Are the recent blooms of *Didymosphenia geminata* in Lake Superior (USA) caused by an aggressive strain or environmental changes?

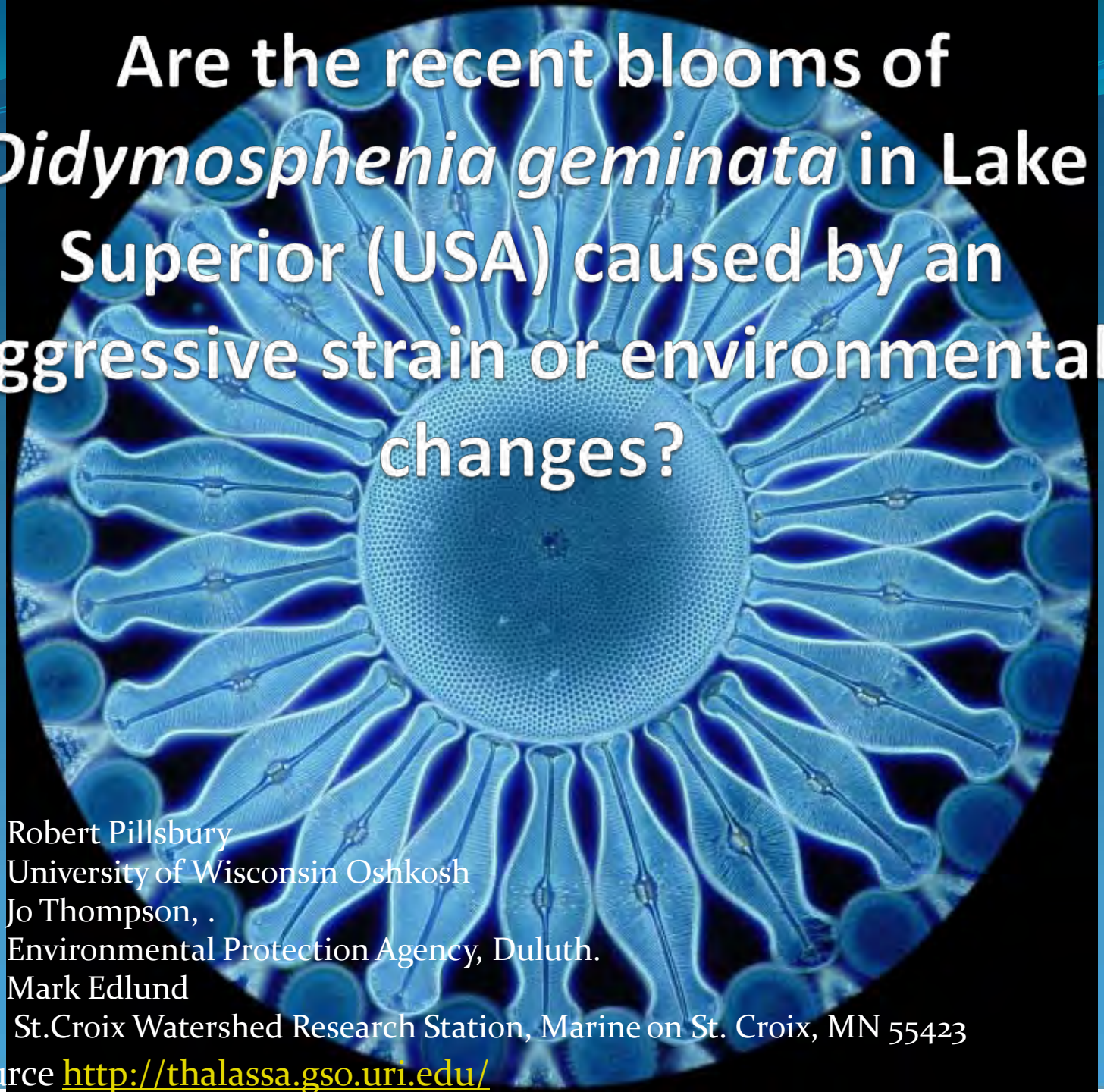

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image source http://thalassa.gso.uri.edu/

North Shore of Lake Superior

Lake Superior, Fall 2008

Typical Lake Superior periphyton on rock.

Rock with Didymo

Questions:

1. Are *D. geminata* blooms typical for Lake Superior but largely undescribed?

2. Do these blooms mark a real change in the littoral ecosystems of Lake Superior?

3. What is the size and duration of these blooms?

Previous Studies: Didymo in Lake Superior.

-Stoermer et al (1986) found *D. geminata* from samples collected in Grand Marais in 1961.

