sampled. Densities and visual counts were used in linear models with various predictors such as temperature, substrate and water chemistry. At sites where we had repeat visits we generated simple graphical time series of didymo density to explore short term dynamics at these sites. Finally, by using the properties of the survey design we can estimate the extent of streams across the entire park that has didymo presence. We are also able to estimate the variance around these proportions (expressed as 95% confidence intervals).

Results

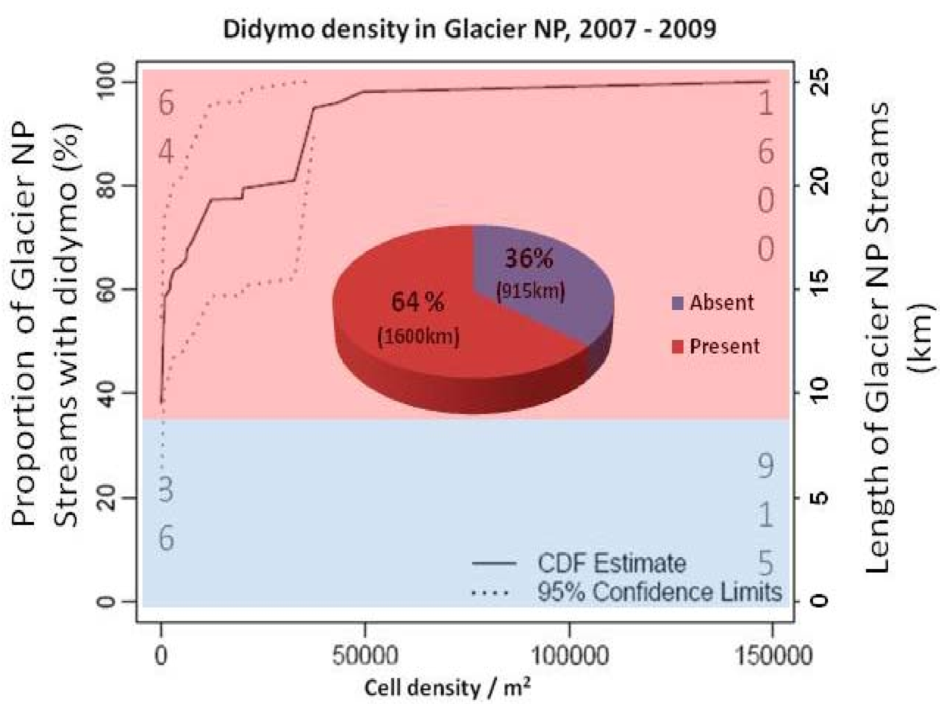


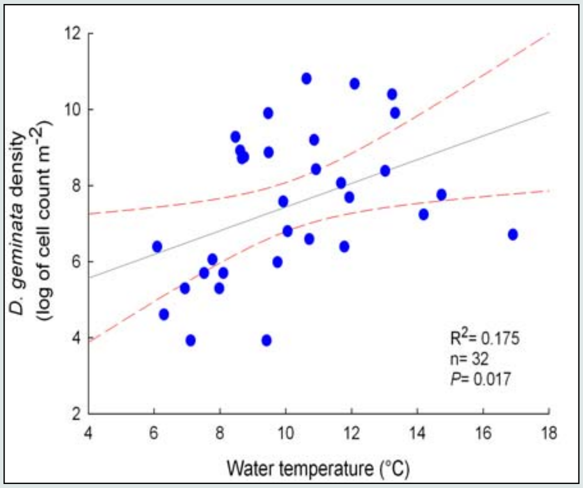
The greatest densities of didymo were found on the western side of the park, with the largest blooms in the North Fork of the Flathead watershed. However, there was considerable spatial variation during 2007-2009 in the density of didymo across the park. The presence of didymo did not appear to be uniform along the length of a single stream.

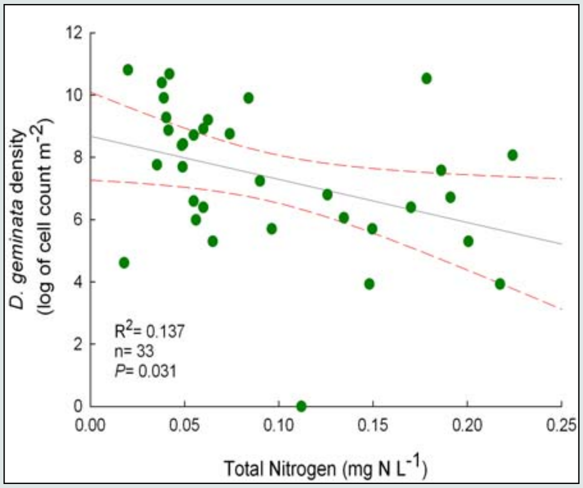


Didymo significantly increased in density at many of our field sites during 2007-2009. Of the 11 sites that were visited multiple times, didymo increased in abundance at eight and decreased at only one. Where we had five or more visits we found significant increases at three sites. These data suggest there has been a recent increase in didymo at select locations in Glacier NP (although our period of record is still quite short).