-Fox et al. (1967) sampled at Stoney Point (15 miles up the shore from Duluth) in 1965 and reported that *Gomphonema geminata* (synonym of *D. geminata*) was present as colonizers on artificially denuded rocks.

-Stokes et al. (1970) described the 1968 periphyton growth at Stoney Point as "A heavy brown layer…on the rocks and sand" and "wooly growth".

-Fox et al (1969) reported on the collection of periphyton samples from 11 north shore locations from Lester River to Grand Marais in 1967. Taxa of the *Gomphonema* group were only abundant at Beaver Bay, "no-name bay" (near Little Marais, Sugar Loaf Cove, and Tofte.

-Nelson et al. 1970 and Nelson et al 1973 reported *G. geminata* in Lake Superior shoreline samples in 1969 and 1970.

-Stoermer (1980) found the presence of *D. geminata* in Lake Superior benthic algal communities usually at <1% relative abundance.

-Edsall et al. (1991) reported "Dense, fleece-like blankets of periphyton" off Isle Royal. Primarily, the growth was comprised of *Cymbella mexicana*, also a stalk former. Other genera, including a *Gomphonema* sp. were present but attached to the *Cymbella* stalks.

-Moffat (1994) collected *D. geminata* in the early 1990s near Marquette, MI (south shore of Lake Superior).

North Shore surveys

-Periphyton sampled from splash-zones sites from Lester R. to Grand Portage.

-Samples were examined at 400x magnification.

-Nov. 2008: 13 out of 14 sites had extensive Didymo mats.

-Nov. 2010: 10 out of 10 sites had extensive Didymo mats.

-April 2011: 11 sites- no Didymo found

-May 2011: 11 sites – no Didymo found

-June 2011: 12 sites- no Didymo found

-Oct 2011: 6 out of 11 sites- had extensive Didymo mats.

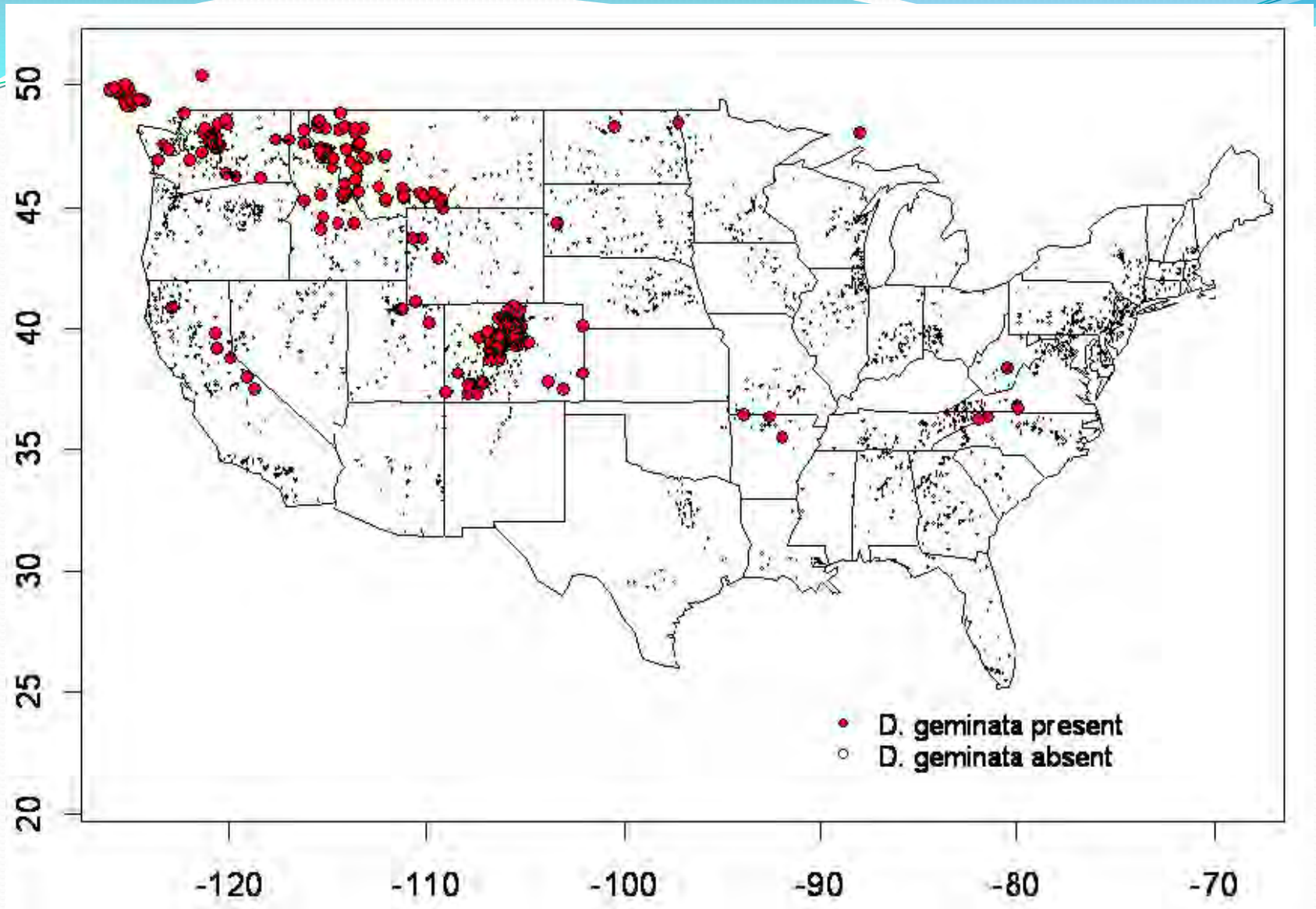
-Oct 2012: 7 out of 7 sites –had extensive Didymo mats

Conclusions (part 1)

- -Periphyton records for Lake Superior are very sparse. Many early studies list only genera and few provide any density measurements.
- -*Didymosphenia geminata* has been part of the Lake Superior benthic community and readily collectable since 1961.
- -Whether *D. geminata* has historically produced regular, massive blooms in Lake Superior or not is inconclusive due to infrequent monitoring and low quality of the data. But since these blooms are relatively easy to identify (both macro- and microscopically), it is surprising that more records of these events were not found if they have always been a frequent occurrence on Lake Superior's shoreline.
- Recently *D. geminata* blooms occur in the fall along a long stretch of the North Shore of Lake Superior.

Background:

- Historically, *D. geminata* considered restricted to cold, oligotrophic waters of the northern hemisphere and was regarded as uncommon (Blanco and Ector 2009).
- However, within the past two decades this alga has greatly expanded its known range, colonizing mainly cold trout streams and producing nuisance blooms (Blanco and Ector 2009, Spaulding and Elwell 2007).
- Why now?



Current distribution of *Didymosphenia* in the US
(Spaulding and Elwell 2007)

Models:

- **Aggressive Colonization model**- an aggressive strain of *D. geminata* has mutated/developed which is now spreading into new habitats.
- **Environmental Change model**- suggests that *D. geminata* likely persisted in low densities (which would typically be unrecorded using a standard count of 500 diatoms/sample) in many locations. However, recent environmental changes (such as an increase in atmospheric nitrogen deposition) have made bloom events from these subpopulations more likely.

predictions

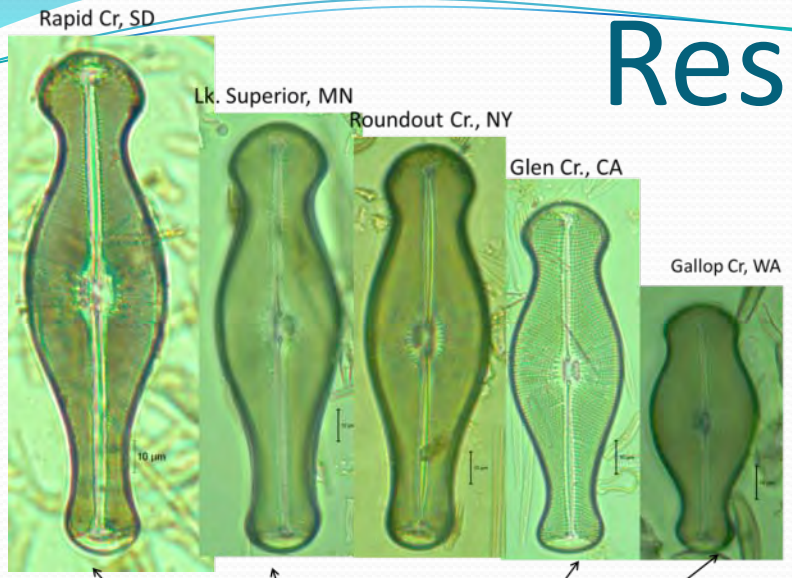
- If the **Aggressive Colonization** model predominates, samples of recent *D. geminata* blooms across N. America should all show similar morphologies. While historic, non-bloom samples should be distinct from recent bloom samples.

-If the **Environmental Change** model predominates, distinct subpopulations across N. America should exist while older samples should be morphologically similar to recent bloom samples at the same location.