Around 64% (+/- 17%) of the flowing water in the park during 2007 – 2009 had didymo present. This equates to about 1600 km of stream length. The mean density across the park was 12124 cells / m^2 with a standard error of 4023. The mean Killroy visual index across the park was 8.0 with a standard error of 2.44. Based on our subjective evaluation of this index in sites that were clearly in a bloom state, the threshold for a bloom is around a Killroy Index value of 40 Using design-based methods this equates to around 5% (+/- 3%) of the park in a bloom state. Importantly, these results describe, with known confidence the state of the entirety of the stream resource in the park in 2007-2009. They are not limited to specific stream sites and as such provide a key baseline for long term monitoring of didymo at the scale of the park into the future.

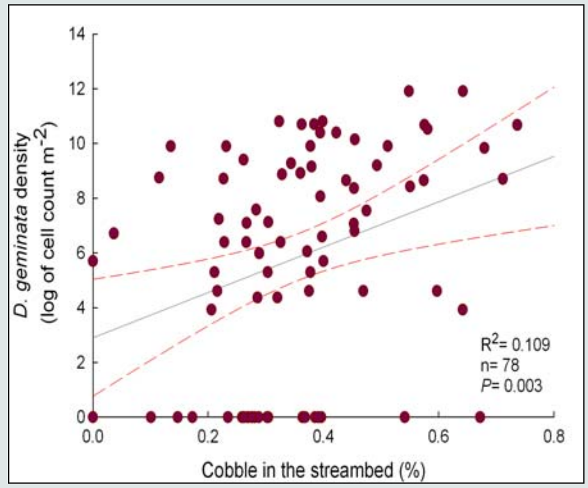






Stream temperatures within our sites at Glacier NP ranged from about 6 to 17°C (42.8 -62.6°F). In sites where didymo was present, we found a relationship between water temperatures and density. Higher densities of didymo were generally found at higher temperatures.

Didymo typically occurs in waters with very low nitrogen and phosphorus concentrations. In Glacier NP, we found that total nitrogen content in the water column was very low- well below a published standard threshold of 1.04 mg/N to avoid nuisance aquatic growth. Unlike other algae, didymo thrives in waters with low nitrogen and in the areas with higher nitrogen concentrations didymo was less dense.



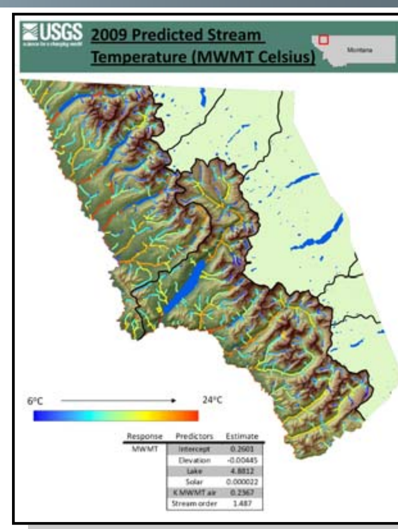
Didymo is most often found in rivers or streams with flowing waters and stable bottoms of cobble or bedrock. In Glacier NP, we found no relationship between flow and didymo density, but didymo densities were generally higher in streams with a high percentage of cobble.

All analyses and data presented in this brief are draft. All interpretation is provisional pending review.

Management Implications and What can we expect in the future?

Didymo has rapidly expanded its range and abundance over the past ten to twenty years and now has a broad distribution in North America. While native to the cool mountain streams of Glacier NP, it has likely increased in abundance and is present in about 64% of the flowing waters in the park. Didymo was formerly considered to have narrow ecological tolerances; however, it now occurs in streams exhibiting a wide range of chemical and physical characteristics. With just a few years of long-term monitoring in the park, we have begun to understand the factors that have allowed didymo to reach its current abundances in the park. It appears to be responding to temperature, nutrients, and substrate. Continued monitoring will allow us to better understand the role that changing climate plays in didymo invasion dynamics. In the meantime, managers can encourage the public to help stop the spread of aquatic nuisance species by cleaning, inspecting, and drying all gear and equipment.

Long-term monitoring programs are a critical component of understanding, predicting, and managing for the effects of invasive species in a changing climate.



Scientists from the USGS have developed spatially-explicit models of stream temperature regimes. By combining models of future temperature and our site level and design-based park scale results we have the potential to help managers predict where and at what density didymo might occur in the park in the future. Figure courtesy of D. Kotter and C. Muhlfeld, USGS

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