Methods

- *D. geminata* was collected during bloom conditions in 9 separate locations across the country during 2009-2001.
- *D. geminata* was collected during recent blooms along a 180 km stretch of the north shore of Lake Superior (2008, 2010, and 2011)
- Site collections from Lake Superior were expanded to include older samples taken before *D. geminata* blooms were typical (1984, 1999, and 2001).
- From each site, at least Didymo 30 cells were measured for ten morphological characteristics.
- Principal Component Analysis (PCA) was used to explore how valve morphology varied over time and space.

Results



Although valve morphology overlaps in many cases, distinct subpopulation of *D. geminata* appear to be present.
-Separated by **maximum length** (Mean length ranged from 78 µm (Gallup Cr., WA) to 156µm (Rapid Cr., SD) and **Head and Foot pole constrictions**.

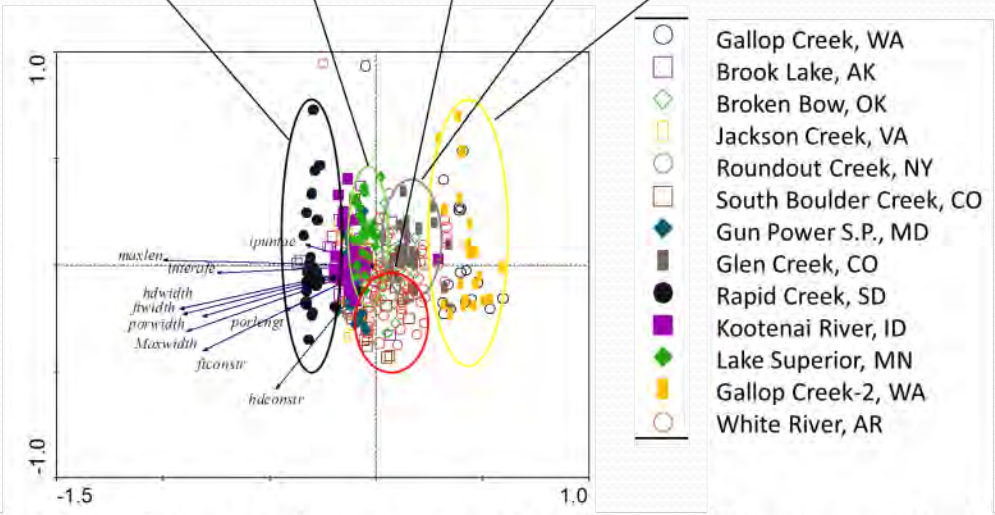


Fig. 2. First two PCA axes, with valve measurements and *D. geminata* cells from 11 locations across N. America. Five of the locations are highlighted with ovals and with a representative cell pictured above. Measurement labels are explained below.

Valve measurements:
Max. length =maxlen
Max. width =maxwidth
Head pole width =hdwidth
Head pole constriction = hdconst
Foot pole width =ftwidth
Foot pole constriction = ftconstr
Number of isolated puntae = ipuntae
Distance between proximal raphe ends=interafe
Pore field length =porlengt
Pore field width = porwidth

Discussion

- Changes in cell size and other measurements could reflect environmental stress such as nutrient limitation.
- But since all of these samples were collected during blooms of *D. geminata*, conditions were likely close to the species environmental optimum.
- Therefore, these relatively distinct morphological groups support the **Environmental Change model**.

Lake Superior populations

Through Time:

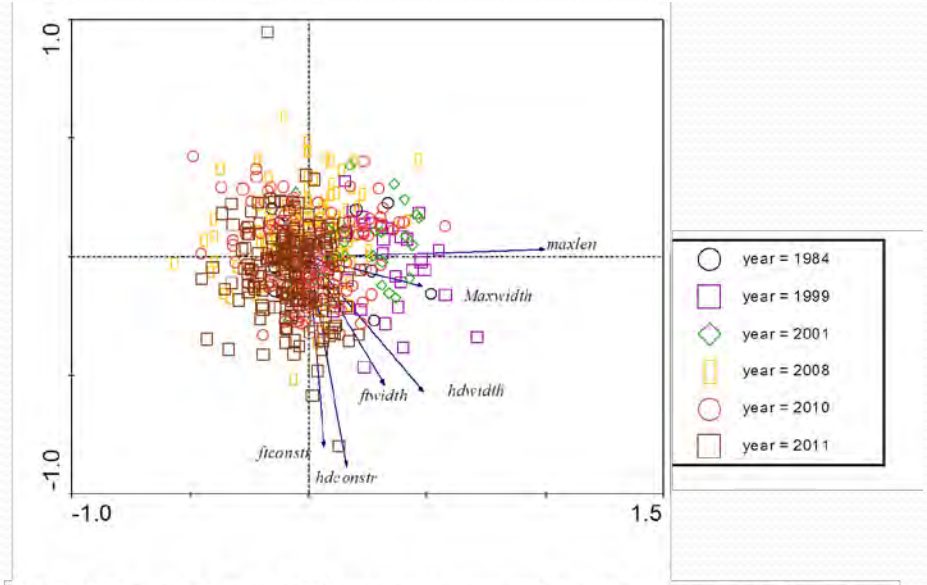


Fig. 5. First two PCA axes, with valve measurements and *D. geminata* cells from sites in Lake Superior locations across collected from 1984-2011.

-No Distinct groups

Over Distance

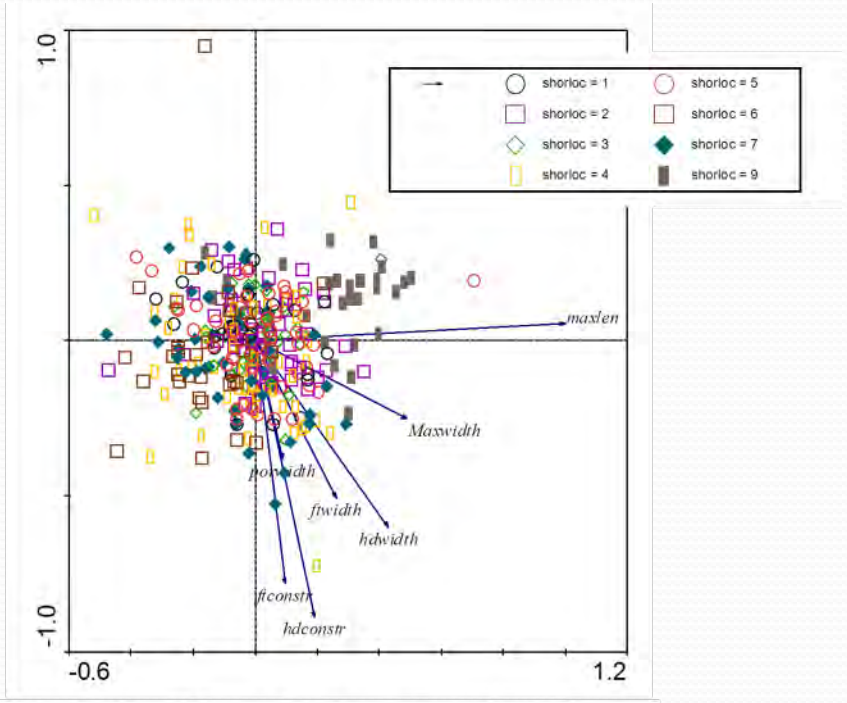


Fig.6. . First two PCA axes, with valve measurements and *D. geminata* cells from sites in Lake Superior locations 1-9 (see fig. 4) from 2010 -2011.

-No Distinct groups

Discussion

- The valve morphology of *D. geminata* from Lake Superior taken over time did not tend to yield distinct sample groups, especially between pre-bloom dates (1984-2001) and recent blooms (2008-2011).
- Neither did *D. geminata* exhibit distinct subpopulations along the north shore of Lake Superior during the now typical bloom events.
- Both suggest that these samples in time and space represent just one subpopulation.
- Consistent with the **Environmental Change model**.

Conclusions (part 2)

- The patterns found here are consistent with the **Environmental Change** model although what might trigger the greater frequency in bloom events remains in question.
- -However the **Aggressive Colonization** model must be important in at least some instances such as the *D. geminata* invasion in New Zealand.

Acknowledgments:

- Acknowledgements: Brian Lamberts assisted with measurements and data exploration. Diatom samples were generously provided by Pat Kociolek , Mark Edlund, Teofil Nakov, and Jo Thompson.
- Doug Jenson of Minnesota Seagrant helped to collect the 2008 North Shore samples

North Shore surveys

- In November 2008 a series of 14 splash-zone sites along the North Shore of Lake Superior from Lester River to Grand Portage were sampled for periphyton (fig. 8). At all but one site (McQuade Safe Harbor), there were extensive brown mats characteristic of *D. geminata* blooms attached to the rocks (figure 4). In November 2010 another 10 sites were samples from Lester River to Taconite Harbor when a brown mat over 80 miles long and often greater than 2 cm thick was discovered extending from the splash zone to a depth of at least one meter. All samples were examined microscopically. *D. geminata* and other stalk forming diatoms structurally dominated nearly all of the samples. We have again search the North Shore in April and May of 2011 but did not find significant growth (> 0.01 relative abundance) of *D. geminata*.